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Reliability Abstracts and Technical Reviews

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The first section of *RATR* contains bibliographic citations, abstracts, and reviews. The items (each identified by an *RATR* accession number) are arranged in subject categories based on the first two digits of the codes developed by the American Society for Quality Control. The complete listing of these ASQC codes appears on the inside back cover. Examples of citations of reports, journal articles, and conference papers are shown below. The principal subject field of the item (and therefore the category in which the item appears in the journal) is indicated by the first ASQC code number; related subject fields are indicated by additional code numbers. The appearance of a *TAB, STAR,* or *IAA* accession number indicates that the item has been announced in, respectively, *Technical Abstract Bulletin, Scientific and Technical Aerospace Reports,* or *International Aerospace Abstracts.*

The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

Left labels	Citation	Right labels
		ASQC CODES
RATR ACCESSION NUMBER	R69-12733 ASQC 844; 413	CORPORATE SOURCE
TITLE	General Equipment Company, Banville, Calif.	
	RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT	PUBLICATION DATE
AUTHOR	John A. Doe 23 Sep. 1966 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	*TAB* AND *STAR* ACCESSION NUMBERS
REPORT NUMBER	(TR-3; AD-629305; N69-15098) CFSTI: HC $3.00/MF $0.65	SALES AGENCY AND PRICE

Left labels	Citation	Right labels
RATR ACCESSION NUMBER	R69-12739 ASQC 814	ASQC CODE
TITLE	**SEMICONDUCTOR RELIABILITY**	
	Joseph A. Smith (Eastern University, Arlington, Penn.)	AUTHOR AND AFFILIATION
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1966, p 478–492.	
	(A69-12569)	*IAA* ACCESSION NUMBER

Left labels	Citation	Right labels
RATR ACCESSION NUMBER	R69-12765 ASQC 773; 221; 823	ASQC CODES
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)	AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1966, 8 p*	
	Available from Assoc. of Reliability Eng., New York: $1.00	AVAILABILITY AND PRICE
IAA ACCESSION NUMBER	(A69-12407)	

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80 RELIABILITY

R68-14176 ASQC 802

PROBABILISTIC RELIABILITY: AN ENGINEERING APPROACH.

Martin L. Shooman (Polytechnic Institute of Brooklyn, N. Y.) New York, McGraw Hill Book Co., 1968, 524 p. 116 refs

$16.50

Reliability concepts and approaches are related to basic probability mathematics in a textbook for college and industrial courses. Probability and differential equations are reviewed, as are set theory, continuous and discrete random variables, moments, Markov models, and estimation theory. Combinatorial reliability is treated, including series and parallel configurations, general techniques, and various models. Catastrophic-failure models consider treatment of failure data, failure modes, hazard rate and failure density, and hazard models. Approximation and bounds, general approaches to computation, and computer methods of analyzing system reliability are described. Methods of reliability improvement considered are systems design and component improvement, redundancy in digital systems and standby redundancy, the human operator as an adaptive controller, and repairable systems. Drift failures, component tolerances, and parameter variations are discussed in terms of deterministic and probabilistic approaches, approximation techniques, and applications to circuits and control system analysis. Reliability physics models and statistical parameter estimation are reviewed; and analog computations, numerical analysis and digital computation, some useful integrals, and number of Monte Carlo trials are presented. M.W.R.

Review: This is a good book on probabilistic reliability and a valuable addition to the growing literature. It can be valuable to any reader with the requisite mathematical background. The dust cover, as might be expected, is overly enthusiastic—for example "...this is the first reliability textbook." Calabro's "Reliability Principles and Practices" was published by the same company six years ago. The book is definitely limited to probabilistic reliability and thus devotes many fewer pages to other factors that are involved in producing high-reliability hardware. This is not to say that they should have been stressed more, but merely to point out that the title is reasonably descriptive and one should not expect to find other kinds of things in the book. The book on the whole is excellent but the reader will have to be careful about taking some of the details on faith alone since there are some errors in the book. Most of the comments in this review are negative since the reader of a book tends to presume that everything is fine unless it is pointed out to him explicitly that something is incorrect. Some of the comments reflect more a difference of opinion, either pedagogically or in the field of reliability, than they do errors. Here the reader of the book and the review must make his own judgments. The specific comments are serially lettered for each chapter. Chapter 1 is a reasonable introduction. The philosophic background for the use of probability in engineering in Chapter 2 is good. The approach is taken that probability theory is a mathematical discipline and, like other mathematics, can be applied to many problems at *the discretion of the engineer or applied mathematician.* In general, the material in Chapter 2 is well presented and is necessary for the understanding of probabilistic reliability theory. It is a useful part of the book. Those without a calculus background will, of course, be lost. (a) In engineering work it is often desirable to distinguish between statistical independence (defined by the formulas in Chapter 2 on probabilities) and physical independence defined by one's view of the physical situation, usually based on cause and effects relationships. (b) There is a misprint on page 34: "All the possible sequences are independent events, ..." is not correct; they are disjoint (mutually exclusive) events. (c) In the derivation of the Poisson distribution from the binomial distribution on page 38 some readers might have felt less carried around Robin Hood's barn if it had been pointed out that $\lim (1-\frac{\mu}{n})^n \equiv e^{-\mu}$ (by definition of e) rather than having a $n \rightarrow \infty$ derivation that is apparently good only for very small values of μ. (d) On page 43 the statement "Since f(x) is a probability, ..." is misleading since f(x) is a probability *density,* not a probability. (e) Equation 2.53 on page 57 is not quite consistent with the previous description; the integration limits should be a and b. (f) In introducing Markov models on page 61 there is no clear definition of what a Markov model *is,* in general; we are told only some of the properties of a Markov model. Unfortunately the author omits giving an explicit reference (but see p. 511, Drake). (g) In equation 2.74 on page 67 the first ϕ should be a capital Φ to distinguish it from the lower case ϕ inside the integral. (h) The discussion of covariance and correlation coefficients on page 72 uses too much statistical jargon. While the term "correlation" is very meaningful to the statistician, it often helps the engineer if the term "linear correlation" is used, to emphasize the fact that only linear relationships are being considered. It is much more reasonable to engineers that variables can be statistically dependent and linearly uncorrelated than that they be dependent and uncorrelated—because of the connotations associated with the lay uses of the words "correlated" and "dependent" (i) In discussing unbiased estimators (Section 2.10.3), it is wise to point out for the specific example that when the sample variance is corrected to be an unbiased estimator its square root (the sample standard deviation) is still biased.

(j) In the discussion of Chebyshev bounds on page 95, one must be careful to use the true mean and true standard deviation rather than estimates. (k) The section on estimation (pages 94–96) is quite brief. Chapter 3 is brief but good. It will be essential for the student to work a great many of the problems in order to appreciate the real meaning and importance of what the text is saying in many places (the author points out in his preface that this kind of thing will be necessary). A solutions manual will be available from the publisher in the spring of 1969. Chapter 4 is concerned with reliability definitions and models for discrete-state items for which the single time-to-failure is the most meaningful measure of reliability. The term "catastrophic" in the title will not convey this meaning to many readers, and is therefore somewhat misleading. The models can apply to non-catastrophic modes. In general this chapter is a good one and occasionally the author gives some very practical advice in pointing out what does not happen or what should not be done. (a) Perhaps one of the most important statements is the following: "The emphasis is on simple models which are easy to work with and contain one or two parameters. ... Also, in most cases, the data are not abundant enough and the test conditions are not sufficiently descriptive of the proposed usage to warrant more complex models". Very often the experienced engineer will find himself making reliability judgments in situations where even the simplest models require too much data and his decisions are made on a phenomenological basis. (b) Unfortunately the author repeats the tendency in the literature to equate the term "random failure" with the constant hazard rate in discussing the bathtub curve; and, by implication, means that the failure behavior in the infant and wearout periods is not random. This implication is not correct since probability distributions are used to express the failure behavior in all three regions. A related misinterpretation which is also quite common is the implication that a bathtub shaped hazard function (see Fig. 4.4 on page 171) is applicable to an equipment consisting of many components. When such a curve is based on a probability density function for a single failure time, it does not take into account multiple failure times or repair and replacement of components. (c) The discussion of the use of hazard rates is generally good in this chapter. The novice must beware in referring to curves such as those in MIL HDBK-217 and subsequent issues, of presuming that the people who drew the figures had extensive amounts of very consistent data upon which to determine their exact shape. Such would rarely be the case, and the shape of many of the curves is determined by the application of what is often known as "engineering judgment" (based on unquantified past experience and "intuition"). (d) Unfortunately, the author does not use a single term for hazard rate in this chapter. In a footnote he does mention that it is sometimes called "hazard" and sometimes "failure rate", and he tends to use them all indiscriminately. The novice may find some confusion in this practice but should note that as long as the reliability is very close to unity there is negligible numerical difference between the hazard rate and the failure rate. That the author has a problem in this regard is clear since seldom in the literature are the two terms distinguished. (e) The statement, "The constant hazard model forbids any deterioration in time of the strength or soundness of the items in the population," is incorrect. It is not difficult to create reasonable cumulative damage models which result in the exponential distribution. These can be interpreted as a decreasing strength from an initial uneven distribution. In fact, many people consider this explanation physically reasonable for many parts, such as capacitors. The constant hazard rate model implies only that whatever the factors are that influence the hazard rate, it winds up being constant. If the environmental severity fluctuates in a random manner, this is an additional variable which allows many more hypotheses about the way in which a constant hazard rate can occur. Chapter 5 extends the ideas of Chapter 4 to combinations of components and continuous-state items whose performance varies over time. It would have been helpful if the chapter title conveyed more of this relationship to the topics of the previous chapter. Equation 5.77 on page 244 contains some obvious misprints. For Chapter 6 a title such as "Designing for Reliability" sould have described the contents better than "Reliability Improvement." This chapter is devoted mainly to redundancy models, with some attention given to repairable systems and the concept of availability. (a) A few pages are devoted to engineering methods (that are not particularly based on probabilistic reliability models) for improving reliability. In the field of mechanical reliability, what is now called physics of failure has for many years been standard procedure in analyzing the metallurgical causes of failure. In fact, much of our failure terminology in reliability has been borrowed from the metallurgist. (b) The footnote on page 276 concerning automobile braking forces is incorrect. The percentages should be reversed, giving 60% for the front wheels and 40% for the rear. This assumes that there is no weight redistribution due to the braking effort; if there is, the percentage of the front goes up to say 75%. (c) In the discussion on component versus unit redundancy, it should be remembered that the figure of merit being used is reliability without any other constraints, such as cost, size, or weight. When these are added, the situation may well be altered. (d) In this chapter the author is very careful about his assumptions and in explicitly stating not only what he has assumed, but what he has not assumed, the latter being of special importance to the novice. The explicit statement of the assumptions and their discussion also can help in further reliability improvement wherein one is willing for example to take a different definition of success. (e) When redundant elements are put on the same integrated circuit, one may well wish to question the assumption of statistical independence of the failure events and it may turn out that little if any improvement is gained. (f) Near the bottom of page 340, if there are two service men, it is the repair *rate* which might double or increase to 1.5 times its usual value, not the repair *time*. Chapter 7 contains one of the best available treatments of drift failures, component tolerances, and parameter variations. However, it could have been improved by giving more practical engineering consideration to keeping the sophistication of the mathematical analysis down to a level commensurate with the uncertainty with which the model represents the real world. It is difficult in a text to do this since one wishes the examples to be simple enough to be followed, yet one needs to get the sophisticated principles of analysis across. Nevertheless keeping the balance is an important part of what is to be learned. (a) For the worst-case analysis, the author states on page 372, "This method gives a somewhat more accurate solution than the previous one..." This of course gives the most accurate analysis possible for $(e_2)_{max}$ and $(e_2)_{min}$; given the model the author is analyzing, one cannot be more accurate. In this entire discussion of drift failures so far (e.g., on page 376 the author states, "Thus a knowledge of $f_G(G,t)$ contains all the information necessary to compute the marginal reliability.") the author seems to neglect the fact that in some engineering systems the direction and rate of drift are reasonably well known and that the probabilistic uncertainty is much less than the total change. Thus a deterministic factor needs to be involved in his probabilistic equation. (b) On page 387 the author tries one of the schemes where one lifts onself by his own bootstraps: instead of one 100Ω ± 10% field coils, one puts two 50Ω ± 10% field coils in series and comes out with a 7% tolerance. Sometimes Mother Nature will let you do it and sometimes she won't. It is quite possible that the two smaller coils would have resistance tolerances greater than 10% when wound in the usual way. One has to look into the engineering reasons why the tolerances occur in either case. E.g., any single 100Ω coil can be thought of as being made up of two 50Ω coils in series with the center terminal not available. (c) On page 388 in a different version of the same problem (comment b above), it is not clear that if one machine consistently produces high values of resistance and the other machine consistently produces small values, then the output of each would be 50Ω ± 10%; in fact it would appear to be obvious by inspection that it could not be. (d) The author considers five possible cases for forcing the proper current through a field coil, but does not consider a constant current source. (e) Equation 7.34 on page 392 contains a misprint: In the expression for the density function of 1/R there is a factor of u^2 missing from the denominator. (f) In the discussion on page 392 suppose we had been brought up to think in terms of conductance rather than resistance. It would be natural then for us to say that these distributions of conductances were Normal (or uniform). The real world would not have changed, but our description of it would be slightly different. The description is only approximate and it is important to consider this in any evaluation. In the case of the uniform distribution, if the resistances lie within 1% of the center point, it is unreasonable from an engineering point of view to expect that the distribution of conductance will be appreciably different from the resistance distribution in any of its important characteristics. Indeed, the author has *unwittingly calculated his values incorrectly. The correct* answers are E(u) = 0.01000033335, var u = 0.3334 × 10^{-8}. The coefficient of variation for u becomes 0.577% which is the same (to within 1 part in 10^4) as the coefficient of variation for 1/u. (g) A better way of stating the difficulty with the Cauchy distribution (see page 398) is that no matter how many Cauchy distributions are added, one never gets a Normal distribution and, therefore, it obviously does not fill any criteria for functions allowable in the central limit theorem. (h) In Example 1 on page 406 it is not necessary that the parts have a Normal distribution; they need only be linearly uncorrelated (regardless of Normality). (i) When reading Section 7.7.1 on page 408 the engineer should carefully distinguish between the problem he wants to solve in the real world and the mathematical representation thereof, especially since when the tail probabilities are smaller than 10^{-3} or 10^{-4} it makes little engineering sense to put great faith in the exact values of the probabilities, unless one has the means for checking what is going on there. Certainly when information is available only in the central portion of the region, it is misleading at best to discuss those tail regions in explicit detail. (j) There appears to be little problem in principle with the discussion of Monte Carlo simulation on page 418. The novice, however, is well advised to get both professional programming and professional numerical-analysis help (programmers are not necessarily numerical analysts and vice-versa). Since it is easy to write an extremely inefficient Monte Carlo program, tricks of the trade can offset appreciably more than the professionals' cost in the Monte Carlo research program. (k) In discussing sensitivities, the statement is made on page 427 that "There is no advantage to making some sensitivities positive and some negative in an attempt to cancel things." This statement is certainly true under the author's assumption but should not be used otherwise; among other things it implies statistical independence. The discussion of reliability physics models in Chapter 8 is very brief. It is combined for some unknown reason with estimation of statistical parameters and is probably included only for the sake of nominal completeness. Certainly in large part the lack of emphasis cannot be faulted, since reliability physics tends to be a catch word for the fact that engineers should work smarter, not harder. (a) On page 499 it is stated that "The hazard model parameters are all proportional to the square of the input stress." Remember that in the mathematical development up to this point, stress has not been defined physically. Therefore, there is no more reason to assume that the stress on a resistor is the voltage than *it is to assume that it is the power or anything else. What is done,* unfortunately, is to work backwards without having said so. That is, one wishes the hazard to be proportional to the power dissipation in a resistor and then decides that the stress therefore must be proportional to the square root of the power. It should be emphasized that the stress is a completely arbitrary function as far as mathematics is concerned and can be any physical variable one wishes it to be. The mathematical development does not require any physical connotation for stress. Therefore, the author's comment that, "...this model predicts hazards proportional to input power for dissipative elements and proportional to potential energy for energy storage elements," is not correct. It does not predict anything of that sort, unless one puts it in there in the first place. That is, decide what you think the hazard rate is proportional to, and then create a stress to give that answer. (b) On page 451 the author discusses methods of estimating the parameters of a Weibull distribution from sample data and suggests matching of moments. One should check, for example, many of the papers by Harter for other methods of estimation. Unfortunately, the author does not give other references. (c) Section 8.4 on accelerated testing is very narrowly construed and deals with only one special case. The formula should not be taken as representative of accelerated testing in general. (d) In an effort to make the Arrhenius model more general than it is or should be (see page 454), the author *has allowed one to substitute any "stress" in place of temperature.* The formulas were originally derived specifically for temperature and should be presented only in that way. In the latter part of this section, the author does make very good points about the Arrhenius equation that would have been better had he not made the equation general in the first place. (e) The discussion of plotting position (see page 458) is given in reasonably simplistic terms. The author's suggestion of using i/n+1 is a good one because it is simple and easy to use, but many plotting positions have been suggested in the literature. When data are sparse the different methods can give widely different appearances; when there are a great many data the results will tend to be the same. If the plotting position is terribly important in your analysis of the results, then you have troubles that will not be remedied by anything so simple as a fortuitous choice of plotting positions. (f) Under least squares estimates (Sec 8.9.2, page 464), it is presumed implicitly that all data are equally weighted. If they are not, other formulas should be used. It is not obvious on its face that each estimate of a hazard rate is equally weighted in this kind of analysis. Of course any mathematical analysis can be applied blindly and it will give a formal answer; the question is what that answer means. The discussion on analog computing in Appendix A is largely on the basic theory. For example, the practical problems of signal amplitudes' not exceeding given levels anywhere in the system is not treated. This is one of the important difficulties in the use of analog computers; it is related to the dynamic range that the signals can possess so that a signal is not in the noise and drift when it is low, nor does it exceed the maximum allowable amplitude when it is high. In the section on digital computing in Appendix B, it is implied that Taylor's series expansions are used to evaluate various functions. This is rarely the case. Most often, special polynomial functions are used to give reasonably accurate results over an interval. In general, these appendices are—and were intended to be—only introductory.

R69-14205 ASQC 800

RELIABILITY METHODOLOGY.

Alexander Sternberg (RCA, Astro-Electronics Div., Princeton, N. J.). *In: 1968 Product Assurance Conference and Technical Exhibit,* sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society, Arno Press, Inc., 1968, p. 43–47.

Most frequently used methods to implement a reliability program are presented; and reliability is considered as a design parameter for concept formulation and a continuous effort throughout system planning, development, and production. Aspects of an *overall reliability program should include a reliability requirements* study, reliability analysis and prediction techniques, failure reporting and analysis, design reviews, testing program, and the reliability specifications of subcontractors and vendors. Mission goals and profile, redundancy requirements, reliability apportionment and estimates, and degradation analysis are considered under requirements. Block diagrams, the mathematical model, worst case analysis, tradeoffs, stress analysis, and failure mode and effects analysis are the prediction tasks discussed. Attention is given to parts selection, evaluation, and control, including the use of standard and nonstandard parts, screening, and part derating. Mention is also made of documentation of results. M.W.R.

Review: This is essentially the same paper as covered by R66-12432 and the review for that paper is applicable here. This is a good but very brief mention of each task. As intended, it gives a better view of the overall picture than it does of any single one of the tasks. Managers and designers not familiar with all of these categories will find the review helpful as will those trying to get a program started. No single task is as simple as it may appear to the uninitiated from a one-paragraph description. Unfortunately there are no references.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14197 ASQC 815; 835; 844; 851

Grumman Aircraft Engineering Corp., Bethpage, N. Y.

HIGH RELIABILITY SCREENING OF SEMICONDUCTOR AND INTEGRATED CIRCUIT DEVICES

J. Lombardi, L. McDonough, and H. Padden Washington, NASA, Apr. 1967 161 p refs
(Contract NAS5-9639)
(NASA-CR-721; N67-23322) Avail: CFSTI

The approach was to find methods and techniques for pinpointing the origin of potential failure mechanisms and to employ these techniques in screening devices susceptible to failure. Developed was an integrated screening-acceptance test specification for semiconductor and digital integrated circuit devices to insure high reliability requirements for NASA programs. Acceptance and qualification test specifications are given. Nondestructive tests included external visual and mechanical inspection, X-ray vidicon analysis, electrical tests, burn-in with variables data, and computerized variables analysis. Destructive tests were conducted by decapsulation, microscopic examination, electrical probing, infrared scanning, microsectioning, electron probe microanalysis, and scanning electron microscopy. Test results are tabulated, and a bibliography is included. K.W.

Review: This report consists of a specification for the manufacture of digital silicon integrated circuits and a description of the background work that led to various provisions of the specification. The general purpose of the work is to achieve higher reliability through detailed inspection and screening of the product. The end result is similar to that recently described by workers at Raytheon (see the paper by William R. Rodrigues de Miranda in Transactions 22nd ASQC Annual Technical Conference, May 68, p. 799–810). Both this Grumman work and the Raytheon work resulted in a specification that tells the manufacturer what is an acceptable-looking integrated circuit. Visual inspection is the main tool of the Raytheon Process Control Specification (PCS); it is only one of the tools required by the Grumman specification. 100% X-ray inspection, 100% hermeticity test, and 100% burn-in of all units are part of the screens required by the Grumman specification. The Grumman specification is intended solely for NASA use in screening circuits for high-reliability systems; the Raytheon specification attempts to be universal. The Grumman document insists uncompromisingly upon certain rigid tests performed in a certain sequence. It is a specification that manufacturers will object to at least in part and on principle if not otherwise. The Raytheon specification is more compromising and easier for the manufacturer to accept. These opinions are based on having read only a description of the Raytheon specification rather than the specification itself. This Grumman report contains the entire specification itself in all its direct unambiguous language. The Grumman specification will be costly to implement and applicable only to a small fraction of the total integrated circuit market. However, it is thorough and its provisions are substantiated as well as can be expected. It is a reasonable document for attempting to achieve the high reliability demanded in space flight. It insists on leaving no possibility of failure unchecked.

R69-14202 ASQC 810

THE RELIABILITY-DESIGN ENGINEER RELATIONSHIP.

Marvin Trieb (Instruments Systems Corp., Huntington, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 1–4.

Relationship between reliability and design engineering is discussed, emphasizing the need for subtle reliability control over design functions. It is shown that the way to control the design function is to make the design engineer dependent upon the services provided by the reliability group. Close contact between personnel representing the two groups is considered a must, as is design know-how among personnel representing the reliability group. M.W.R.

Review: This paper attempts to go beyond the organization chart approach to reliability management by showing some of the techniques that reliability engineers can use in order to be effective in their daily work. The suggestions are worthy of consideration although their usefulness will depend on the particular kind of formal and informal organizations of a company. Using reliability engineers as service personnel rather than as controls and inspectors is rather widely practiced, especially in the non-electronic fields.

R69-14204 ASQC 815

ROLE OF CONTRACTORS' PARTS SPECIFICATIONS IN HIGH RELIABILITY PROGRAM.

Peter Amedeo (Grumman Aircraft Engineering Corp., Reliability and Maintainability Control, Bethpage, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 31–35.

Parts specifications are considered to be a diversified design tool rather than just the means for procurement control. Specification control drawings and related aspects of parts specifications are discussed to determine their impact on the design process. Costs of specification activities are noted, as is the economic attractiveness of parts screening that is related to reduction in numbers of failures. Screening techniques are considered in terms of overall costs and improved reliability of parts. M.W.R.

Review: The author's stated purpose in this paper is "to present some thoughts on the role of the part specification in a high-reliability program," and he has accomplished this in a concise and readable way. He emphasizes the importance of the part specification in an effective parts program. The idea that the specification should serve as a design tool rather than merely as a method of procurement control is brought out. The role of part screening as an investment that pays dividends in terms of design reliability is indicated. Illustrative figures show the basic elements of project tasks in a parts reliability program, the purposes and use of parts specification control drawings, typical content of parts specifications for high reliability programs, a typical screening outline, and an outline for estimation of average cost of parts failure. This paper will be worthwhile reading for those concerned with the specification and procurement of parts for high-reliability projects.

R69-14206 ASQC 810; 831; 871
MAINTAINABILITY—A TOTAL SYSTEM VARIABLE.
John V. Sanderson and Robert Suslowitz (U. S. Naval Applied Science Lab., Systems Performance Effectiveness Branch, Brooklyn, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 51–60. 6 refs.

Two techniques presented for management of maintainability at the systems level are Design Disclosure for Systems and Equipment (DDSE) and the Generalized Effectiveness Methodology (GEM). These techniques, which are within the context of DOD and Navy requirements, encompass data processing and design criteria. Maintainability as a total system variable is viewed in terms of its impact on people and hardware, and the operational effectiveness of the two combined. Planning requirements documents impacting on maintainability are discussed, as are the applicable design specifications documents. The DDSE program as presently elucidated in MIL-HDBK-226 (Navy) is discussed in terms of the various aspects of management control; and capabilities of the GEM program for system maintainability measures are summarized. M.W.R.

Review: This paper contains technical summaries of two techniques developed by the Navy for use in system analysis. They are the Design Disclosure for Systems and Equipment (DDSE) technique and the Generalized Effectiveness Methodology (GEM) Program. The first of these is a technical communication tool created to bridge the communication gap between the many people involved in a development program. The second is a computerized method for prediction, evaluation, and control of system configurations and system variables in terms of important effectiveness and maintainability parameters. They have been applied with success on certain Navy programs, and have potential applicability to other military and aerospace systems. This paper will be of value to those who are interested in getting a quick picture of the essential capabilities of these two techniques. Those who wish to look into them in more detail will find appropriate references cited in the paper.

R69-14207 ASQC 814; 831
A COST EFFECTIVENESS STUDY OF A CENTRALIZED AUTOMATIC TEST SYSTEM.
Vincent C. Iacono (U. S. Naval Applied Science Lab., Maintainability Engineering/Test Equipment Branch, Brooklyn, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968 Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 61–78. 2 refs.

Methodology is presented for calculating the cost effectiveness of various combinations of test systems that support prime systems aboard Navy vessels. Both computer simulation and computer analytic models are included, such as a maintenance simulation model of shipboard equipment behavior, a status model depicting systems relationships aboard a typical ship, and a cost model. Prime systems availability, probability of correct status, and failure prediction were analyzed as measures of cost effectiveness; and in all three cases it was shown that automatic testing increased cost effectiveness. M.W.R.

Review: Highlights are presented in this paper concerning a computerized cost effectiveness study of automatic testing. Ample illustrations support the discussion. The cost effectiveness models are sketched only; full details are not presented. The material has the flavor of a realistic problem, although it is not stated whether the results were used for actual applications. No formal allocation techniques were used and, although it is not so stated in the paper, apparently the complexity of the appropriate cost and effectiveness models compelled the search approach which is used. An interesting result of this study is that Cost Effectiveness improves as the degree of automation increases. This is true for the three measures of Effectiveness which were analyzed, namely, Availability of Primes, Probability of Correct Status, Probability of Failure Prediction.

R69-14209 ASQC 817; 875
MAINTAINABILITY DEMONSTRATION PROCEDURE AND DATA.
C. E. Cunningham (Philco-Ford Corp., WDL Div., Palo Alto, Calif.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968. Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 85–95. 4 refs.

Seventeen maintainability (*M*) demonstrations, with the mean-time-to-repair in a prescribed support environment as the prime *M* criteria, were performed in compliance with MIL-M-26512 and its updates or with MIL-STD-471. Each of the demonstrations was made to determine the degree to which the contract end item of ground electronic equipment satisfied the *M* requirements specified in the contract; and in each case a sample of malfunctions was established statistically to represent the lifetime population of corrective maintenance tasks expected for the given equipment. Methods for duplicating or simulating each malfunction were determined; and malfunctions were inserted one at a time into the installed equipment under conditions as close to actual operation as could be achieved. These maintainability data indicated the log-normality of the distribution of maintenance task times, which were measured on equipment designed under a maintenance concept of logical troubleshooting where some 75% of task time was spent in fault isolation involving a large component of technician "think time". M.W.R.

Review: Reliability and maintainability activities have similar difficulties in regard to demonstrations of a contractual requirement, although maintainability people have additional difficulties due to the newer nature of their activities. This paper deals with a specific set of tests, and is short and well prepared. There are two questionable points, however. These are (1) the method for truncating the maintainability demonstration test and (2) the logNormality of the repair-time data. The method of truncating is admittedly an arbitrary decision. The problems associated with it, however, would not appear to be statistical but rather contractual and engineering in nature. That is, once the contractual requirements and engineering needs have been determined, the statistics will be straightforward. The second point—involving the logNormal distribution—the author considers settled; but the cumulative distribution shown in Figure 4 is almost clearly not a logNormal distribution (although why the actual distribution would be important if the sample mean is the only statistic of concern contractually is not clear). The remainder of the paper appears to be a reasonably clear and concise description of the experiments. Obviously there is the distinct quandry about accepting a maintainability demonstration when at least one of the failures cannot be repaired.

R69-14212 ASQC 810; 871
MANAGEMENT OF A RELIABILITY/MAINTAINABILITY DEPARTMENT.
Richard R. Johnson (Litton Industries, Data Systems Div., Van Nuys, Calif.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 155–162. 3 refs.

A general view of the functions of a reliability department is presented from the point of view of a newcomer to the field. Organization of the reliability department, reliability goals, and typical problems encountered in a military electronics establishment are described. A sample failure and maintenance form is included, and the percentage distribution of reliability engineering on a sample program is included. M.W.R.

Review: For a "newcomer" to the field of Reliability and Maintainability the author has stated a lot of the problems rather succinctly. For example, he states: "Reliability is a curious mixture of problems requiring mathematical and physical analysis, coupled with the need for a multi-level visibility and control program. Neither aspect stands alone since no amount of analysis can affect good reliability; and arbitrary controls or rules without sound technical reasons are dangerous," and "The most profound problem...dealt with the inability to define the equipment deficiencies in terms which would permit engineering management to take appropriate corrective action." The paragraphs on reliability predictions are quite apropos—different people predict different things and, although they may have justification, it is disconcerting to everyone in the field. The Failure and Maintenance Report given in the paper could, for some programs be too long, complex, and subject to error and possible misinterpretation by too many individuals. Typically the newcomer to the field wants to collect all the data he ever expects to use. He then becomes inundated with information and the whole system bogs down. Another element overlooked by the author is the matter of the profit contribution made by his reliability program efforts. When the profit contribution motive is not a prime target, the program will frequently be curtailed as soon as the impetus (such as a contractual requirement) for it is removed. This paper is worthwhile reading for those concerned with reliability and maintainability management, although it is not an in-depth treatment of any of the topics covered.

R69-14213 ASQC 815; 835; 863
MANAGEMENT PLANNING FOR INTEGRATED LOGISTIC SUPPORT AT THE NAVAL SHIP SYSTEMS COMMAND.
Abe Luft (U.S. Naval Applied Science Lab., Systems Performance Effectiveness Branch, Brooklyn, N. Y.). and Jacob Sacks
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 171–177. 6 refs.

Various documents generated to implement the integration of logistic support for the Naval Ship Systems Command are discussed, along with pertinent directives and techniques to meet the required goals. Dependence of quantified measures of logistic support on measures of effectiveness is noted, as is the mutual influence of design and logistic support on each other. Management aspects of integrated logistic support are discussed, and the role of the industrial community in enhancing this support is mentioned. Caveats related to proposals and performance for contractual services are included. M.W.R.

Review: This paper is valuable to those who do business with the Navy, particularly with the Naval Ship Systems Command. It tells the reader what he may expect in the near future in requests for proposal, specifications and requirements. The paper interprets the documents referenced and points out their significant elements and characteristics. The logistic portion of the system effectiveness theory and practice has long been dormant and the philosophy being discussed by the authors indicates that having the right part, skill, support equipment, documentation, etc., concurrently available when a failure occurs is as important as estimating, predicting, and designing rapid maintenance features into the device. This topic is important to those doing work for the Navy and might be important to others when the philosophy is adopted by other agencies. The paper itself attempts to bridge the gap between military specification writing and the more readable prose.

R69-14215 ASQC 816; 351; 833
THE ONE THAT GOT AWAY.
James A. Marshik and Robert E. Sisco (Honeywell, Inc., Aerospace Div., Minneapolis, Minn.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 209–221

Product procurement is discussed in terms of failures or defects that do not normally show up during inspection for various reasons including testing is too costly, the defect is hidden, or the parameter is not called out. Examples presented to illustrate the problem area deal with contaminated miniature relays, intermittently open relay contacts, loose pointers on aircraft instruments, paint peeling from a device. Others are thermistor lead fracture, unreliable solder joints on transformers, open tantalum capacitor inadequacy, inadequate process instruction for a bandpass filter. In each of these cases, failure analysis, problem cause, and problem solution are noted. A latent defect detection program is considered for possible solution of such problems; and economics of such a program, most likely trouble areas, failure rate considerations, selection of items and program implementation are discussed. Mention is made of latent defect detection tests and disposition of material with latent defects. Results of a quality assurance questionnaire sent to eight suppliers are included. M.W.R.

Review: The title of this paper could mislead the casual reader who does not bother to look carefully at the contents, because it gives the impression that the authors are speaking about defects which are inadvertently missed at receiving inspection. Actually they are discussing those hidden defects pertaining to characteristics of the procured product which are not normally inspected. They describe what they mean through the medium of eight case histories, which serve to illustrate very clearly the types of problems which can arise, as well as to give some indication of what was done about them in the cases under consideration. The authors then address the question of what can be done about problems of this kind. The diversity of the examples makes generalization difficult, but the suggestions appear quite reasonable. Better communication between customer and supplier is certainly part of the answer; in fact it should be broadened to include a feeling of partnership between customer and supplier, so that the supplier appreciates all facets of the customer's needs and works with him in every way feasible to meet these needs. The search for latent defects and the pursuit of most likely trouble areas are fine ideas too, but, as the authors have indicated, their implementation becomes a matter of the economics of the program. This is a good case history paper addressed to a practical problem. Some readers may well feel that other solutions would have been better or have different ideas as to who was at fault in some of the cases. For example, one might argue with some justification against penalizing the seller for a fault which was really caused by the purchaser's procurement activity. However, such considerations as this are not really in the broad context of the problem to which the paper is addressed, namely, difficulties of this kind do arise, so what can be done about them?. In this context, the authors have presented a very worthwhile description and discussion of important practical problems. In addition to its value for those who are active in the field, it is worthwhile discussion material for teachers of quality control, reliability, and purchasing as illustrations from the real world.

R69-14216 ASQC 816; 833
VENDOR PERFORMANCE—THE ONLY SUPPLIER EVALUATION TOOL THAT WORKS.
O. Lee Fletcher (Lockheed Electronics Co., Quality Assurance, Metuchen, N. J.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 223–227.

Advantages of using past performance data for initial vendor selection and for future management actions with vendors are stressed, and controls exercised by an industrial electronics organization are reported. Three categories of suppliers are considered, namely vendors, outside production groups, and distributors; and industrial cooperation is discussed as a means of improving vendor performance. M.W.R.

Review: The author's statement that "past performance is the only workable and consistently valid indicator of future performance" sets the tone of this paper. However, the author takes issue generally with all methods of numerically assessing the past history of a supplier's performance. His suggestion is that industry should get together to establish an industry-wide vendor rating program. While this sounds like a good idea, there may be reason to be concerned about the legal aspects of such an arrangement, e.g., restraint of trade. It is understood that such a task some years ago was developed to the point that one could evaluate a product, transmit the results of a test, but offer no conclusions, and that this system later became the Interservice Data Exchange Program (IDEP). In spite of the many publications on this subject, the author cites no references. While he condemns other approaches to the problem, he offers little that constitutes an improvement. Thus this paper offers little except conversation on the subject.

R69-14217 ASQC 810; 836; 844
RELIABILITY TECHNIQUES APPLICATION—COMMERCIAL SYSTEMS—A GENERAL REVIEW.
George Ebel (Conrac Corp., Caldwell, N. J.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 229–235. 1 ref.

An overview of commercial applications of reliability techniques is presented; and distinction is made between medical, industrial, and consumer fields and their respective reliability needs. Computer aided design, design review, maintainability analysis, and failure analysis are discussed as the reliability techniques used in the commercial field. A 6-step method for handling part removals during manufacturing failure analysis testing is outlined; and the determination of priority items relating to removals is illustrated by a chart which includes costs and savings. Feedback to designers is discussed as one of the most important aspects of failure analysis. M.W.R.

Review: The first part of this paper is an essay on high reliability (along with a minor bit of flag-waving for the free/private enterprise system). The second part of the paper discusses some reliability techniques. All in all the paper is a reasonable one and gives a reasonable summary of what people are doing. While one might take issue with a few individual points, the overall impression of the article is good and it can be of use to management and newcomers in the reliability field. (The same paper was presented at the 1968 IEEE International Convention, New York, N. Y., 18–21 Mar. 68.)

R69-14219 ASQC 810; 836
THE METHODS OF RELIABILITY.
William B. Rossnagel (General Electric Co., Re-Entry Systems Dept., Philadelphia, Pa.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society, Arno Press, Inc., 1968, p. 259–268. 13 refs.

Prediction and analysis, design and specification reviews, drawing review and sign-off, test procedure review and sign-off, failure analysis, and corrective action are discussed as the major portions of a reliability program. Ground rules are presented which include specific methods for achieving an effective reliability program; and problem situations that could arise are cited; and guidelines for corrective action are included. Other activities considered to be part of the reliability program are listed as training, configuration control, vendor control, and audit. M.W.R.

Review: This paper lists a wide range of topics, all of which have importance in the achievement of an effective reliability program. Design and specification review, on which much has appeared in the Reliability literature, occupies most of the paper; it is treated in reasonable detail and provides many practical suggestions. The idea of a producibility review is a good one and should be extended further to a review of methods for production. This paper could serve as reasonable reading for those who are new to the field, but its value as tutorial material is reduced by the fact that nine of the thirteen references are not identified as to date or source. This poor bibliographic technique makes the references useless to those who are not already familiar with where they may be obtained. (Reference 7, for which the source is identified, was covered by R65-11934.)

R69-14220 ASQC 810
THE EIA EFFECTIVENESS QUANTIFICATION TASK.
Keith N. Sargent (ARINC Research Corp., Santa Ana, Calif.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 273, 274.

The program for effectiveness quantification undertaken by the Electronic Industries Association through its G-47 committee is summarized. The five-year program has as its objective the realization of means to measure explicitly all system characteristics, which is expected to lead to design and development of more effective military and civilian electronic systems, provide the structure for advancing the capability of electronics industries to evaluate the effectiveness of their products, and lead to identification of critical areas that require gap-filling techniques. Efforts will be made to coordinate all EIA engineering activity, including reliability, maintainability, quality assurance, value engineering, human factors, electromagnetic compatibility, safety, and integrated logistics support. This function does not include supervisory activity, but rather includes the suggestion of areas to cover gaps in the overall program and to assure a cohesive application of all efforts. The G-47 committee is also charged with undertaking specific efforts to fill gap areas not specifically assigned. M.W.R.

Review: This is a very brief description of the program for effectiveness quantification which has been undertaken by the G-47 Committee of the Electronic Industries Association. The paper is not intended to convey technical details, but it does give an impression of the magnitude of the tasks which are involved in the program and some indication of the approach which is being taken. The paper will serve a purpose for those who wish to have a general awareness of what is being done in this field.

R69-14222 ASQC 810
EFFECTIVE CONFIGURATION MANAGEMENT AND ITS IMPACT ON CORPORATE OPERATIONS.
James P. Dunn, Jr. (Aerospace Avionics, Inc., Bohemia, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit. Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 291–293.

Industrial experience with a configuration management technique that has proven to be a cost effective means of providing end item verification is reported. All configuration policies, systems, and procedures are implemented by a configuration manager who reports directly to the manager of the aerospace electronics company involved and sees that there are no discrepancies between the contract, internal paperwork, specifications, drawings, hardware, and inspection documents. Identification, control, accounting, and general duties of the configuration manager are included. M.W.R.

Review: Only a reader at the level of a senior clerk would have anything to gain from the contents and philosophy of this outline on configuration management. It provides the reader with a few definitions, some terminology, and a sketchy picture of the tasks involved in complying with configuration management policy requirements and thus is an outline of a potentially good paper. No references are cited. By contrast, the paper beginning on page 295 in the same Transactions provides a substantially different and better coverage of the same subject.

R69-14223 ASQC 810; 830; 841; 842; 863
CONFIGURATION MANAGEMENT—ITS ROLE IN THE AEROSPACE INDUSTRY.
Edward G. Hantz and Alan E. Lager (Grumman Aircraft Engineering Corp., Bethpage, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 295–302. 3 refs.

The role of configuration management in the aerospace industry is considered in terms of the characteristics of the industry itself and the history, principles, and techniques of configuration management. Specifically, the major role of aerospace configuration management is defined as the orderly maintenance of the various interfaces that exist in the industry; and each of these interfaces is documented by appropriate baseline configuration identification and is systematically administered by the formalized processes of configuration control. In addition to interfaces between DOD and the service agencies, service agencies and prime contractor, and prime and subcontractors, there are in-house interfaces that the aerospace contractor must maintain. This means that configuration management must encompass positive management control at all levels and across all interfaces and throughout the product life cycle. M.W.R.

Review: This paper is highly recommended. Configuration management as described in this well-written and well-documented paper is a challenge to all Reliability and Quality Assurance specialists. The authors have explained in detail with a few examples the techniques of configuration management and the problems with which configuration managers have to contend. Basically, the configuration manager must be continuously aware of all items, their changes, and related information. The problems of identifying the components in a complex device are well illustrated, and as a result the reader obtains an understanding of the task that faces a configuration manager, and an appreciation for his problems. The impact of good configuration management on the tasks of Reliability and Quality Control is touched upon and the general picture is presented sufficiently clearly that a specialist in these endeavors should have no difficulty in defining the prime values for his assigned task.

R69-14225 ASQC 810
RELIABILITY PREDICTION CAN CONTRIBUTE TO THE ASSURANCE AND CONTROL OF PRODUCT RELIABILITY.
Bernard Tiger (RCA, Defense Electronic Products, Camden, N. J.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 323–325. 4 refs.

Reliability prediction is considered useful for the assurance of good design and system configuration as well as for the control of development and production to assure that the equipment will achieve the reliability and cost effectiveness projected during design and system configuration. Maintainability and systems effectiveness are also considered a part of reliability prediction. Both human and technical problems that go along with reliability prediction are mentioned. M.W.R.

Review: This paper undoubtedly made a good talk. It gives the listener some practical advice on how to be an effective reliability engineer. Just as with the hardware, the author asserts that many of the reasons why reliability engineers are not effective are people problems, and he gives practical suggestions for those who wish to be maximally effective. It is the kind of presentation which one will rarely take the time to read, but to which one will listen at a conference.

R69-14227 ASQC 810; 720
RELIABLE SOLDERING OF PRINTED CIRCUIT BOARDS.
Paul J. Bud (Electrovert, Inc., Mt. Vernon, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 333 – 354. 14 refs.

Wettability and solderability are discussed as prerequisites for sound joint formation, and hot tinning is emphasized as the most appropriate preconditioning for both printed wiring boards and components leads. Surface preparation for solderability, standards for coating thickness, and different pretinning processes are discussed with special attention to integrated packages and resultant solderability problems as well as copper and Kovar leads. Attention is given to component mounting and to wave soldering with and without oil. A new technology, ultrasonic wave soldering, was developed for fluxless production soldering to solve problems relating to integrated circuits. M.W.R.

Review: This is a very worthwhile paper for those who are concerned with the problem of soldering in the production of reliable electronic equipment. It presents a comprehensive discussion of reliable soldering, with particular reference to printed circuit boards. The discussion includes the basic concepts of wettability, solderability and surface preparation. Also considered are specifications, processes, standardizing activities, and wavesoldering, concluding with a description of ultrasonic wavesoldering. The whole discussion is keyed to 14 references which are cited. Also included with the paper are the figures which were apparently shown in the form of slides accompanying the oral presentation.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14182 ASQC 824; 844

Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.

RELIABILITY-CONFIDENCE COMBINATIONS FOR SMALL-SAMPLE TESTS OF AEROSPACE ORDNANCE ITEMS

A. G. Benedict 1 Jul. 1968 17 p

(Contract NAS7-100)

(NASA-CR-95397; JPL-TR-32-1165, Rev. 1; N68-28775) Avail: CFSTI

Reliability-confidence combinations for small-sample, no-fail tests of aerospace ordnance items are considered in some detail. Component reliabilities corresponding to confidences of the order of 70%, as based on tests by attributes, are shown to be satisfactory for calculation of simple series and parallel system reliabilities; it is suggested that 70% confidence levels may also be a good choice for tests by variables. Author

Review: This paper tries to analyze a problem which is interesting, but the treatment itself (a) uses specific examples to imply a general conclusion—for example, Eq. (4) on page 6; (b) is very hard to follow (the reader must scan the appendices and re-read the paper in order to understand the definitions and approach); and (c) uses poor nomenclature and inadequate and misleading notation (the author uses a new language as illustrated by the expressions "failure rate", "pass rate", and "inherent reliability" wherein his definitions are different from those in ordinary use or the term is one not usually used). The choice of notation leads to confusion; e.g., R_s in Eqs. 7 and 9 mean different things. The notation for probability of a system being good does not distinguish between the conditional probability (that is, given the fraction good of a lot) and the unconditional probability (i.e., averaged over all fractions good for the sampling situation considered). The very general problem with which the author is concerned is what confidence level to use when estimating the reliability of components so that the estimated system reliability will be nearest "correct." The specific question the author attempts to answer is: Given that (a) parts are nominally alike; (b) large lots have a fraction good which is initially uniformly distributed between zero and one (rectangular distribution); (c) a sample of n parts is examined from each lot (Bernoulli trials) and the lot is rejected if the sample contains a defective part; (d) the system is constructed of parts from only one lot, and a sample from that lot contains no defectives, what confidence level should be attached to the estimate of fraction good so that when the estimate of fraction good is substituted in the appropriate system equation it will give the correct average fraction of systems that are good? The solution is sought by using two specific examples: a parallel system for which one faulty item is tolerable, and a series system. Using the results of these two examples, it is concluded that component reliabilities expressed at a 70% confidence level as the result of no failed tests of attributes may be compounded to yield fair approximations for pass rates for sample series and parallel systems, at least over a wide range of practical situations. (See Conclusion (4) on page 6.) While this analysis is fun from the "theoretical" point of view, it has two important limitations: (a) there is no guarantee that the confidence level of 70% is appropriate in other sampling situations and other kinds of systems; and (b) there is no special reason for using the average fraction of systems that are viable versus other figures of merit such as confidence limits. The conclusions of the paper are conjectures which are based on specific evidence. Further documentation and theoretical work remains to be done. No references are provided, which is surprising in view of the large number of papers published in this area. (A paper also bearing on this topic is "Informational aspect of statistical reliability estimates," by Ya. A. Rips, *Automation and Remote Control*, vol. 27, 1967, no. 7, p. 1117–1125.)

R69-14184 ASQC 824

United Technology Center, Sunnyvale, Calif.

COMPARISON OF SOME RELIABILITY GROWTH ESTIMATION AND PREDICTION SCHEMES

W. J. Corcoran and R. R. Read 1 Jun. 1967 51 p refs

(Contract NAS7-356)

(NASA-CR-87993; UTC-2140-ITR-ADD.; N67-35338)

Questions of predicting the growth of reliability and the development of simulation models are discussed. Many reliability growth models provide only mathematical expression for growth without any associated scheme for estimating the model parameters from some form of failure data. Various statistical estimation methods could apply generally to such models. Problem areas are identified and it is concluded that the major problem is the selection of a measure of effectiveness. Results of pilot experimentation performed on a computer using several common measures are evaluated. S.P.

Review: This paper is theoretical, and design engineers and program managers would have a difficult time trying to find out from it what they should do. It is, however, of value to other theoreticians, since it compares and estimates the properties of some reliability growth schemes which have been proposed in the literature for estimation of current reliability or prediction of future reliability. Not all of the mathematics was checked, but it appears to be competent. Some reliability growth prediction and estimation schemes which have appeared in the literature are quite unsatisfactory, since the behavior of the curve in the prediction region has little to do with its behavior in the estimation region; and very few people take the trouble to calculate the uncertainties in their predictions. From an engineering viewpoint, about the only conclusion the article reaches is that this kind of thing is still strictly a very tricky business.

R69-14193 ASQC 824; 838; 882

Polytechnic Inst. of Brooklyn, N. Y. Electrical Engineering Dept.

MODELS, ANALYSIS, AND APPROXIMATIONS FOR SYSTEM RELIABILITY AND AVAILABILITY

Martin Messinger Jun. 1967 312 p refs

(Contract AF 49(638)-1402)

(PIBMRI-1365-67; AFOSR-67-1438; AD-671474; N68-32524)

Probabilistic models are formulated for the computation of the system reliability in terms of the component reliabilities. Emphasis is placed on obtaining bounds and approximations that can be used to simplify the necessary computation. In evaluating the usefulness of these results the concept of goodness is introduced. The system structure is modeled in terms of a reliability graph. From the minimal cut sets of the reliability graph, good bounds are obtained for the high reliability region, and from the minimal tie sets, good bounds are obtained for the low reliability region. For the special case of the k out of n structure, useful approximations are developed for the system reliability based on the normal and Poisson approximations, and for the special case of chain type structures, the Weibull reliability function is shown to provide a good approximation to the system reliability. Two models are considered for the analysis of non-repaired systems with component dependence. The first is the state dependent hazard model where the component hazards are assumed to be conditional only on the set of failed components and not on the times at which these failures occur. The second case treated is where the component hazards are functions of the present time and times of all previous failures. Mathematically, the first case is treated as a Markov process and the second case is treated by means of multiple integrals. Finally, analog and Monte Carlo simulation are considered. Author (TAB)

Review: Reliability analyses of large redundant structures present extremely difficult problems to solve exactly. This report contains the models with the assumptions explicitly stated and indicates the methods of analysis for such problems. Both exact and approximate procedures are provided. Some of the approximate methods should be used with care and the author is careful to so indicate. This report contains a great deal of detailed material and the reader will need a fundamental probability background for easy reading. Many examples are given to aid the reader in understanding the subject matter. Further basic mathematical and statistical material may be found in [1]. This report might be read in conjunction with [1] for additional examples and information, particularly in the area of availability. In connection with the suggestions for further research on p. 261, it may be remarked that a computer program which obtains approximations to the reliability of a system step by step, stopping when the upper and lower bounds are sufficiently close together, is described in [2]. This program starts with a precedence list of the components and generates the paths and cuts by use of matrix algebra. It then computes the probabilities using the bounds by adding additional terms until a sufficiently precise answer is obtained. The precedence list portion of the program was obtained from the Naval Applied Science Laboratory, Brooklyn, New York.

References: [1] Shooman, Martin L., *Probabilistic Reliability: An Engineering Approach,* McGraw-Hill, New York, 1968. [2] Practical Reliability, Volume II—Computation, NASA CR-1127, prepared under Contract No. NASw-1448 by Research Triangle Institute, Research Triangle Park, N. C. for National Aeronautics and Space Administration, Washington, D. C., August 1968.

R69-14199 ASQC 824; 433
Air Force Systems Command, Wright-Patterson AFB, Ohio. Systems Engineering Group.
RELIABILITY PROGRAMS FOR AEROSPACE SYSTEMS AND THE BAYES THEOREM TO ASSURE RELIABILITY
Samuel R. Porter 10 Aug. 1967 16 p refs
(SEF-TN-67-5; AD-664586; N68-18692) Avail: CFSTI

The development of the Bayesian approach will provide a tool for the accomplishment of the present reliability assessment requirements which are not being met by classical statistical methods. Utilization of the Bayesian assessment early in the component development program will provide for efficient and economical use of funds rather than making later decisions in the interest of reliability which are extremely costly or funds may not be available. TAB

Review: It is difficult to see who would be able to profitably use this paper. There does not appear to be anything incorrect in it, but it is so brief that the technical points are difficult to understand even for a person who is knowledgeable in the field—at least, without having to work backwards from the answer to see what the author is trying to do. The tables, in particular, which are abstracted from a reference, have no explanation and are almost completely incomprehensible without one. Some of the formulas which are given for Bayes calculations are true only in a very special case, viz., only two possible values permitted, but this important restriction is not stated in the text. Thus, while the exhortation to apply Bayesian techniques is worthwhile, the paper accomplishes nothing else.

R69-14200 ASQC 824; 831; 838
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
THE KIEV COMPUTER, DESIGN AND USE
L. N. Dashevskiy, S. B. Pogrebinskiy, and Ye. A. Shkabara 12 Jul. 1967 328 p refs Transl. into ENGLISH of the publ. "Vychislitel'naya Mashina Kiyev, Proyektirovaniye i Ekspluatatsiya" Kiev, Izd. Tekhn., 1964 p 1–324
(FTD-MT-65-592; AD-666095; N68-21601)

This book collected the experience in the design and use of the asynchronous universal digital computer Kiev. The principles of its construction and structure circuitry, the method of performing control and arithmetic operations, and the schematics of the elements, components, and basic units of the computer are described. The book includes the methods of calculating and investigating the reliability of a digital computer and problems of organizing the use of large electronic digital computers. The book is intended for engineers, researchers, students and graduate students in the field of computer technology and cybernetics and also for specialists interested in the development and use of computer and control equipment. TAB

Review: This review is addressed to Chapter 6 "Exploitation and Questions of Reliability," on pages 235–317 in the document cited above. The first thing to note about this chapter is that there is nothing in it that does not appear in American literature. Therefore, this chapter will be read only to find out what the Russians have been doing (or perhaps out of idle curiosity). It mentions the poor reliability of vacuum tubes and subsequent improvement with semiconductors. Failures of the computer were due to poor ventilation during the summer in some of the early days. Preventive maintenance is appropriately discussed including failures that occur during this scheduled down time. None of the mathematics employed is very complicated and, in general, the constant hazard rate is assumed for failure times and the Normal distribution for a "stress-strength" relationship. The concept of safety margin and reliability improvement by screening is mentioned. The author also says that (a) improved design, good maintenance crews, and better ways of finding failures are all necessary for higher reliability, (b) during the break-in period, there are naturally many more failures than there are later on, and (c) redundancy can improve the reliability of equipment. The above are the kinds of ideas that are presented in an elementary way in this paper. The translation is poor, so one ought not to waste his time reading it under the incorrect notion that he will learn something new about reliability that is not in the standard American literature.

83 DESIGN

R69-14178 ASQC 830; 815
RELIABILITY GOES IN LONG BEFORE THE WRAPPER GOES ON.
A. O. Adams (Leach Corp., Leach Relay Div., Los Angeles, Calif.). *In: Annual National Relay Conference, 16th, Oklahoma State University, Stillwater, Okla., Apr. 23, 24, 1968, Proceedings.* Conference sponsored by Oklahoma State University and the National Association of Relay Manufacturers. Scottsdale, Ariz., National Association of Relay Manufacturers, 1968, p. 7–1 to 7–6. 8 refs.
(Paper 7; A68-28187) $5.00.

General review of the requirements for reliability of relays used in missiles and aircraft, and the basic principles involved in obtaining high reliability. It is suggested that the first step in achieving reliability involves a thorough analysis of the design parameters and manufacturing tolerances on overall performance. Reliability potentials are discussed for the final capabilities of a relay in relation to the motor used to drive the contacts. The straight pull type of motor, the rotary type, armature type, balanced armature type, and the balanced-force/balanced-armature type of motors are briefly examined. The proper choice of electrical contact materials is reviewed. IAA

Review: This paper begins with some admonitions for designing a reliable relay. Presumably only particular kinds of relays are being described, for example, virtually all telephone relays would be excluded by the author's criteria. A brief summary of the various kinds of motor design is given, ending with what is called the "balanced force" motor, presumably an innovation by the author's company. In this design, the holding force in the nonenergized position is provided by a permanent magnet rather than by the conventional springs. Some portions of this description are not clear at best and are possibly misleading. For example: The force-stroke curves are given for power-on and power-off phases but they do not seem to be drawn to the same scale; if they were, it appears that the relay would not energize. However, in a private communication a representative of Leach Corporation Relay Division has indicated that they are drawn to the same scale and that a fuller explanation may be found in [1]. One can also take issue with some of the recommendations for reliability. In particular the atmosphere surrounding the coil is not isolated from that surrounding the contacts. (This leads one to reminisce about the humorous ads of a well-known relay manufacturer which some time ago went on at length about the wonders of hermetically-sealed relays and at the end suggested that the only valuable thing that the user could do to solve his problems with them was to put a very small hole in the can. Those days are gone forever—we hope—at least if the relays are as good today as the makers tell us they are.) In the private communication mentioned above the company representative has pointed out that only non-outgassing materials are used and contact contamination is not a problem. The biggest difficulty in implementing the author's recommendations is that the designer may be pushing the state-of-the-art with regard to size, sensitivity, etc., and thus is not allowed some of the "necessities" for high reliability, especially large safety margins. So he may have to resort to nondestructive testing which can, in many cases, negate the admonition that you cannot inspect reliability into a product. The whole purpose of non-destructive testing is to inspect unreliability or poor quality out of a product. In effect, this leaves the high-reliability high-quality product for the consumer. Regardless of the above remarks, the author's exhortation "to build as much reliability into the relay as possible" is, of course, well founded. (But such exhortations should rarely be taken as complete treatments of the subject or such advice considered to be limiting or complete. It is in this sense that the above remarks are made.)

Reference: [1] J. C. Schuessler and A. O. Adams, "Tomorrow's Relay Today—The Balanced Force Series," presented at the 15th Annual National Relay Conference, April 1967.

R69-14190 ASQC 833

Stanford Research Inst., Menlo Park, Calif.

HIGH RELIABILITY CONNECTIVE DEVICES Final Report, 1 Feb. 1964–31 Jul. 1966

Gunther Steinberg and Marvin Garrison Jun. 1967 164 p refs
(Contract DA-36-039-AMC-03727(E))
(ECOM-03727-F; FR-5; AD-653847; N67-33687) Avail: CFSTI

The study established that electrical contacts can be successfully lubricated with solid organic compounds. Octadecylamine hydrochloride (ODA.HCl) is capable of providing durable low friction sliding on gold and is regarded as a type of solid organic compound that has inherent lubricity, can be sheared easily, but has the ability to support a load. For good durability, the lubricant must be present in reservoirs in the surface of the contacts. A contact lubricant decreases friction and attendant wear, and maintains the integrity of a protective gold (or other precious metals) platings. Preservation of this plating prevents gross corrosion in sliding contact tracks. Several methods for application of the ODA.HCl to commercial contacts were tested and methods for identifying the presence of the lubricant film were developed. Author (TAB)

Review: This is an extensive report on a project addressed to the achievement of high reliability and stability for contacts in sliding-type connective devices operating at low signal level. With the miniaturization of electronic equipment this topic has assumed increased importance, especially since the reliability of connective devices has not kept pace with the reliability improvements made possible by transistors and microcircuitry. The major conclusion drawn from this program is that electrical contacts can be successfully lubricated with solid organic compounds. The author in a private communication has indicated that an important corollary to this major conclusion is that solid organics were considered superior to liquids because solids (1) provide good load bearing films, (2) do not creep, (3) do not wet and hold dust particles to the contact surface, (4) do not readily dissolve deleterious vapors from the atmosphere, and (5) prevent corrosion to some extent. He has also mentioned that the material used in most of the study is a model compound, useful under low severity conditions. Less reactive and better materials can be and are being developed based on the requirements outlined in this report. The conclusions and recommendations, including suggested criteria for military connector contacts will be of interest to designers of electronic equipment. However, the details of this lengthy report will be pursued only by specialists in the study of connective devices.

R69-14192 ASQC 836

SYLVANIA'S DESIGN REVIEW PROGRAM *WORKS.*

Michael R. Nusbaum (Sylvania Electronic Systems, Reliability Assurance Dept., Waltham, Mass.).

Evaluation Engineering, vol. 7, Jul./Aug. 1968, p. 12–14, 16, 62.

An industrial design review program is discussed in terms of its overall effectiveness. Consisting of system concept, circuit, physical configuration, and design release reviews, the program uses various checklists and involves both design and review personnel teams. Each of the four types of design review includes planning, preparation, meeting, and follow-up phases that are held at specified times to review specific tasks. M.W.R.

Review: This is another one of the papers describing a specific design review program for a particular company. It follows the usual lines, due consideration being given to the practical problems such as preparation and follow-up. Those who wish to institute design review procedures can profit from reading this and other papers on the subject. Similarly, those who have existing programs and wish to compare them with what others are doing will find this paper of value. The novice should be warned that virtually all such papers he reads will look good (otherwise they would not have been published) but that obviously there are many difficulties in industry today that have not been cured by such programs. This is not to say that such programs are not useful or that this is not a good example of a useful program, but merely emphasizes the ignorance on the part of the reader even after he has read the paper. The number of man-hours actually spent in these design reviews is considered to be a worthwhile investment, but this amount will vary considerably with the nature of the program and the kind of industry. If it is looked upon as a service function to the designers (incidentally, there is no reason why this should not be done for Production also), many designers who would otherwise be antagonistic can look upon this as free help.

R69-14194 ASQC 832
National Aeronautics and Space Administration, Washington, D. C.
AN INTRODUCTION TO THE ASSURANCE OF HUMAN PERFORMANCE IN SPACE SYSTEMS
1968 42 p refs Prepared by Martin Co.
(NASA-SP-6506; N68-20357) Avail: CFSTI

To assess the role that man plays as a potential source of error in space technology, studies were conducted to determine what human performance assurance effort is appropriate for various projects and to show how this effort relates to various phases in the development cycle. A method for classifying programs and systems according to mission complexity and significance is developed, and human engineering and serviceability functions appropriate for specific development phases of the programs are categorized and described. Man–machine capabilities are summarized as an aid in determining the relative superiority of each. An example is presented in which the techniques are applied to a hypothetical micrometeoroid deep space satellite, a concept based on studies of an unmanned satellite program of medium-to-small cost and complexity. The reliability program provision for space system contractors, concerning prevention of human error, is included. M.G.J.

Review: As most hardware failures are caused by a human error made somewhere in the life-cycle, human performance is important to reliability. This introduction to the assurance of human performance is a good source of ideas. Its format lends itself to quick reading and it is easy to find what is wanted. All phases of the life cycle for space systems are included. The contents include such topics as perspective, program considerations, and check-off lists. There is no quantitative analysis nor any data. This is not surprising, as most reliability predictions are mute on just how human considerations fit into the analysis, notwithstanding the first sentence of this review.

R69-14195 ASQC 838
Westinghouse Electric Corp., Baltimore, Md. Surface Div.
SELF-REPAIR TECHNIQUES INVESTIGATION Final Report, 1 Jun. 1966–31 May 1967
Frank B. Cole and Samuel E. Zimmerman Aug. 1967 108 p
(Contract DA-28-043-AMC-02343(E))
(MDE-2566; ECOM-02343-F; Rept.-4; AD-657247; N67-39299)

The report documents, in abbreviated form, all metallurgical testing conducted in support of the Phoebus 2 Nozzle Program. The tensile properties of forgings, strip, weldments, and brazements are presented as individual test data and as statistical means with sigma limits through the temperature range of −423 to 1800°F. The mechanical properties of shear strength, bearing strength, low cycle fatigue, and thermal cycling are also presented. In addition, the manufacturing and fabrication processes are presented from raw material melting through fabrication of individual hardware components. Metallurgical analysis of thermal treatments and processing are also provided. Author

Review: This is a final report on a study of techniques for implementing in digital systems a self-repair capability. By self-repair the authors mean the ability of a system to detect, locate, and automatically switch out a failed module and in some cases switch in a replacement. The technical quality of the work and of the report is high. Two topics are presented in detail: residue coding for fault detection and location; and spare switching for fault detection, location, and repair. The topic of residue coding is discussed in considerable detail with respect to the particular implementation chosen by the authors; it is dismissed as impractical due to the hardware and instruction execution time costs derived for that implementation. While residue coding may be undesirable for failure detection and location, not enough evidence is given in this report to make a convincing argument for its dismissal. The topic of spare switching is treated in a highly practical manner. Some of the problems encountered when applying a redundancy scheme to actual hardware are discussed. The detailed results presented represent one of the better treatments of digital system redundancy, due to the practical orientation and to the fact that the switchable spare approach to redundancy has cost and power advantages over the usual voting techniques.

R69-14196 ASQC 835; 844
GETTING BENEATH THE SURFACE OF MULTILAYER INTEGRATED CIRCUITS.
Frank J. Barone and C. Frank Myers (Motorola Semiconductor Products Inc., Phoenix, Ariz.).
Electronics, vol. 41, Jul. 22, 1968, p. 84–88.
(A68-37396)

Description of a method for testing inaccessible semiconductor devices, based on a test-pattern technique that evaluates the processing parameters of high-density ICs during fabrication, providing design and reliability data to both user and manufacturer of the devices. The test-pattern technique may also be used as a look-ahead indicator of the final yield for the circuits. To demonstrate the value of the technique in manufacturing and evaluating complex ICs, the production steps for an 8-bit adder consisting of 448 components on a 53×119-mil chip are traced. IAA

Review: Developing satisfactory screening tests for conventional integrated circuits as a means of improving reliability will seem a simple assignment compared to the task of testing the multilayered integrated circuits now in the research and development phase. This paper attacks the latter problem by recommending the inclusion of a test pattern in the photomasks used to build the integrated circuits. The purpose of the test pattern is clear—it provides data descriptive of individual process steps that otherwise would not be available. This idea is very commendable; even with the relatively simple integrated circuits that are now on the market, the relationship between processing variables and circuit performance and reliability are not known. Any contribution to change this undesirable condition is good. Wringing all the potential value from the test pattern may prove difficult; the present paper provides little evidence to indicate that the test pattern has had any major impact as yet, although the first author in a private communication has stated that test patterns have been in use for three years at Motorola and are now used on all complex circuit wafers. He has indicated that publication of data showing the usefulness of these test patterns may be forthcoming. Some details are omitted from the paper or some assumptions are not given, leaving unanswered such questions as the following. (1) How does one measure transistor yield by a single measurement on the multi-emitter transistor structure (all emitters are coupled by metallization)? (2) How do the measurements indicated in cross section 7 give the sheet resistivity of the buried layer? (3) How does Quality Control use the data at Motorola? The authors have answers for such specific questions but the reader interested in this detail will have to communicate with them.

R69-14198 ASQC 838
General Electric Co., Philadelphia, Pa. Missile and Space Div.
APPLICATION OF REDUNDANCY STUDY, VOLUME 4 Final Report
Lee E. Hauguane, Jr. 28 Jul. 1967 359 p Prepared for JPL
(Contract NAS7-100; JPL-951112)
(NASA-CR-89703; N67-40411) Avail: CSFTI

Applications of redundancy to both the mission and spacecraft system levels of the Voyager program are considered, and the evolution of the mission configuration decision model is presented. Nominal probabilities, costs, and values are used for the decision model; with no attempt to determine the sensitivity of the resulting policies to these three nominal variations. For these values, an unmanned Mars project appears to offer the highest return of expected value. For 1971, a Mariner flyby with an atmospheric probe is suggested; for 1973, large surface landers with extensive television and physical experiment capability; and from 1975 through 1981, landers of the VBL class. Aspects of spacecraft system redundancy selection that are detailed include the mission outcome and values, system definition and description, hardware failure modes and mission effects, and system optimization. For mission configuration selection, details are presented of a pilot study; potential mission configurations; decision, probability, cost, and value models; and the SPAN computer programs. M.W.R.

Review: This report, in addition to being of direct value to the Voyager project, can serve as an excellent starting point for anyone called upon to make similar calculations. In a brief review such as this, it is obviously not possible to examine completely the technical adequacy and the validity of the many engineering judgments. Suffice it to say that spot checks and careful reading show the approach to be quite reasonable in view of the state of the art, and the discussions of many factors to be excellent. The concept of System Worth (a weighted reliability) is introduced and it is this Worth that is maximized. The authors take care to point out that many judgments are quite subjective regardless of how much one might wish to cloak them in mathematical sophistication; this point is worth remembering by those engaged in other kinds of system evaluation. The reliability calculations are made on the basis of constant hazard rate for each non-redundant element, as is customary. The hazard rates are extrapolated from available historical data in order to estimate the hazard rates the parts would have when purchased for this particular mission. Much of the size of the task comes not from the complexity of any individual calculation but from the sheer magnitude of the job. Naturally, extensive use was made of computers; and extensive research was done on the various algorithms used in order to be sure they are adequate. All in all, this will be an excellent reference document for anyone who may be called upon to perform a similar kind of task.

R69-14201 ASQC 831

SYSTEM EFFECTIVENESS APPROACH TO RELIABILITY OF VEHICULAR COMMUNICATIONS.

Edward T. Parascos (CBS Labs., System Effectiveness, Stamford, Conn.).

In: 1967 IEEE Vehicular Technology Group Annual Conference Record, 19th, New York, Dec. 6–8, 1967. Conference sponsored by IEEE Vehicular Technology Group and New York Section of IEEE. New York, IEEE, Inc., 1968, p. 98–104. 42 refs.

Basic system effectiveness objectives and tasks are presented that must be accomplished to optimize the development, manufacturing, and testing of vehicular communication equipment. Terms relating to systems effectiveness are defined, and a functional diagram and discussion of system effectiveness assurance are included. Mention is made of quantifying system effectiveness. A unified approach is stressed that will integrate the various support disciplines of reliability, maintainability, quality assurance, human factors, system safety, integrated testing, and cost effectiveness/value engineering. M.W.R.

Review: This paper has nothing to do with vehicular communications per se and is basically an elementary introduction to the concepts involved in system effectiveness. It does two things reasonably well: (1) gives short definitions to many of the concepts involved, and (2) supplies an extensive bibliography although it is largely limited to papers given at the 1966 Reliability and Maintainability Conference and the 1965 (11th) National Symposium on Reliability and Quality Control. The author's attempt to distinguish between system effectiveness and the assurance function thereof is probably worthwhile. It is difficult to see how the two things are actually confused; one being a number describing a system, and the other being all the actions one goes through to assure that number. At the end of the paper the author introduces his own definition of system effectiveness, which is at odds with everything he has said so far. The defining equation in Figure 11 should not contain the middle expression since it involves an incorrect approximation which is not true in general, especially for the cases being considered by the author. This defining equation of the author for system effectiveness involves only the costs associated with the entire program relative to the costs associated with the system effectiveness assurance part of the program. It involves that ratio together with a fudge factor. This fudge factor is poorly described and of little purpose except apparently to make an answer come out right. Thus the only value of the paper is that of introducing the novice to some of the very brief definitions that are useful in this concept and of providing the bibliography.

R69-14208 ASQC 830

SELF-REPAIR—NEXT MAJOR SYSTEMS DESIGN GOAL.

W. W. Gaertner (Gaertner Research Inc., Stamford, Conn.).

In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society Arno Press, Inc., 1968 p. 79–84. 5 refs.

A self-repair approach for electronic systems design is described which is compatible with existing and future microelectronic technology and which is considered to provide advantages with respect to maintainability and logistics support as well as cost effectiveness. The system contains built-in adaptable back-up circuits that are switched into the signal path in response to the fault isolation by built-in test equipment. With proper equipment partitioning a single back-up element can be used to replace several primary elements in much the same way as a spare tire can be used for any of the wheels on a car. It is estimated that 30% additional components could provide full double redundancy for the equipment, and that the total increase in equipment power consumption is usually less than 10% because the power is disconnected from all unused elements. Some logic circuits are illustrated, as are block and flow diagrams for the self-repair and malfunction-recording system. M.W.R.

Review: This is a very brief paper which presents an idea for electronic switching of logic circuits in and out of a system. The switching is used in conjunction with redundant elements in a block, so that repair can be effected by changing the signal coding to a block. The author suggests further research for finding the most effective and feasible ways to perform this "self-repair". The development is heuristic and appears reasonable. No reliability improvement figures are given. If the damage is caused by external weapons effects, the failure events are extremely likely not to be statistically independent and any nominal reliability improvement due to statistically independent redundancy will be vastly overrated. It is sometimes too easy to wax eloquent on the benefits of self-repair; the practical advantages and manifestations thereof are less easy to come by. Self-repair is obviously already in use in some of the newer telephone electronic switching systems and is in common use in automatic switchover for standby systems, although it is often not identified by that name.

R69-14211 ASQC 835

PACKAGING AND RELIABILITY IN INTEGRATED CIRCUITS.

R. L. Coren and T. J. Matcovich (C & M Associates, Maple Glen, Pa.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society, Arno Press, Inc., 1968, p. 137–140. 13 refs.

Reliability considerations in solid state devices and integrated circuits are discussed, along with some present-day interconnection techniques and a packaging scheme to improve IC reliability. The greatest limitation on IC reliability is considered to be in the lead connections to the outside world, and the use of hybrid circuits is considered a practical means of overcoming this limitation. Packaging schemes have been devised for use with large hybrid systems, and one such scheme involves an intimate stacking of circuit boards and has a multilayer ceramic board. In addition to three-dimensional stacking and high density, this scheme has short lead lengths, all interconnections in a single module, standardization of modules and external package, and ruggedness of the complete package. M.W.R.

Review: This paper treats the way in which the packaging of an integrated circuit affects its reliability. The biggest problem is asserted to lie with interconnections. The suggestion is then made that the best way to get rid of the interconnection problem is to convert them to intraconnections, and a few such schemes are shown along with a brief discussion of advantages and disadvantages. This paper will be useful to those who are trying to develop an insight into the problem, but it offers no cures.

R69-14214 ASQC 830
SYSTEM EFFECTIVENESS.
S. R. Calabro (Aerospace Technology Corp., Bloomfield, N. J.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 201–207. 3 refs.

Mission reliability, operational readiness, and design adequacy are discussed as the principal system effectiveness factors. These three factors are, in turn, affected by human factors, logistics, costs, administration, and operational military characteristics; and the total of all these define the required capability of the system to achieve its effectiveness or the desired function in the mode and manner of its application. Intrinsic and operational availability, storage and free time, repairability, serviceability, and operating time are the operational characteristics discussed; and reliability and maintainability are considered. Attention is given to quantitative measurements of system effectiveness, and a general equation is included for operational readiness. M.W.R.

Review: This is a brief presentation of definitions and concepts pertaining to the factors involved in system effectiveness, namely mission reliability, operational readiness, and design adequacy. It will serve as tutorial material for those who want to obtain a quick picture of the factors involved in system effectiveness, and who already have an acquaintance with the basic concepts of reliability. No topic is treated in depth, as is to be expected in a brief presentation on a subject which has as many facets as this one does. The discussion of the system design considerations will be particularly worthwhile for designers. An earlier paper by the author (covered by R68-13711) provides an example of the calculation of system effectiveness from failure-time and maintenance-time data.

R69-14221 ASQC 831
SYSTEMS EFFECTIVENESS AND THE NAVY.
Pantelis Sgouros and John V. Sanderson (U.S. Naval Applied Lab. Systems Performance Effectiveness Branch, Brooklyn, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968 p. 275–282.

An overview is presented of the system effectiveness efforts of the Navy, as well as answers to an Aerospace Industries Association (AIA) questionnaire on the government's position on system effectiveness. The effectiveness analysis encompasses (1) mission/performance envelopes, cost determination, system parameter delineation, and total system tradeoffs; (2) selection of techniques and the policy for implementing a fully competitive environment and encouraging a variety of design solutions; (3) establishing requirements for tradeoff analyses, costs, and scheduling on the basis of total system impact; and (4) assisting management's decision making with a variety of effectiveness measures. The Generalized Effectiveness Methodology (GEM), maintenance and scenario simulation models, and other techniques and guidelines are briefly discussed. Answers to the questionnaire, which are appended, deal with the definition of systems effectiveness and cost effectiveness, requirements for their evaluation and interfaces, and the relative importance of both. Effectiveness evaluation capability, current and past applications, effectiveness specification and modification, incentives, and impact on the nation are also covered by the questionnaire. M.W.R.

Review: The discussion of systems effectiveness in the Navy along with replies to Aerospace Industry Association (AIA) questions give a timely overview of the topic. As the replies to AIA questions were coordinated through a Navy-wide steering committee, a truly Naval response is presented. Both achievements and deficiencies are treated, with the probing AIA questions doing much to bring out discussion of the deficiencies. A minor blemish on the paper is that the documentation pertaining to the Navy systems effectiveness program is blended into the discussion. It would seem that by now some of this would have been released for general dissemination and thus be readily available to Government-Industry workers. Reliability considerations appear to be an important part of systems effectiveness, as reliability indices enter into all five of the computerized systems effectiveness calculations which are noted. The bulk of the material presented in this paper pertains to policy and to the development of technical matter necessary to implement that policy. The pay-off of systems effectiveness concepts of course comes with actual implementation in the Navy program offices. Feedback from the implementations are necessary to effect refinement of the policy and the techniques. With regard to this question the material contains a figure noting the implementation of some 54 Systems Performance Effectiveness (SPE) products. An Appropriate question is "Just how extensive is this SPE implementation relative to a Navy-wide base?" In the answer to an AIA question (the last one), a call is made for an even more active role by industry. An important point to industry which is sometimes overlooked by Government spokesmen is that of just how extensively the Government program offices will implement the policies. System performance effectiveness and total lifetime cost policies and techniques appear very sensible, but so have their predecessors in support areas, including reliability, maintainability, and quality control. The industry response to systems effectiveness will come over a period of time and be determined largely by what industry experiences in proposal requests, and more particularly in contract negotiations and contract implementations.

R69-14224 ASQC 838
7 YEARS OF OAO.
J. E. Anderson (International Business Machines Corp., Federal Systems Div., Electronics Systems Center, Owego, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 303–307.

Design approach and performance data are presented for the Primary Processor and Data Storage (PPDS) unit built for the Orbiting Astronomical Observatory in 1961 to include real time and delay mode capabilities. Quad redundancy at the component level was selected as the best of available techniques to increase reliability. A summary of the most probable failure modes was made, and the circuit design used for the processor generally fit into the following five mathematical logic arrangements: (1) quad redundant parallel series network with all subnetworks identical, (2) quad redundant parallel series network with upper subnetworks differing from lower subnetworks, (3) triple modular redundancy, (4) quad redundant parallel configuration requiring three or four parallel paths, and (5) dual parallel redundancy with identical subnetworks. These arrangements are discussed, as is the effect of undetected parts failures, recycle and retest results, and the effectiveness of redundancy. Even though the equipment experienced nine component level failures, overall system performance was improved by employing quad redundancy design techniques. M.W.R.

Review: This paper discusses a method of redundancy not often mentioned in the literature any more, viz., quad-redundancy. The two standard-type quad analyses do not have the shorting bar across the center and thus are appropriate to circuits in which failures are more likely to be the shorting type. The analysis of triple-modular redundancy is appropriate only to those units where good/bad is an acceptable description of their behavior. The other two figures analyzed are simply two and four units in parallel. All of these analyses, except the majority voter, presume that good/open/short are adequate descriptions of the behavior of both the parts and the circuits. There is no indication in the paper of what kinds of units were quadded and what were not, e.g., no resistor failures are mentioned at all. Most of the failures were semiconductors. There is also no indication of how transistors were quadded. Thus this paper is too sketchy; it has no real information for designers or reliability engineers that they cannot already easily get in the literature. But the paper is an interesting applications example and more information is undoubtedly available from the author.

R69-14229 ASQC 837
Army Missile Command, Huntsville, Ala.
TOLERANCE PHILOSOPHY
William E. Keeling Jun. 1967 44 p
(AD-816406; N68-88697) Avail: CFSTI

The report is designed to establish the interdependency of test equipment tolerance limits to other parameters of system design and to establish a general tolerance philosophy. Included is a graphical development of tolerance philosophy and a derivation of applicable tolerance handling formulas. The central theme of the report proves that test equipment tolerance is a dependent function of a parameter called delta sigma and is basically unrelated to the item under test tolerance. This theme is then expanded to include other elements necessary to establish an overall tolerance philosophy for use by the Government, contractors, and designers. Also included are some of the relationships of mathematical tolerance manipulation to the laws of distribution probability, particularly as they relate to the incorrect presumptions currently employed. Author (TAB)

Review: This is a difficult document to read because a large portion of it is written in jargon which is not at all in widespread use. Some good ideas can be gotten from the main portion of the text in which the sources of cumulative deviations and tolerances are discussed. The mathematical discussion should be avoided. There are good papers on the mathematical treatment of tolerances which include, for example, a distinction between bias and uncertainty, something which the author does not do. The term rss apparently means the square root of the sum of the squares, a term not often used. The author also uses the term "rms addition" which appears to be a logical contradiction since rms is an averaging procedure. Section 5 is very misleading and should not be read at all except by experts who will not be led astray. Section 6 is an extremely naive treatment of tolerances involved during multiplication and division; it is usually handled better in most Freshman Physics courses (some of the arithmetic contains errors and gross circumlocutions). The discussion of unsymmetrical tolerances, presumably being some sort of exact treatment for multiplication and division, fails to consider some of the important problems involved and generally beats a reasonably dead horse. In general, the paper should not be read by anyone except those who are able to distinguish the good from the bad, but they will not need to read it.

84 METHODS OF RELIABILITY ANALYSIS

R69-14177 ASQC 844
AN ANALYSIS OF LIFE LIMITING FACTORS FOR MEDIUM-SIZED REED SWITCHES.
S. Mitani (Hitachi Ltd., Totsuka Works, Tokyo, Japan)., G. Kamoshita (Hitachi Ltd., Central Research Lab., Tokyo, Japan)., K. Ono, and T. Tanii (Nippon Telegraph and Telephone Public Corp., The Electrical Communication Lab., Tokyo, Japan).
In: Annual National Relay Conference, 16th, Oklahoma State University, Stillwater, Okla., Apr. 23, 24, 1968, Proceedings. Conference Sponsored by Oklahoma State University and the National Association of Relay Manufacturers. Scottsdale, Ariz., National Association of Relay Manufacturers, 1968, p. 6–1 to 6–6.
(Paper 6) $5.00

Life-limiting factors for medium-sized reed switches were analyzed and experiments were conducted on switches filled with argon, helium, and nitrogen. Material transfer of contact for both argon and helium filled switches was investigated, and electron microscopy observations were made of the surface of reed contacts. Alignment and life of contacts were also studied. Helium was found to be the best inert gas for filling reed switches, and exhibited less material transfer of contact in a wet circuit. Mechanical alignment of reed contacts was improved by a method using electrolytic polishing, and some experimental data for the life characteristics of the improved reed switches are presented. M.W.R.

Review: This paper describes some experiments which show that a helium back-fill in these particular reed switches, when operated under these particular circumstances, gave better life than either an argon or nitrogen fill—at least as far as the median failure point is concerned. It is not at all clear from the data that the very small fraction-failed point is improved any by the helium. The data show that the electrolytically polished samples performed longer than those without such polish. One should not infer from these results that the same kind of behavior would occur for other test conditions. The behaviors of relays are extremely sensitive to the kinds of tests performed, the criteria for success, and the operating conditions.

R69-14181 ASQC 844
RELAY FAILURE ANALYSIS TECHNIQUES.
J. J. Lombard, Jr. (Grumman Aircraft Engineering Corp., Bethpage, N. Y.).
In: Annual National Relay Conference, 16th, Oklahoma State University, Stillwater, Okla., Apr. 23, 24, 1968, Proceedings. Conference sponsored by Oklahoma State University and the National Association of Relay Manufacturers. Scottsdale, Ariz., National Association of Relay Manufacturers, 1968, p. 11-1 to 11-11. 6 refs. (Paper 11; A68-28188) $5.00.

Detailed description of a step-by-step procedure for failure analysis of relays. An important feature is the incorporation of state-of-the-art analytical techniques into the test sequence. One of the most significant techniques employed is X-ray vidicon analysis. Another technique is gas chromatography. This procedure is designed so that all the nondestructive tests are performed first. This allows causes of failure to be traced to an electrical, mechanical, or seal defect without destruction of the relay. The destructive techniques are then employed to positively identify the failure mechanism. IAA

Review: This well-prepared paper not only shows how to analyze relays (hermetically-sealed), but gives examples of the horrible hardware and foolish failures that have been uncovered by these techniques. The examples are such as to make a believer of most anyone (except, of course, the ad writers for the manufacturers). An undertaking such as the one described tends to be expensive, and in general will have to be adequately supported by a high-reliability program. For many industrial purposes, one would like to think that the incoming quality would be high enough to be reasonably acceptable for production, with failed units being returned to the original manufacturer for his own analysis. For anyone who is going to become involved in the analysis of relay failures, this paper provides a good summary of the kinds of things to be done, equipment to be used, and dangers of which to be aware. No mention is made of the costs of operating such a facility, although there probably is the comeback which says "it doesn't cost, it pays."

R69-14185 ASQC 844; 711; 712
Illinois Univ., Urbana. Dept. of Theoretical and Applied Mechanics.
CUMULATIVE FATIGUE DAMAGE UNDER CYCLIC STRAIN CONTROL
T. H. Topper, B. I. Sandor, and Jo Dean Morrow Philadelphia, Pa., Naval Air Eng. Center, Jun. 1967 35 p refs
(Contract N156-46083)
(NAEC-ASL-1115; AD-659302; N68-10968)

Cyclic deformation resistance and fatigue damage accumulation are investigated using multiple level strain control. Data are reported for 2024-T4 and 7075-T6 aluminum alloys, aircraft quality SAE 4340 steel, and Titanium 811. Effects of cyclic strain level, sequence of straining, number of blocks, and mean stress are investigated. For combinations of relatively large cyclic strain ranges there is no mean stress present and damage summations based on completely reversed strain vs life plots are close to one. Tensile or compressive mean stresses may be induced when the cyclic strain sequence is from a high to a low level. Damage summations based on completely reversed strain vs life data are reduced if the mean stress is tensile and are generally increased if the mean stress is compressive. Author (TAB)

Review: This paper presents a comprehensive, well-documented study of cumulative fatigue damage under various cyclic strain conditions. The work is part of a broad research program which is aimed at predicting the fatigue life of spectrum-loaded notched members based on material properties obtained from smooth specimens. The successful completion of this program may lead to the long-sought-after prediction of fatigue failure for structural elements, under known service conditions, based on information obtained from smooth specimens.The data are presented graphically and illustrate the correlations obtained between (a) cyclically hardening and softening materials and (b) linear cumulative damage rules. Some useful qualitative design information is presented for the four materials tested, but before quantitative design information can be demonstrated, additional research efforts must be undertaken. These research areas are identified. Two companion papers [1, 2] would be useful supplementary reading. [1] is required for a complete listing of material composition, mechanical properties, and fatigue behavior in this report.

References: [1] T. Endo and JoDean Morrow, "Cyclic Stress-Strain and Fatigue Behavior of Representative Aircraft Metals," paper presented at the ASTM Summer Meeting, Boston, June 1967, see also Report No. NAEC-ASL-1105, U. S. Naval Air Engineering Center, Philadelphia, Pa., June 1966. [2] T. H. Topper, R. M. Wetzel and JoDean Morrow, "Neuber's Rule Applied to Fatigue of Notched Specimens," paper presented at the ASTM Summer Meeting, Boston, June 1967, see also Report No. NAEC-ASL-1114, U. S. Naval Air Engineering Center, Philadelphia, Pa., June 1967.

R69-14186 ASQC 844; 090; 775
Army Materials Research Agency, Watertown, Mass.
A REPORT GUIDE TO FATIGUE TESTING LITERATURE
Charles P. Merhia May 1967 69 p refs
(AMRA-MS-67-05; AD-652881; N67-32858) Avail: CFSTI

The main objective of the compilation is to provide simple and fast access to information on the subject of fatigue testing and yet provide sufficient information in the form of abstracts and word descriptors to make the listing useful. TAB

Review: This guide presents abstracts of 128 papers pertaining to nondestructive testing techniques for the detection of metal fatigue. The title of the guide is somewhat misleading since the majority of the papers deal with fatigue detection rather than fatigue testing. Many of the abstracted papers are further limited to the field of ultrasonic methods of nondestructive testing. The guide suggests interesting aspects of fatigue detection that would be of value to researchers or those in quality control who wish to predict total fatigue failure of a structure from early crack propagation history. This document appears to be a rather complete listing of abstracted papers within the limited subject area. Ten additional report guides are referenced and afford a broader coverage of the nondestructive testing techniques which are applicable to fatigue testing. In a private communication the Chief, Materials Testing Laboratory, AMRA has supplied the following additional information. "The abstracts were taken from the April 1967 holdings of the Nondestructive Testing Information Analysis Center. The holdings are constantly growing and as of September 1968 another 30 abstracts on the same subject have been added by the Center. Presently, the abstracts are available free of charge to qualified DDC users."

R69-14187 ASQC 844
MIGRATION AND WHISKER GROWTHS OF TIN AND SOLDERS INDUCED ON THIN METAL FILMS BY DIRECT CURRENT AND HEAT.

G. M. Bouton and W. G. Bader (Bell Telephone Labs., Inc., Murray Hill, N. J.).
In: 1968 Electronic Components Conference, May 8–10, 1968, Proceedings. Conference sponsored by IEEE, and Electronic Industries Assoc. New York, IEEE, Inc., 1968, p. 135–140. 6 refs.
$7.00

Solders were shown to react with nickel-chromium thin films used at terminals of tantalum nitride resistors, and tin whiskers and other growths were observed under high overload conditions. Tantalum nitride itself does not support whisker growth; rather growth occurs when tin breaks through the oxide layer on the nichrome film. Electrotransport is proposed as the principal driving force for the growth mechanism, which involves the following steps. The palladium and copper films are dissolved during soldering, and dissolution of residual copper may continue under high load operation of the resistor. Solder breaks through the oxide and interacts with the nichrome film. Accelerated by electrotransport forces, diffusion and migration towards the negative terminal occur in the nichrome layer under an oxide film. Tin nucleates in spots, accumulates into islands, and breaks through the oxide layer deposited on the nichrome. A heavy copper layer deposited over the nichrome will not dissolve during soldering, and titanium layers in place of nichrome will also prevent whisker growth. M.W.R.

Review: This paper is an example of what is often called Reliability Physics, wherein some of the details of the anomalous behavior of a component are investigated much more thoroughly than is usual. With the burgeoning of thin-film technology, the discovery of migration and whisker growths of tin on some of the thin-films is important. The paper is concerned largely with what is happening and why, rather than with the immediate problem of stopping it, since understanding is often a major step toward a cure. The paper is well-written, informative, and copiously referenced. It will be of value to those who are concerned directly with this problem.

R69-14188 ASQC 844; 770; 833
THE RELIABILITY OF SCREENED METAL FILM RESISTORS.
J. P. Maher, D. P. Burks, W. G. Seeley, and H. Geller (Sprague Electric Co., North Adams, Mass.).
In: 1968 Electronic Components Conference, May 8–10, 1968, Proceedings. Conference sponsored by IEEE and Electronic Industries Assoc. New York, IEEE, Inc., 1968, p. 271–277. 5 refs.
$7.00

Screened metal film resistors were found to be unusually stable, and comparable to both thick and thin film resistors of other types. Accelerated tests indicated the existence of a well-behaved aging mechanism in screened metal film resistors, and that resistor aging rates could be reliably predicted by hot spot temperature calculations. Voltage effects were not observed with stresses up to 500 V/in, and extremely low drift rates were obtained over a wide resistivity range. Under rated conditions, only one screened metal film resistor failed in 3.5 million unit-hours operation. Construction of the test units is described, along with test conditions and procedures. Effects of substrate material, underglaze, and other variables are discussed. M.W.R.

Review: This paper is a brief description of the resistors and test program together with a listing of the test results. The tests were extensive and the results appear to be good. The main reliability results are in the form of an equation containing fractional-change-in-resistance, the time, and the hot-spot absolute temperature. While the temperature form was chosen to be of the Arrhenius type, the time behavior would have to be modified somewhat to put the equation in the Arrhenius form. No mention is made of the statistical uncertainties involved in the coefficients nor in the extrapolations from the equations. The paper will be of interest to those who are using this type of resistor as well as to those who are involved in similar kinds of testing.

R69-14189 ASQC 844; 716
AGING CHARACTERISTICS OF TANTALUM NITRIDE THIN FILM RESISTORS.
J. S. Fisher (Bell Telephone Labs., Inc., Allentown, Pa.).
In: 1968 Electronic Components Conference, May 8–10, 1968, Proceedings. Conference sponsored by IEEE and Electronic Industries Assoc. New York, IEEE, Inc., 1968, p. 299–303. 8 refs.
$7.00

For anodized tantalum nitride thin film resistors in inert substrates, resistance change was found to depend only on time and temperature. Field transport or electrochemical effects can be discounted when substrates of alkali-free glass or high alumina are used. Observed time and temperature dependence of resistance change was consistent with grain boundary and bulk diffusion of contaminant into the thin film structure. Drift constants for raw and thermally stabilized films can be derived from simple oven aging tests, and charts can be developed for circuit design use on the basis of end-of-life stability requirements to substrate temperature. Time and temperature relations that determine parametric failures were found to be similar in form to those for semiconductor devices. M.W.R.

Review: This paper briefly reports the results of some aging experiments. It is difficult to judge the adequacy of the analysis since only the final results are given in most cases. The results appear reasonable (as is to be expected in a published paper) and the equations are conventional. One lack in the results is the absence of any indication of the statistical uncertainties in the estimated values; for example, activation energies are given to three significant figures, whereas it is likely that the statistical uncertainty in the answer would be on the order of 10 percent. The activation energies are all given as negative, contrary to custom, apparently because the Arrhenius equation was written without a negative sign in the exponent. The fact that there appear to be no electric-field stress-effects is quite interesting and allowed appreciable simplification of the study.

R69-14191 ASQC 843
MAKE YOUR OWN CONDITIONAL FAILURE NODE PROBABILITY CALCULATOR.
J. T. Henderson (Gulton Industries, Inc., Data Systems Div., Albuquerque, N. Mex.).
Evaluation Engineering, vol. 7, Jul./Aug. 1968, p. 10, 60, 61.

Development, capability, and use of a conditional failure mode probability calculator are described. Designed with a multiplier of 10^{-6} failures/hour, the calculator reduces the work involved in a failure effect mode and criticality analysis. The next higher assembly experiencing the component's given failure mode can be obtained when the next higher assembly failure rate, the component failure rate, and the conditional probability of a component's failing in a certain failure mode are known. The elements of the calculator are included in the article; and these can be mounted on cardboard or plastic to permit the reader to make his own device. Assembly instructions are outlined. M.W.R.

Review: This short note describes a calculator the author has made for solving a particular problem. The calculator appears to be adequately described although one has to read the entire article to figure out what the author is doing and what he means by the terms he uses. The biggest difficulty with the article is that the formulas on which the calculations are based are not given. These would have been much more appropriate to include than a discussion of how to make circular five-cycle log paper. In order that there be no ambiguity on the problem being solved, the following derivation is given. (Conventional probability notation is used.)

A is event of failure of next higher *A*ssembly
C is event of failure of selected *C*omponent
C_i is the event of failure of the Component by means of its i*th* mode
$f_i \equiv P(C_i|C) = P(C_i)/P(C)$ since $C \cdot C_i = C_i$
Then $P(C_i|A)$ is the desired answer.
$P(C_i|A) \equiv P(C_i \cdot A)/P(A) = P(C_i)/P(A) = f_i\ P(C)/P(A)$, since $A \cdot C_i = C_i$.
If $P(C) \equiv 1-\exp(-\lambda_C t)$, $P(A) \equiv 1-\exp(-\lambda_A t)$; and if $\lambda_C t$,

$\lambda_A t << 1$, then $P(C_i|A) = f_i \frac{\lambda_C}{\lambda_A}$. (Note restrictions on λ's)

The final formula involves one multiplication and one division. It is not at all clear why an ordinary slide-rule is not more than adequate for this if one keeps the formula handy, although the ordinary slide-rule will not place the decimal point. Those who are interested in gadgets, or who make so many of these calculations that they would like to try out the special slide-rule, can use the results of this article.

R69-14210 ASQC 844; 835
FAILURE ANALYSIS STUDIES AND MECHANISMS ASSOCIATED WITH ELECTRONIC PACKAGING.
J. Arleth, T. Guida, and R. Komuves (Grumman Aircraft Engineering Corp., Electronic Systems Center, Microelectronics and Circuit Design Section, Bethpage, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 127–133. 3 refs.

Electronic packaging failure mechanisms and their means of detection are listed under the categories of contamination, thermal, chemical, and electrical. A number of case histories and photographs illustrate some unusual packaging failures, and some corrective actions are included for these. M.W.R.

Review: This paper serves its purpose well in illustrating the troubles that packaging defects can cause. These examples lead to the old comment that high reliability is developed by infinite attention to detail, and, in this sense, the paper is typical of many that have appeared. These papers are good because they remind designers that horrible hardware can happen and they remind those who are producing this kind of hardware that their own ads are not necessarily to be believed. The authors go further and suggest that packaging techniques should be designed with failure analysis in mind. This is a valid point to raise, but its implementation would be difficult except in the special circumstances of a large special order for a particular project wherein this capability of failure analysis is of overriding importance. A price would have to be paid for this kind of design, both in terms of reliability and money; the big question is whether anyone would be willing to pay it.

R69-14226 ASQC 846; 874
COMPARISON OF PREDICTED AND DEMONSTRATED RELIABILITY AND MAINTAINABILITY FIGURES.
Anthony Coppola and John E. Daveau (Rome Air Development Center, System Effectiveness and Support Section, Griffiss AFB, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 327–332.

Measured field reliability and maintainability data were compared with predicted and acceptance test results for five data processing components of the Back-up Interceptor Control (BUIC) system, four display consoles, and two large tracking radars. Except for the display equipment, predictions were uniformly conservative in terms of gross field MTBF values, and no point estimate of field MTBF fell below a predicted value. Conservatively, the data processing units and radars were operationally 2-1/2 and 2 times, respectively, better than predicted; while display consoles were closest to unity when comparing operational MTBF with predicted values. MTBF measurement from acceptance tests and mean-time-to-repair values are also included; and inability of data to adequately predict the latter is noted. Furthermore, MTTR data derived from field operational failures were found to be universally higher than the predicted and test values. M.W.R.

Review: This good collection of data compares reliability prediction with the reliability occurring in the field. The agreement is not nearly as close as sometimes indicated in the literature; perhaps these authors had no ax to grind and were thus more realistic, or perhaps they have just been less lucky. The authors wisely refrain from giving exact explanations of all of these events, although they do suggest possible causes. This paper will perhaps be good medicine for those who are overly enamored of the results of reliability paper-predictions. One is reminded of the comment often heard, "You tell me what reliability number you want and I'll calculate it for you."

R69-14228 ASQC 844; 711
Rock Island Arsenal Lab., Ill.
THE RESISTANCE OF GREASE LUBRICATED METAL COMBINATIONS TO FRETTING DAMAGE Final Report
S. Fred Calhoun Jun. 1967 16 p
(RIA-67-1594; AD-655276; N69-10908) Avail: CFSTI

Five different metals were oscillated against each other to assess the extent of fretting damage. They were all lubricated with the same grease and were subjected to the same pressures and vibration rates. The extent of the fretting damage was dependent upon the softness of the metals and also upon the nature of the metals in contact. Metal specimens oscillated against a like metal suffered less damage than when different metals were in contact. Author (TAB)

Review: This is a short paper which describes the results of tests that were carried out to categorize fretting damage for five different metals. Despite the limited number of samples tested, well-defined differences were established and obvious conclusions were drawn. There is no indication that the author attempted to (a) analyze the test results statistically, or (b) establish a rigorous foundation for the distinction between like and unlike materials. The paper is interesting and may provide an immediate satisfaction to the needs of a design engineer who is attempting to apply a particular metal combination, but in general the analysis of the test results is too over-simplified to be of any far-reaching research value. Access to a previous report (Rock Island Arsenal Report No. 62-651, 20 Feb 62) by the same author is required for a description of the test apparatus and procedure.

85 DEMONSTRATION/MEASUREMENT

R69-14179 ASQC 851; 770
A REALISTIC AND DYNAMIC LIFE TEST FOR REED SWITCHES.

Dean H. Fox (Hathaway Instruments, Inc., Denver, Colo.).
In: Annual National Relay Conference, 16th, Oklahoma State University, Stillwater, Okla., Apr. 23, 24, 1968, Proceedings. Conference sponsored by Oklahoma State University and the National Association of Relay Manufacturers. Scottsdale, Ariz., National Association of Relay Manufacturers, 1968, p. 8–1 to 8–8. 3 refs.
(Paper 8) $5.00.

A dynamic reed switch life test that has been used for six years is described that tests reed contacts during each opening and closing operation. The test procedure defines magnitude and type of contact load, drive level, failure and/or miss level, and end of life; and life expectancy for any particular reed switch at any specified load can be obtained with a confidence level of at least 90%. Definitions of miss and failure are included, with failure defined as the display of 5 or more misses in any 100,000 consecutive operations; and data are included for both levels of malfunction. Test equipment, conditions, and parameters are described; and some graphs depict life testing data for various switches and loads. M.W.R.

Review: This paper emphasizes the need to test relay properties, especially the contact resistance, under operating conditions. In the Proceedings of the 1967 Relay Conference, a paper showed that relays which appeared good on a static test had very poor dynamic contact resistance. This problem had been the source of some trouble in the field. The emphasis in the present paper is on describing the testing arrangement and requirements. The author stresses the need for standardization of reliability tests of relays, and points out that designers are at a distinct disadvantage without good reliability data. His curves show how the data can be obtained only through standardized tests. While these points are good in themselves, it should be remembered that where the parameter is critical the wise designer will have it tested and proved in-house and not just take a manufacturer's word for it. It should also be remembered that the existence of a set of nice-looking curves for a particular type of relay does not necessarily mean that every lot of relays bought under that type number will have those characteristics.

R69-14180 ASQC 851; 773
TESTING HIGH RELIABILITY RELAYS BY USE OF AUTOMATIC EQUIPMENT.
C. C. Bates and J. R. Guth (Sandia Lab., Albuquerque, N. M.).
In: Annual National Relay Conference, 16th, Oklahoma State University, Stillwater, Okla., Apr. 23, 24, 1968, Proceedings. Conference sponsored by Oklahoma State University and the National Association of Relay Manufacturers. Scottsdale, Ariz., National Association of Relay Manufacturers, 1968, p. 9–1 to 9–14. 3 refs. Research sponsored by AEC.
(Paper 9) $5.00.

Design of a fully automated relay tester is described, along with its use as a diagnostic tool and product acceptance tester for the procurement of high reliability relays. Most of the control circuitry for the tester uses solid state devices even though over 100 relays are used in a test. Measurement techniques used are described for coil resistance, contact resistance, insulation resistance and dielectric strength, and function time. Functional elements of the test system include the system programmer, switching matrix, and data recorder; and except for the temperature chamber, typewriter, and IBM punch, all of the equipment is housed in a single cabinet that has a master control panel. A typical set of electrical function data for a single unit is shown, and codes for interpreting the numerical output are defined. Dropout current characteristic during the mechanical life of two types of crystal case relays is illustrated, and histogram reductions of electrical parameters are included. M.W.R.

Review: This paper deals with the testing of relays at one time only and thus is not, per se, concerned with the life of a relay. The rather extensive sets of measurements serve to characterize how well the relays are doing a particular job and are therefore useful for uncovering defects in design or manufacture. In critical applications, such tests are important, especially in those situations in which the relay may be called upon to operate only a few times and on those occasions must operate perfectly. The paper describes electrical tests of the relay which can be put in any kind of environmental chamber desired, e.g., temperature or vibration. It should be emphasized that not all relays have to pass the same kinds of tests because the relays will be used under many different kinds of conditions. If all relays had to pass all the tests that anyone ever dreamed up, it is likely that few would ever get out the door, much less used.

R69-14183 ASQC 851; 835; 844
Sperry Rand Corp., Blue Bell, Pa. Univac Div.
RELIABILITY TEST PROGRAM OF ULTRASONIC FACE DOWN BONDING TECHNIQUE Final Report, 10 Nov. 1965–31 Jan. 1967
Robert P. Moore Griffiss AFB, N. Y., RADC, Jun. 1967 94 p refs
(Contract AF30(602)-3921)
(RADC-TR-67-138; AD-655781; N67-36702)

A study was made to determine the overall reliability of its face-down-bonding process and to determine whether the bonding process damages the chip. The ultrasonic direct-bonding process was used to fabricate approximately 900 test samples for this study. Samples were subjected to the following tests: shear, mechanical shock, thermal shock, vibration, centrifuge, high-temperature storage, elevated-temperature back bias, step stress and comparison, and temperature and humidity. Defective units were examined for causes of failure. The test results indicate that the stresses applied during bonding do not affect circuit operation. The bond failure rate was high, but the distribution of failures suggests that this was due to inadequate substrate process control rather than inherent problems with face-down bonding. The substrate interconnect wires corroded in high-temperature and high-humidity ambients. Several potential solutions to this problem are suggested. Author (TAB)

Review: It is strongly recommended that anyone who is interested in the results of these tests read the entire report rather than just the abstract. One can easily mislead himself by reading only the abstract. The description of the experiments in the text is good and the conclusions drawn seem reasonable. The euphemism of "needing better process controls" appears as a conclusion from several of the tests. It is easy to get the feeling that anyone unsympathetic to the cause might make a much stronger statement. Some of the awkward test results, caused by an error in the test circuitry, show the importance of the routine portions of the testing program and point up the fact that test programs themselves need extreme attention to detail. This report should be considered as a progress report on ultrasonic face down bonding rather than a firm conclusion on the matter.

R69-14203 ASQC 851; 773; 774; 784
VIBRATION TESTING IN ACCORDANCE WITH MIL-STD-781 AND AGREE COMMENTS.
Farris W. Smith (L.A.B. Corp., Quality Control, Skaneateles, N. Y.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, 1968, Transactions Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society, Arno Press, Inc., 1968, p. 5–9. 3 refs.

Equipment available to conduct vibration tests formulated by AGREE and MIL-STD-781 are discussed and illustrated. These include small vertical machines, large horizontal machines, horizontal machines with vertical mounting surface, two-directional low cost machines, and vibration chambers. Means of achieving speed variation are considered, as are noise disturbances in vibration machines. M.W.R.

Review: This paper presents an excellent set of descriptions of the various vibration machines which are available for testing small systems or components. The introduction and general comments are in the negative vein, and do not express the positive side of the growth of vibration testing. For example, no description is given of the advantages which accrue to the testing agency when they use vibration as the critical parameter. Neither is there any mention of the disadvantages, which include the destructive aspects and the question of correlation between the tests and the actual in-use environment. There is no discussion of cost or of the economic advantages of vibration testing. As industry has been testing for many years and almost all specifications require vibration testing, some mention of the cost element with an appropriate reference would have been desirable even though it may have been done before. This paper will be of historical value to a senior test engineer, but it will not satisfy the overall needs of the junior engineer seeking information on the total concept of vibration testing.

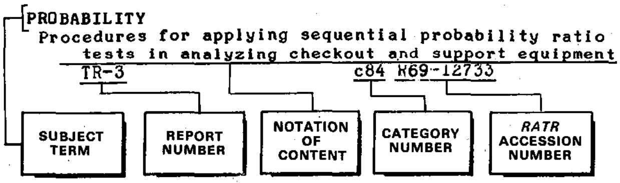
R69-14218 ASQC 851; 844
ASSURING RELIABILITY OF YOUR HI-FI SET.
Richard F. Powell (H. H. Scott, Inc., Maynard, Mass.).
In: 1968 Product Assurance Conference and Technical Exhibit, Long Island, N. Y., June 7–8, Transactions. Conference sponsored by American Society for Quality Control, Institute of Electrical and Electronic Engineers, and Standards Engineers Society. Arno Press, Inc., 1968, p. 243–251. 7 refs.

Market factors that have made for improved reliability of hi-fi equipment are discussed, including the changes in the type of customer and in marketing methods. Increased complexity of the equipment and its use by technically untrained consumers are also considered. Emphasis on equipment design that is foolproof and preparing better instruction books for hi-fi equipment are among the means for improving overall reliability. A study of commercial reliability programs indicated that while they were highly individualistic, they all included elements concerned with (1) collection and analysis of field failure data, (2) performance testing of the product over an extended period of time, (3) failure analysis down to and including the component level, and (4) design review. These were included in a hi-fi reliability program, to which reliability profile stress testing was added for testing one or more units manufactured in the pilot run. Some graphs depict contribution to field failure and life test failure by various causes, short-term life test results, the reliability profile test, and analysis of warranty service by trouble and by period of manufacture. M.W.R.

Review: This paper makes interesting reading as much because of most readers' enthusiasm for "hi-fi" sets as anything else. The points made in this paper about failures are the kind made many times before in the literature and thus the main value of the paper is in showing what a company in the consumer-product business is actually doing. The paper will be of interest largely to consultants who are aiding this type of business and to those companies who are wondering how the discipline of reliability can help them. It is perhaps a truism to say that the big thing these companies need to do in order to get high reliability is to perform the engineering which they "should" have been doing in the first place.

SUBJECT INDEX

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

R

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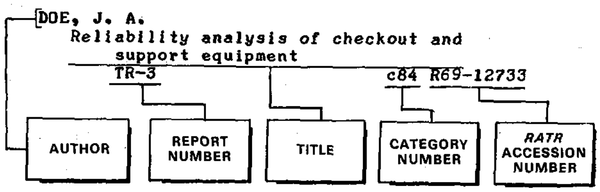
PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



The category number and the *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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REPORT AND CODE INDEX

List of Report Numbers

This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR,* and *IAA,* respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 1

List of *RATR* Accession Numbers

This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each *accession number* is the category number for locating the abstract-review in the abstract section of *RATR*.

NASA-Langley, 1969

Reliability Abstracts and Technical Reviews

FEBRUARY 1969

Volume 9
Number 2

R69-14230--R69-14280

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

ASQC CODES
***RATR* ACCESSION NUMBER**
CORPORATE SOURCE
R69-12733 ASQC 844; 413
TITLE
General Equipment Company, Banville, Calif.
PUBLICATION DATE
RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT
AUTHOR
John A. Doe 23 Sep. 1966 27 p refs
CONTRACT OR GRANT
(Contract NAS15-13411)
***TAB* AND *STAR* ACCESSION NUMBERS**
(TR-3; AD-629305; N69-15098) CFSTI: HC $3.00/MF $0.65
REPORT NUMBER
SALES AGENCY AND PRICE

***RATR* ACCESSION NUMBER**
R69-12739 ASQC 814
ASQC CODE
TITLE
SEMICONDUCTOR RELIABILITY
Joseph A. Smith (Eastern University, Arlington, Penn.)
AUTHOR AND AFFILIATION
JOURNAL REFERENCE
Electric Journal, vol. 8, Apr. 1966, p 478–492.
(A69-12569)
***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER**
R69-12765 ASQC 773; 221; 823
ASQC CODES
TITLE
TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES
Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)
AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE
Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1966, 8 p
Available from Assoc. of Reliability Eng., New York: $1.00
AVAILABILITY AND PRICE
***IAA* ACCESSION NUMBER**
(A69-12407)

VOLUME 9 NUMBER 2

Reliability Abstracts and Technical Reviews

A Monthly Publication of the National Aeronautics and Space Administration

February 1969

80 RELIABILITY

R69-14263 ASQC 800
IS RELIABILITY NECESSARY?
Patrick P. Donnelly (Boeing Co., Huntsville, Ala.).
In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 61–65.

The view is offered that reliability is not only a number but a discipline needed to give visibility to both the engineer and the engineering manager. Reliability is seen as a Parts and Materials Program, a Design Review Program, as a calculation, a measurement, and a set of program activities, with each element being tied in one way or another with reliability mathematics. Data are defined as a collection of qualitative and quantitative information needed to perform an analysis, and including test reports, failure rates, test anomalies, unsatisfactory condition reports, and engineering change requests. The threefold responsibility of checking, analyzing, and presenting the data is discussed, with stress placed on the need for presenting the data in such a way that an engineering manager can comprehend the significance of the findings. M.G.J.

Review: This paper is a good-humored cajoling of reliability engineers to get them to communicate with their supervisors more efficiently and effectively. The overall message of the paper is a good one although one could easily nit-pick several details. For this reason, it was probably much more effective as a talk wherein the overall impression is remembered rather than as a paper in which details can be read and analyzed. Nonetheless the paper is short and easy to read and contains a good message.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14231 ASQC 810; 640; 814
RELIABILITY IN PERSPECTIVE.
William B. Bunker (U.S. Army, Materiel Command, Gravelly Point, Va.).
(Institute of Electrical and Electronics Engineers, Annual Symposium on Reliability, Boston, Mass., Jan. 16–18, 1968.)
IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 55–58.
(A68-35149)

Discussion of the role of the reliability practitioner in today's environment. Management techniques are described and evaluated, including PERT, the contract definition procedure, configuration management, cost/effectiveness analysis, and life-cycle costing procurement. The requirements for the reliability practitioner are outlined, and emphasis is given to the reliability and management roles as they relate to military and industrial products. IAA

Review: The paper begins by briefly describing five management tools which DoD uses, vis., PERT/COST, contract definition procedure, configuration management, cost/effectiveness, and life cycle costing procurement. These capsule summaries will be quite helpful for those who have not been intimately involved with the techniques and have, consequently, wondered what they are. After this "little 'Cook's tour'" the role of reliability is discussed. That this role is not clear-cut is evident from the discussion since it tends to lean first one way and then another. The question of how much management responsibility a reliability group should take is one not easily handled. The phrase "total quality control" is, in effect, virtually synonymous with the total engineering effort and thus, obviously, cannot be handled by a small subset of the engineering group, e.g., reliability and quality control personnel. Three very worthwhile and interesting points the author makes are the following: (1) Paper estimates of reliability are useful but are no substitute for actual verification and demonstration. (2) Programs which look good on paper can easily fall short of our expectations for them. (The first point is obviously not official DoD policy since some contracts do allow reliability "demonstration" by means of paper calculations.) The author suggests reasons why good-looking programs fall short of our expectations. Another reason they tend to do this is that many such programs are based on the fact that everyone will do his job correctly, on time, etc.; that no problems will arise such as failures of suppliers to meet shipping schedules; and so forth. A further difficulty with them is that they double as selling documents and are subject to all the vagaries thereof. (3) The reliability of a system is determined largely by decisions and actions of people other than the reliability expert. Therefore reliability experts must somehow communicate practical working knowledge to these non-experts. Trying to introduce the techniques of the reliability discipline to the consumer, social and political aspects of our lives is a difficult task for at least two reasons. First, the public has the impression that they are not being applied too well in industry (by simply looking at the goods they buy) and second, an effective selling campaign is monumentally expensive in terms of time and money, and who can afford it? All in all, the paper (as distinct from the talk which had a much greater emotional impact on the audience) will be useful to those reasonably high in management who want a very broad outlook on the problem.

R69-14261 ASQC 814; 831

SYSTEM COST EFFECTIVENESS—THE END OF THE FIRST ERA.

Jerome Klion (USAF Systems Command, Research and Technology Div., Rome Air Development Center, System Effectiveness and Support Section, Griffiss AFB, N. Y.).

In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 21-40. 11 refs.

(A68-23836)

Discussion of the technical, cost-analysis, and management tools necessary for application of system/cost effectiveness to modern day Air Force systems. Progress, to date, pertinent to the development of the tools is reviewed. It has been found that system effectiveness analyses are not only feasible, but practical as well; that sufficient know-how exists to design for system effectiveness; that demonstration and validation techniques for system effectiveness are under development; that steps are being taken to improve the cost-effectiveness technology so that it can be utilized as a more precise tool; and that documentation for system/cost effectiveness implementation has been initiated. IAA

Review: This is a good paper even though one who reads the summary first may be disappointed. It is largely a description of Air Force programs whose purpose was to investigate, analyze, and provide implementation tools for the system effectiveness concepts. We are not told the details of any of these methods but are given brief descriptions of them. The tables and graph at the end of the report do give quantitative comparisons of some of the predictions and achievements and, if anything, the agreement is much closer than might ordinarily be expected. This paper is important to anyone who is concerned with such contractual requirements and Government documents because it gives reasonably up-to-date information on the status of these Air Force research projects. The philosophy underlying these projects appears sound in that the Air Force is trying to "bite off small pieces and digest them" in order to find out what it is doing, what it is talking about, and how feasible it all is, rather than trying to grab the whole situation in one "bite" and then living in a flurry of meaningless grandiose terms. It is expected, naturally, that, as system effectiveness requirements are translated into quantitative contractual terms, individual contract monitors will sometimes not understand these provisions well or will disagree with their program-managers in industry on the meaning of them. One hopes that the lessons learned in the application of reliability requirements to contracts over past years will have prepared both sides in their struggle to do their jobs well. Industry is naturally wary of high-sounding terms and requirements which are not or cannot be enforced, or are only perfunctorily enforced. DoD is likewise naturally concerned that the industries it pays do their jobs well and meaningfully. Perhaps the most sobering thing to remember is that these system concepts and requirements do not effect themselves but are carried out by people, some of whom are less competent than others.

R69-14262 ASQC 813

THE EVOLUTION OF A SYSTEM ENGINEERING AND RELIABILITY PROGRAM.

D. L. Roelands (North American Rockwell Corp., Aerospace and Systems Group, Space Div., Seal Beach, Calif.).

In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 43–58.

(A68-23837)

The paper traces the development of a program for an integrated system engineering and reliability engineering effort to meet the objectives of a large space vehicle development project. It starts with the classical reliability group and discusses how new concepts of systems management have led, through a series of steps, to an organizational arrangement achieving the objective of an integrated program. Author (IAA)

Review: This is a good paper because the author describes some of the vagueness, ambiguities, uncertainties, conflicts, and overlaps that beset a comprehensive complicated engineering effort. He then follows with a brief discussion of how these problems tended to be resolved. When the engineering task is large, it must be broken down into small tasks that any particular group can handle. But if there are reasonably intelligent people in any of these groups, they immediately see that they are confined by the definition of the group and that in order to be effective they must greatly expand their operation—even into taking over the entire engineering effort. In this organization apparently many of the strongest and best people were in the reliability organization and, as is common regardless of the nominal organizational structure, they proceeded to fill any vacuums left by less agressive groups and gradually took over most of the non-design roles. Combining the reliability and systems groups into one certainly made sense under this situation, and it is apparently they who had the primary supervisory–staff tasks, i.e., making sure that each of the line groups was doing not only a good job but all of the jobs that needed to be done! The paper does not give much indication of the probable emotional trauma that went on until the organizational structure finally settled down. (Nor, it should be pointed out to the reader, can he tell by reading this paper whether or not the program was as successful as the author claims. This is not to disparage the author or his writing at all, but merely to point out that if all the management success stories that are written in the literature were true, we would have long since solved all of our problems.) It should further be pointed out that the organization finally adopted probably depended more on the particular people associated with particular groups than it did on any abstract reasoning, independent of those people. All in all, this is a good paper with a good message, if it is read carefully.

R69-14265 ASQC 817; 838; 873

ON-ORBIT MAINTENANCE VERSUS REDUNDANCY TRADE-OFF STUDY.

Lawrence J. Courant (International Business Machines Corp., Federal Systems Div., Electronics Systems Center, Owego, N. Y.).

In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968 p 89–103

(A68-23839)

Analysis of a data-processing system for a manned space flight under the constraints of two distinct methods of reliability improvement. The tradeoff between on-orbit maintenance and redundancy demonstrates a method for assessing reliability gains in view of weight penalties and then compares the apparent advantages and disadvantages of each improvement technique. IAA

Review: This paper is typical of those which show how to optimize reliability under certain constraints. In this case, the constraint is weight and the method of increasing reliability is to add switchable spares or to perform the maintenance by hand. The presentation in the paper is clear, so that those not familiar with this method can follow it with ease yet the reader is not burdened with extensive arithmetic. The thing the author has not shown (and is not immediately obvious) is that optimizing each step necessarily produces the optimum overall solution; in general, this is not true. Not all of the formulas were checked; in particular, the formulas for redundant reliability were not checked since the details of the derivation are not given. All in all, the paper serves a useful tutorial purpose in showing how to use this particular technique. Whether or not it is the best technique to use is something else again.

R69-14266 ASQC 813; 844

SYSTEM SAFETY—IMPLEMENTATION IN THE RELIABILITY PROGRAM, THE RELIABILITY ENGINEER'S RESPONSIBILITY, AND METHODS OF ANALYSIS.

Richard F. Johnson (Lear Siegler, Inc., Avionics Group, Astronics Div., Santa Monica, Calif.).

In: Utilization of Reliability: Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 105–123.

(ADR-711; A68-23840)

Development of the theme that safety should be jointly considered with reliability in a reliability program. Methods of safety-ranking analysis at the conceptual design level are stressed. The danger of calculating the total probability of a fail-safe event without dissecting the event is demonstrated by an example. The circulation of the probability of an ordered-event sequence is also demonstrated. Finally, the organized approach to fault-tree analysis is briefly discussed. IAA

Review: The thesis of this paper is that while the reliability engineer is considering the events which cause mission failure and is doing failure modes and effects analysis, he should be doing the same thing for system safety. The author spends a considerable amount of time developing and giving examples of Boolean (event) algebra and showing how things are calculated. He switches back and forth between two kinds of logical-operation notation so as to render the paper difficult to use for tutorial purposes; in addition, some of the symbolic-logic notation is not explained. Little of the algebra and examples was checked for accuracy or completeness. In the fault tree discussion, the example is done both in words and in symbols. In the word description, a time sequence is important. In the symbol description of the same situation, there is no reference to time. All in all, there are few who will find both the style and subject matter of this paper suitable for their needs without further explanations.

R69-14269 ASQC 810; 863

MANAGEMENT OF INTEGRATED LOGISTIC SUPPORT.

H. S. Jensen (Raytheon Co., Space and Information Systems Div., Sudbury, Mass.) and J. J. Parent

In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 163–172.

A manager's approach is presented to an integrated logistic support (ILS) system which will develop, schedule, and control the support disciplines in a coordinated manner. The ILS, as defined by the DoD directive, is "a composite of the elements necessary to assure the effective and economical support of a system or equipment at all levels of maintenance for its programmed life cycle. It is characterized by the harmony and coherence obtained between each of its elements and levels of maintenance." The need for recognizing the support goals prior to system design is stressed, and the nine basic elements of the ILS are identified. These are: maintainability, maintenance planning and analysis, repair parts and supply, technical manuals, tools and test equipment, facilities, training and personnel, data collection and analysis, and field engineering. The three phases of the ILS effort are listed as planning, implementation, and demonstration. The advantages of integration from concept through operation are discussed. Consideration is also given to the responsibility for ILS management, and to ILS management in practice. M.G.J.

Review: It is appropriate that persons in the Government–Industry environment be cognizant of the ever-changing management approaches and of their titles and acronyms. Integrated logistic support (ILS), sketched in this paper, is the type of management program which seems so reasonable but has evolved in DoD only through much effort and experience. The program pulls together previously scattered support functions and compels their consideration early in the life cycle. The paper does not so note, but the other principal project managment functions are administration, design, and production. Not noted in the paper either, but nevertheless appropriate to bear in mind, is that maintainability, as well as reliability, is very much in the hands of the hardware designers, and the achievement of desirable goals rests in large part with the designers. The inclusion of designing for maintainability is one of the elements noted in the ILS program. However, this would normally be implemented by some logistic activity through support and surveillance of the design function and not by assumption of this design function. While this paper is adequate as an overview, those readers wishing more information should see [1] which in turn notes the existence of a draft of an ILS implementation aid entitled "DoD Systems and Equipment Integrated Logistics Support Planning Guide" (AD-663 456), which is based on the Raytheon "Integrated Logistics Management Manual" (June 1966) by the authors and Mr. C. P. Dewey.

Reference: [1] "Integrated Logistic Support: The Life-Cycle Task of Support Management," by Gerald Holsclaw and Fred T. Carlson, *Defense Industry Bulletin*, vol. 4, Jun 68, p. 1–12.

R69-14278 ASQC 810

Joint Publications Research Service, Washington, D. C.

PRELIMINARY ANALYSIS OF RADIO COMPONENT RELIABILITY

I-An Li *In its* Transl. on Communist China: Sci. and Technol., no. 383 27 Jun. 1967 p. 1–11 refs

(N67-35606)

Foreign literature on radio component reliability is reviewed. Factors in component damage are identified as engineering design, operation, manufacture, and miscellaneous. Only the most conventional components are considered, and these include solid carbon resistors, carbon diaphragm resistors, winding resistors, potentiometers, and capacitors. Tropical weather, desert weather, cold zone weather, upper atmosphere weather, and mechanical environment conditions are investigated. Production automation and miniaturization are briefly discussed as means of increasing component reliability. N.E.N.

Review: This is a very qualitative discussion of the general factors involved in component and equipment reliability. It is the kind of information that one might give in a speech to a group of non-technically-oriented managers. It is thus of no value to reliability engineers except those who wish to know what the Chinese are saying. Credit is given to the works of Dummer.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14230 ASQC 820; 614; 615

ALGORITHMIC OPTIMIZATION OF SYSTEM RELIABILITY.

Buddy L. Myers and Norbert Lloyd Enrick (Kent State University, Management Dept., Kent, Ohio).

In: American Society for Quality Control, Annual Technical Conference, 22nd, Philadelphia, Pa., May 6–8, 1968, Transactions. Milwaukee, American Society for Quality Control, Inc., 1968 p. 455–460.
(A68-31436)

Development of some algorithmic solutions for those types of reliability design problems which involve optimal combinations among independent components. In instances where dependences occur, the task of finding optimality becomes considerably more complex. It is suggested that in these cases, dynamic-programing procedures will be the only ones that work. A brief review is given of dynamic-programing procedures. IAA

Review The algorithmic procedures mentioned in this paper are Lagrange multipliers, linear and mathematical programming, and dynamic programming (dynamic programming is a term that still has several meanings). The authors perhaps interpret "algorithmic procedure" very narrowly since they state, "A recent survey of mathematically oriented research in quality control and reliability...did not yield a single paper in which a full-fledged algorithmic procedure was applied.". While the application of these procedures to reliability problems has been limited, this statement may give a rather misleading impression, since applications of algorithmic procedures have been reported in the literature. The reader interested in following up on this should see the relatively recent papers covered by R66-12867, R67-12936, R67-13177, R67-13406, R68-13601, and R68-13774, and the document N67-40411. It should also prove fruitful to check through the Proceedings of the Annual Symposia on Reliability (in which over 750 papers have appeared through January 1968). It is difficult to see for whom this paper will be of tutorial value. The Lagrange multipliers are explained in the most detail, but certainly not sufficiently for someone else to know how to use the method. Mathematical and linear programming are explained virtually not at all, and one who did not know what mathematical or linear programming was about before reading this paper will not know afterwards. The authors do not even state what dynamic programming is supposed to be. It is interesting that despite the authors' emphasis on completeness of statement of the problem for algorithmic approaches, they do not state their problem completely. The thing they omit is that the variables must be integers. In their Lagrange multiplier approach in converting from decimal numbers to integers, it is not at all obvious, without making the calculation, which way the numbers should be rounded off in order to give the optimum solution. The paragraph at the bottom of page 456 contains misstatements and the final probability of success is given incorrectly. (The correct answer is 86.5%.) The differentiation explanation in the Lagrange multiplier approach can be misleading. The differentiation with respect to the Lagrange parameter just gives one of the already-existing equations. In general, one can get the impression that to maximize a function, one can differentiate with respect to all of the variables and get the right answer. One can differentiate only with respect to those variables which are independent, and in the authors' text the number of these is not four but three. All in all, it is difficult to see who will benefit from reading the paper.

R69-14233 ASQC 825; 615; 838

SYSTEM RELIABILITY ALLOCATION AND A COMPUTATIONAL ALGORITHM.

David E. Fyffe, William W. Hines, and Nam Kee Lee (Georgia Institute of Technology, School of Industrial Engineering, Atlanta, Ga.).

IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 64–69. 6 refs.
(Grant NsG-657)
(A68-35151)

Discussion of an allocation method of system reliability designed to select the optimal solution in the context of the tradeoff analysis. It is noted that the problem may be structured as an n-stage sequential decision problem. A computational algorithm is developed using dynamic programing. IAA

Review: This is essentially the same as the paper covered by R67-13406.

R69-14234 ASQC 823; 433

LIFE DISTRIBUTIONS DERIVED FROM STOCHASTIC HAZARDS FUNCTIONS.

Carl M. Harris (Research Analysis Corp., Advanced Research Dept., McLean, Va.) and Nozer D. Singpurwalla (Hughes Aircraft Co., Systems Effectiveness Dept., Logistics and Operations Research Group, Fullerton, Calif.).

(Operations Research Society of America, National Meeting, 32nd, Chicago, Ill., Nov. 1, 1967.)
IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 70–79. 11 refs.
(A68-35152)

Most of the familiar time-to-failure distributions used today are derived from hazard functions whose parameters are assumed constant. An unconditional time-to-failure distribution is derived by assuming that a parameter of a classical failure distribution (exponential and Weibull) is a random variable with a known distribution. With the use of the derived compound distributions and Bayesian techniques, it is possible to join the test data with prior information to arrive at a combined, and possibly superior, estimate of reliability. The prior distributions considered here are the two-point, the uniform, and the gamma. Conceptually, such a scheme may be a more realistic model for describing failure patterns under specific conditions. Author (IAA)

Review: The idea of being able to combine test data with prior information in estimating reliability has been the motivation for studying the application of Bayesian techniques to this problem. The prior information considered in this paper is available in the form of a known probability distribution for a parameter of the lifetime distribution. The cases considered are (a) a single value of the parameter is drawn according to a fully specified distribution function, and all observations are taken according to the known conditional distribution of lifetimes (the Bayesian problem); and (b) each lifetime observation is taken in accordance with a different value of the parameter, where each value of the parameter represents a sample chosen with respect to the known prior distribution (the compound distribution problem). Problems associated with the statistical estimation of the parameters and of the reliability for the two cases are indicated, together with appropriate classical and Bayesian statistical techniques for handling them. This is a competent and appropriately documented paper which makes a worthwhile contribution to the theory of reliability estimation. (This paper is the same as Technical Paper RAC-TP-280, Advanced Research Dept., Research Analysis Corp., McLean, Virginia, October 1967, AD664142.)

R69-14235 ASQC 823; 844

PHYSICAL ANALYSIS OF STRESS TESTING FOR FAILURE OF ELECTRONIC COMPONENTS.

Clarence F. Kooi (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Electronic Sciences Laboratory, Palo Alto, Calif.).

IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 80–84. Research sponsored by the Lockheed Independent Research Fund and NSF.
(A68-35153)

Starting with an assumption concerning the type of physical process causing failure and an assumption concerning the random distribution of components with respect to a failure threshold, cumulative distribution functions in time, temperature, and voltage are derived. These cumulative distribution functions are identical to each other if the random variables are certain functions of time, temperature, or voltage, thus showing the equivalence of time, temperature, and voltage as stresses. The cumulative distribution function in time is the familiar log-normal function. If it is known that the assumed physical process is the only one causing failure, then one can rigorously replace time by temperature or voltage. However, it is demonstrated that in an accelerated test—i.e., a test in which time is replaced by another stress such as temperature—one can never be sure that another process will not be predominant at longer times; thus, one can never make a certain extrapolation to longer times. One might be able to circumvent this difficulty by having a thorough knowledge of the physics, chemistry, and metallurgy of the possible failure processes in the component.
Author (IAA)

Review: This paper is quite similar to an earlier one by the same author in the Dec. 67 issue of the same Transactions. It is similar enough so that the first part of the review (R68-13906) is worth repeating. "Trying to find a suitable model, which is based on some simple elementary concepts, for failure of electronic components is an activity of the theoretically inclined engineers which too seldom finds its way into print. Not all of the ones appearing in print will go down in history as the turning point of the ages. In fact, what is probably needed is a place where these theories can be aired without having to become archival documents since many of them definitely are not suited for that category. This paper is one of those interesting attempts; the physics is handled reasonably well but the mathematics is ..." In the present paper the author's difficulties are largely with statistics. One of his main stumbling blocks is that he insists that a random variable must have values between $-\infty$ and $+\infty$ whereas, of course, its domain can be anything one pleases. Since that is the reason he chose Bose–Einstein statistics rather than Maxwell–Boltzmann statistics, his choice was in vain; especially since for all his examples the Bose–Einstein formulas turned out to be most inconvenient. It is interesting to note that the derivation for the Bose–Einstein distribution assumes that the number of particles is not conserved; for example, it applies to photons as opposed to molecules. The author has confused the logNormal distribution with the Normal distribution of a logarithmic variable—he calls it the logNormal distribution of the logarithmic variable which makes it a "double log". The paragraph near the bottom of page 81 which ends "...Thus, the equivalence between time and temperature for this simple model is established" is unnecessary since that equivalence was established in Eq. 8, which may be written more simply as

$$F(t, T) = G\left\{\frac{\alpha(t_c) + \beta(T_c) - \eta_o}{\sigma}\right\},$$

where G(u) is the cumulative (from the left) Gaussian distribution function. In the discussion of two competing processes beginning on page 82, the graph in Fig. 5 is, of course, an asymptotic one. It is the standard kind of graph that appears in most discussions of the Arrhenius type equation. Appendix I, concerning statistics, is reasonable up to the point where the author begins applying it to the text. Again he runs into the situation that he will not let a variable be a random one and have a cumulative distribution function unless the domain of the variable is from $-\infty$ to $+\infty$—a ridiculous limitation. Appendix II, trying to justify the use of the Gaussian distribution, is rather weak since the expression which is considered to have a Gaussian distribution is so completely arbitrary in the first place. It should be noted that the author has not shown "...the equivalence of time, temperature, and voltage as stresses," except under the conditions of his specialized model. What he presumably means is that one can equivalently affect the degradation rate by proper changes in voltage or temperature, in situations where his assumptions hold—in particular, damage has only one dimension in his model, whereas, of course, it often has many. In general, if the statistics had been corrected before publication and the physics appropriately modified, the ideas would have made a good, short note.

R69-14236 ASQC 824; 833

BAYESIAN ANALYSIS OF THE WEIBULL PROCESS WITH UNKNOWN SCALE PARAMETER AND ITS APPLICATION TO ACCEPTANCE SAMPLING.

Richard M. Soland (Research Analysis Corp., Advanced Research Dept., McLean, Va.).

IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 84–90. 17 refs.
(A68-35154)

The Weibull process with unknown scale parameter is taken as a model for Bayesian decision making. The family of natural conjugate prior distributions for the scale parameter is exhibited and used in prior and posterior analysis. Preposterior analysis and several sampling schemes are then discussed. Preposterior analysis is given for an acceptance sampling problem with utility linear in the unknown mean of the Weibull process, in which the sampling scheme yields the first r failures in a life test of n items. An example is included. Author (IAA)

Review: This paper is essentially the same as the one covered by R68-13651.

R69-14238 ASQC 821; 882

A METHOD FOR PREDICTING SYSTEM DOWNTIME.

Eginhard J. Muth (General Electric Co., Instrument Dept., West Lynn, Mass.).

(Institute of Electrical and Electronics Engineers, International Convention and Exhibition, New York, Mar. 20–23, 1967.)
IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 97–102. 11 refs.
(A68-35156)

Study of a system whose components, upon failure, are repaired or replaced. Only two-system states, the "operating" state and the "failed" state, are distinguished. The system is defined by a reliability network and by the failure rate and repair rate of each

component. The time to failure and the time to repair of the components are assumed to be exponentially distributed. A criterion of system worth is the random variable "downtime," denoted by D(t), which is defined as the time the system is down during the time interval (O,t). The distribution function of D(t) is established, and a method for computing this distribution function is indicated. IAA

Review: This paper is the same as the one covered by R68-14050.

R69-14239 ASQC 824; 872
EVALUATION OF REPAIRABLE SYSTEM RELIABILITY USING THE "BAD-AS-OLD" CONCEPT.
Harold E. Ascher (U.S. Naval Material Command, Naval Applied Science Laboratory, Brooklyn, N. Y.).
IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 103–110. 9 refs.
(A68-35157)
Analysis pointing out the inconsistency between the commonly accepted concept of wearout of repairable systems and the a priori use of renewal processes for modeling these systems. Basic procedures for evaluating data from repairable systems and for formulating bad-as-old probabilistic models are outlined. The results of Monte Carlo simulations are presented, which illustrate the grossly misleading results which can occur if independence of successive failure times is invalidly assumed. IAA

Review: The thesis of this paper is that the exponential distribution is not an adequate model for describing the failure times of repairable systems. The author argues that the assumption that a system is as good as new after repair is not plausible for a complex system. To overcome this difficulty he proposes a "bad-as-old" model based on a time-dependent Poisson process. In principle this is a good idea, and the topic is one which has not been adequately pursued in the reliability literature. The author states that his paper is not intended to provide a rigorous definitive treatment of "bad as old" models. He presents some intuitive arguments to counteract the blind and unconscious application of renewal processes to situations which he feels should not be modeled by them. There is a lack of clarity in the basic concepts, and it is difficult for the reader to be sure that the fundamentals are really valid or appropriate for real-world problems. The index, called "failure rate," which is used repeatedly throughout the paper, is nowhere defined. In the context of the discussion it could mean either the hazard rate as commonly associated with the probability density function of a single failure time or it could mean the renewal rate which is associated with multiple failure times. In a private communication the author has indicated that he intended "failure rate" to loosely mean the number of failures per unit time. The concepts advanced in Section IVA are based primarily on models pertaining to the probability density function of a single failure time (e.g., Eqs. 2a and 9 in the paper). Thus there is an absence of the type of model which would be pertinent to an equipment containing many replaceable items. The discussion in paragraph C on page 104 as well as remarks made elsewhere in the paper imply that the author feels that the conditions of being independent and identically distributed necessarily go together for a renewal process. However, this is not so, as there can be non-identical distributions of times between successive failures and they may or may not be statistically independent. A theoretical paper concerning renewal theory for non-identically distributed variables is [1]. In a private communication the author suggests that using the approach involving non-identically distributed variables poses formidable probabilistic and statistical problems. Aside from possible mathematical intractability, a distribution corresponding to successive times to failure would have to be selected. In addition, he states that data would have to be gathered to obtain accurate estimates of the parameters of these distributions. However, data would also have to be gathered to obtain accurate estimates of the parameters of other possible distributions such as those the author is proposing. In summary, it is suspected that the complexities in the modeling would be sufficiently severe just with non-identical distributions of times between failures so that statistical independence would be a reasonable, tractable assumption, at least for getting started. This paper is addressed to a worthwhile topic; however, it will require a great deal of effort on the reader's part to clarify what the author is saying and supply the rigor required for treating realistic systems' problems.

Reference: [1] "On the Elementary Renewal Theorem for Non-Identically Distributed Variables," by Walter L. Smith, *Pacific Jour. of Math.*, Vol. 14, No. 2, 1964, pp. 673–699.

R69-14240 ASQC 822; 872
MAINTAINABILITY DERIVATIONS USING THE ANALYTICAL MAINTENANCE MODEL.
Elmer L. Peterson (North American Rockwell Corp., Aerospace and Systems Group, Space Div., Downey, Calif.) and Hue B. Loo (McDonnell Douglas Corp., Douglas Aircraft Co., Huntington Beach, Calif.).
IEEE Transactions on Reliability, vol. R-17, Jun. 1968, p. 111–114. 5 refs.
(A68-35158)
Description of the application of the analytical maintenance model to the analysis of the launch readiness of systems. The maintainability contribution to the system operational readiness is also derived. A simplifying process using the gamma distribution is described which expresses the maintenance capability in terms of a probability of performing the restore function within a time limitation. Similarities between the empirical distribution and the gamma distribution are discussed. The reason for considering the gamma distribution as a potential alternate is its relative algebraic simplicity. The rationale for this approach is described. The potential usefulness of the procedures developed will apply to maintainability prediction, assessment, and validation, and further to system or subsystem levels. IAA

Review: The essence of this paper is that the gamma distribution should be used as a model for downtime. No comparisons are made with other possible distributions. No reasons are given as to why the gamma distribution is desirable, except a general statement about its relative algebraic simplicity. It is remarked once in the paper that data analyzed were obtained from systems in an actual launch, but it is not clear where the actual data were used. In a short section of the paper titled "Maintainability Estimates of Model Outputs" there is an incomplete discussion of how the gamma distribution was used. Apparently the use had to do with a Monte Carlo type of simulation, although this is not so stated. If this is the case, then it would not seem to make much difference what distribution is being sampled if it described reality accurately. Brief remarks about spares shortage are made without any prior introduction, an indication that this section is not self-contained. There is nothing in this paper for those who are already familiar with the gamma distribution, nor is there a convincing argument that the gamma should be used as a downtime model, even though it may in fact be a good choice.

R69-14246 ASQC 824
TWO EXPERIMENTAL METHODS FOR THE DETERMINATION OF THE TECHNICAL RELIABILITIES OF A SYSTEM AND ITS COMPONENTS.

E. Muff (Laboratoire Suisse De Recherches Horlogères, Neuchatel, Switzerland).
Microelectronics and Reliability, vol. 7, Aug. 1968, p. 265. 1 ref.

A system without any redundancy and with the reliability F(t) is split into n components with the reliabilities Fi(t), where these components are assumed to be independent of each other. An equation is formulated and two ways for the experimental determination of F(t) and Fi(t) are discussed: (1) In the case of system breakdown by component failure, the system could be repaired every time and subjected once more to statistical observations, while continuing to keep track of those components of the repaired system which had not been repaired and including them in the statistical evaluation. The Fi(t) can be determined immediately from the frequency curves of the first breakdowns of the components, and the F(t) from the total breakdowns. (2) Each system which has suffered a breakdown is excluded from the subsequent statistical observations (no repairs). In this case the F(t) is calculated directly from the histograms of the total breakdowns. An equation for finding Fi(t) is formulated. Author

Review: The methods presented for experimentally determining reliabilities of statistically independent subsystems of a series system are both unclear and misleading. It is not that they are incorrect, since any number (with the correct units) can be used to estimate any quantity. The biggest difficulties with the methods are that once the experimental data have been determined (that is, the failure times for the systems or subsystems and the knowledge of which subsystems failed), there is no indication in the paper of exactly what one should do with those numbers. The author does not distinguish between the reliability, which is a characteristic of a population, and our estimates of that reliability found from experimental data. There is no indication whether parametric or nonparametric methods are being used for the estimates. It is not clear how "run-outs" are handled ("run-outs" are elements which were unfailed when testing was stopped). The equations that the author has are correct, although some of his nomenclature is poorly chosen (e.g., $\phi_i(t)$ is not the failure density of the component as that term is ordinarily used). A statistical estimate may be good, bad, or indifferent; so one of the functions of statistics is to discuss the properties of estimates and to suggest how population parameters can be estimated from data. This article is at best a first step in the direction of putting the system equations in the form which may make estimation from the data easier. A statistician should be consulted for the appropriate methods to use in actually estimating these qualities.

R69-14247 ASQC 824; 831
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Lab.
A METHOD FOR SYSTEM RELIABILITY ANALYSIS
B. P. Zelentsoz 1 Aug. 1967 11 p Transl. into ENGLISH from Izv. Sibirsk. Otd. Akad. Nauk SSSR (Novosibirsk), no. 2, 1965 p 44–48
(AD-663354; FTD-HT-23-501-67; N68-16756)

The known mathematical models for system reliability analysis are based either on the mass servicing theory or on the theory of simple homogeneous Markov circuit with finite number of states. The first approach requires the establishment of a large number of differential equations while the second often demands the application of high order matrices. The present author proposes a new more direct method which, after relatively simple calculations, yields the average time for the restoration of the system into its stationary state. It is based on a solution proposed earlier by Einhorn (S. J. Einhorn, Reliability prediction for repairable redundant systems. Proc. IEEE, 1963, vol. 51, no. 2) for the case of one kind of element with identical reliability indexes. The author assumes that (1) the time of flawless operation and the time of element restoration follow the exponential distribution; (2) malfunctions and repairs of the system are mutually independent; (3) all elements which are in good order are under hot operating conditions while the failing elements are out of operation; and (4) at a single instant of time there can occur only single transitions of an element from its operating state into a malfunctioning state and vice versa. The method is illustrated by an evaluation of a two-element system with four available states. Results show that the new method is faster than the existing methods. TAB

Review: This derivation is simpler than some which can be used to arrive at the same conclusions. The reason that it is simpler than some of the long drawn-out derivations is that it calculates only mean values and nothing else. A Laplace transform method could also be used to get the equilibrium answer and perhaps be as short. The result itself is not new. The author is merely trying to indicate the superiority of this technique (in view of its shortness) over the conventional techniques of Markov chains and queueing theory. Unfortunately, in some copies obtained from the Clearinghouse, the reproduction is so poor that much of the detailed mathematics cannot be followed. Even though this particular technique is seldom shown in the literature, it is probably reasonably well known.

R69-14264 ASQC 823
STRESS/STRENGTH MODELS—A SOLUTION TO ACCELERATED LIFE TESTING.
S. P. Aranoff (Raytheon Co., Space and Information Systems Div., Sudbury, Mass.).
In: Utilization of Reliability: Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 67–87. 5 refs.
(A68-23838)

Development of a stress-strength model for failure of electronic components. The model allows for the calculation of the acceleration relationship between failures under above-normal environmental conditions and under normal conditions. Life-test-to-failure data for three types of components—gas-filled light bulbs, Mylar tape-wrapped epoxy capacitors, and rf inductors—have been used to test the model. The results were highly accurate. A method is presented for application of this technique to any new components. Author (IAA)

Review: There is little in this paper that does not appear elsewhere in a form that can be much more easily assimilated and which is much less misleading. Examples of the difficulties are as follows: (1) This paper gets so involved with algebraic details that it is extremely difficult to find the points the author is making. (2) There is a strong implication that accelerated tests have only recently been invented, whereas of course in one form or another, they have been known for a long time. (3) Figure 1 and associated equations are extremely misleading since the point y_1, not otherwise defined, comes at the intersection of the stress and strength curves. This intersection point has no physical meaning. (4) Equation 6 is at best not clear since there is an implication that the reliability of a part depends only on the stress and time, not on any parameters of the part. (5) When trying to compare accelerated testing theories, the author appears to use comparisons both of reliability and of hazard rates without being aware that the two methods can give different answers. (6) When the Weibull distribution is introduced, none of the usual restrictions on the parameters are given. (7) Equation 11 is incorrectly said to be a series of powers of t; it is, in fact, the exponential. (8) Beginning with Equation 16 and following to the conclusion, there is virtually page upon page of high school algebra which is completely out of place in such an article and obscures the point the author is trying to make. Presumably, the superscript I's are primes wherever they appear. In much of the mathematics between Equation 16 and the conclusions, it is not at all obvious what the author is doing or why he is doing it. (9) In the equations on page 80, it is asserted that time is the mean time between failures, yet this fact does not seem to be used anywhere in the derivations. Therefore it is not clear why these times may not be chosen at the discretion of the reader.

R69-14267 ASQC 824; 431

PRIMER OF MARKOV CHAIN APPLICATIONS TO RELIABILITY PROBLEMS.

William H. Sellers (Raytheon Co., Missile Systems Div., Bedford, Mass.).

In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 125–143. 5 refs.
(A68-23841)

Elements of Markov chains which are essential for the successful building of a Markov chain mathematical model for a given type system are presented and discussed. A general computer program for the calculation for the Markov chain matrix equation is developed and included for convenience of immediate application by the reader. Several applications of the Markov chain mathematical model are developed and summarized which indicate the wide variety of complex reliability problems that can be reduced from intractable problems to relatively straightforward step-by-step simple probability problems. Author (IAA)

Review: This paper is so full of typographical errors that it is virtually unreadable. Presumably the author was not permitted to proofread the material before publication. In any case the material is of very little use. Only one tiny aspect of Markov chains is presented. Surely in this day and age it is not necessary to publish a computer program which merely carries out vector and matrix multiplication! Furthermore it is known that one may encounter serious roundoff errors in attempting to compute the N*th* power of a stochastic matrix for large N and that eigenvector methods are much more efficient. One of the best primers on Markov chains is still the book by William Feller, "An Introduction to Probability Theory and its Applications," Volume I, Third Edition, John Wiley and Sons, Inc., New York.

R69-14268 ASQC 824

RELIABILITY—AN INSEPARABLE PART OF THE DESIGN PROCESS.

Gerald E. Ingram (General Electric Co., Center for Advanced Studies and Defense Programs Div., TEMPO, Santa Barbara, Calif.).

In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 145–160.
(A68-23842)

The paper discusses the rationale and some techniques for considering reliability during the process of designing a system or the elements which constitute the system. Emphasis is placed on the fact that the approach to the design process in a probabilistic sense does not present an intractable problem. It is pointed out that time-sharing computer systems, used from remote access terminals, allow engineers of either the small or large companies to solve complex probabilistic problems efficiently and economically. Author (IAA)

Review: A major portion of this paper is given over to an explanation of the author's method for combining probability density functions (the same method he described in the paper covered by R65-12275) and to a pitch for the use of time-shared desk-side computers. Time sharing versus batch use of computers is a problem which has been discussed elsewhere in the literature and is not peculiar to reliability problems or to reliability engineers. The method of combining probability density functions is not proved to be accurate nor is a reference given, but in any event it is probably good enough. Actually if the computer program is going to do it, the engineer presumably need not know how it is done, as long as it is right. An interesting comparison of this paper with several others given at the same conference is that some of the others tend to deprecate the numbers side of reliability and emphasize engineering aspects, whereas this one insists on the importance of the numerical calculations.

R69-14270 ASQC 824; 882

GROUND ALERT FACTORS INFLUENCING MISSION SUCCESS PROBABILITY.

K. A. Lyman (International Business Machines Corp., Federal Systems Div., Electronics Systems Center, Owego, N. Y.).

In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 195–210.
(A68-23843)

Analysis of the availability vector of probability that an avionic system is available upon demand. This is especially important in case of a strategic or tactical system deployed at remote sites and undergoing periodic checkout and maintenance. Results are desired which enable a determination of the optimum time between checkouts and sensitivity to the system probabilistic parameters. It is found that the optimum time between checkouts does not depend on active failure rate, repair rate, or false-alarm rate when the proportion of system failure rate undetectable by Central Integrated Test Sets (CITS) is zero, but is quite sensitive to the combination of passive failure rate and maintenance cycle length. For a constant failure rate, the optimum cycle length decreases drastically with a decrease in maintenance time. Cycle length, however, is one parameter quite easy to adjust and can in practice be varied even as field failure data are received. IAA

Review: A well-balanced presentation is given in this paper concerning availability models for an operational environment which includes periodic checkouts. Desirable features include statement of the assumptions, definitions of terms, ample figures and illustrations, and presentation of only key equations. The paper is concerned with aircraft at remote sites, but the material presented would be applicable, at least in part, to other systems such as those for missiles or ships. A 7094 computer program is mentioned briefly. The main difficulty with the results, from the viewpoint of practical utility, is that the system is treated as an entity. Typically the periodic maintenance situation will vary quite a bit for the various commodities which make up most modern-day systems. Further, redundancy is usually present in modern systems, and this is not treated. For these reasons practical applications usually lean toward the Monte Carlo type of simulation rather than analytical models of the type in this paper. The author acknowledges the redundancy limitation.

R69-14271 ASQC 824

A THEORY OF RANDOM FATIGUE.

R. W. Lardner (East Anglia University, School of Mathematics and Physics, Norwich, England).

Journal of the Mechanics and Physics of Solids, vol. 15, May 1967, p. 205–221. 23 refs.
(A67-30094)

A theory of the fatigue process is given which enables the survival probability under general broad-band random loading to be calculated. In this theory the growth of fatigue damage is regarded as taking place continuously in time, rather than discretely, per cycle. The total damage increase in a time interval is obtained by integrating a damage-rate function over the interval for the particular stress-time curve which has operated. Forming averages over different stress-time functions for the random problem can then be carried out. For a normally-distributed random stress and a particular (realistic) damage-rate function we have calculated the mean damage, its standard deviation, and the survival function. We have also established that this approach gives good results for fixed-level tests. Author (IAA)

Review: This is a theoretical paper which constructs a model of the fatigue process based on the concept that damage occurs continuously in time rather than cycle-by-cycle. The model ignores load frequency and stress history effects, but the author recognizes and clearly states that a reasonable theory must include these factors. This type of approach to the fatigue problem can be justified if all variables and their dependency on time are defined and included in the model. The paper is editorially well done; but, because of the rather complex mathematics which is used to describe the fatigue damage model, the paper must be studied carefully rather than simply read. The mathematics of the paper was not checked in detail, but it appears to be correct. Theorists rather than design engineers will probably derive the greatest benefits from the paper.

R69-14275 ASQC 824
USE OF THE PROT METHOD IN THE FATIGUE TESTING OF LIGHT ALLOYS.
M. N. Stepnov and Yu. A. Shukhmin (Moskovskii Aviatsionnyi Tekhnologicheskii Institut, Moscow, USSR).
(Zavodskaya Laboratoriya, vol. 33, Jul. 1967, p. 868–870.) *Industrial Laboratory*, vol. 33, 1967, p. 1018–1020. Translation.

Some suggestions are offered on the selection of the conditions of accelerated fatigue tests by the Prot method; the results obtained in testing a large batch of specimens (30 to 100) of light structural alloys are used as the basis. The analyses and the mechanical properties of these materials are tabulated. Also given is the modified Prot equation which takes account of the behavior of light alloys and which gives the fatigue strength for various numbers of cycles. It is pointed out that the rapid Prot method gives a reliable estimate of the fatigue properties of light alloys provided that the level of the initial stress and the number and rate of increase of stress ranges have been correctly selected. Author

Review: This paper shows the results of some mathematical manipulation of formulae associated with Prot testing. Those involved in fatigue testing of light alloys may wish to consider this method, but they should be careful not to accept it as Gospel. Too many arbitrary coefficients give many people much trouble. However, it is a paper which is worthwhile reading and analyzing to see where it might assist in fatigue testing. The Prot method itself is somewhat notorious as requiring much judgment on the part of the experimenter; this modification will increase that need.

R69-14276 ASQC 824
INFORMATIONAL ASPECT OF STATISTICAL RELIABILITY ESTIMATES.
Ya. A. Rips
(Avtomatika i Telemekhanika, no. 7, Jul. 1967, p. 140–150.) *Automation and Remote Control*, vol. 27, 1967, p. 1117–1125. 3 refs. Translation.

The idea of informational aspect of the choice of statistical reliability estimates is formulated, in the sense that the criterion of choice is the ratio of information obtained to the a priori entropy of the situation. An expression is obtained for the quantity of information contained in the results of an experiment. Optimal confidence intervals are determined for the reliability in the case of normal frequency distributions. Computed materials are presented. Author

Review: This is an interesting paper in which the concept of statistical entropy (information) is introduced in connection with reliability estimates. The mathematics is not very complex but is different enough from that usually encountered by engineers, so that they would have to study this paper as opposed to reading it casually. One trouble engineers will have with this paper is that it sounds reasonable, yet is arbitrary, as are all mathematical derivations, and the various criteria for reasonableness are often hidden. The following are examples. (1) "The uniform distribution is chosen as the *a priori* distribution for the probability of success." There are excellent arguments to the effect that in practice no engineer really has this distribution for his prior belief. For example, if he were making wagers on the outcome of the experiment, especially if he were connected with the design, he would undoubtedly not take the wagering odds from the uniform distribution. (2) The statement, "This gives sufficient justification for basing the optimal estimates on the hypothesis of equi-probable values of p..." should be evaluated carefully. The justification is sufficient for going ahead with it in the text but not necessarily sufficient for using it in one's everyday analyses. (3) The use of information as defined in this paper as the criterion for goodness of estimates is an interesting and worthwhile one but also not necessarily the one that should always be used in everyday calculations. (4) Only interval estimates are possible with this method; there will be no point estimates. (5) Some of the notation may be confusing. The author uses $Q(p_i/p_k)$ to mean $Q(p_i|p_k)$, viz., the slash does not indicate division in this kind of expression. Despite these minor difficulties, this is an interesting worthwhile but not necessarily definitive paper on the subject of reliability estimates. Another paper which gives a very different treatment of the same question (that is, what confidence interval to use for reliability estimates) is the one covered by R69-14182.

R69-14277 ASQC 824
CALCULATION OF CIRCUIT RELIABILITY FROM THE STRUCTURAL EQUATION.
R. K. Antoshin
(Avtomatika i Telemekhanika, no. 7, Jul. 1966, p. 158–160.) *Automation and Remote Control*, vol. 27, 1967, p. 1132–1134. 1 ref. Translation.

The determination of the reliability of circuits from their structural formulas is considered, using the exponential function, taking into account two types of failures. The analogy between these functions and the Boolean formula of the circuit in certain cases makes it possible to synthesize Boolean formulas for prescribed reliability characteristics. Author

Review: It is difficult to find the purpose of this paper. It discusses logic-type circuits with two kinds of failure: failure to operate when required, and operating when not required. An exponential series is used to approximate a power law and these approximations are used in some simple expressions for probability of failure of a system. Offhand, it would seem that the original p^n and $(1-p)^n$ could be evaluated more easily and more quickly than the exponential series. There is nothing new in the paper at all and it need not be consulted by anyone except those interested in what the Russians are printing.

83 DESIGN

R69-14232 ASQC 831; 817
THE INNOVATION OF SERVICE-LIFE EFFECTIVENESS.
Jack A. Morton (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).
(Institute of Electrical and Electronics Engineers, Annual Symposium on Reliability, Boston, Mass., Jan. 16–18, 1968.)
IEEE Transactions on Reliability, vol. R-17 Jun. 1968 p. 58–63.
(A68-35150)

Discussion of three interrelated "people processes," each aimed at either improving cost, performance, or reliability—three criteria of system effectiveness that allow choice and evaluation of alternate solutions to a problem. Materials, devices, and systems are the specialist levels of innovation in integrated electronics. Each level performs four basic functions, including (1) formulation of requirements on the entity as a whole, (2) establishment, by analysis, of a design theory based on a hypothesized model, (3) exploration of methods for fabricating structures to meet specified requirements, and (4) development of test methods to measure the actual functions produced. These functions must be iterated for performance, cost, and reliability. It is concluded that the virtue of developing a well-ordered structure for a such a complex innovation process lies in calling for the right kinds of information at the right time, and identifying missing knowledge. IAA

Review: The author is well-known for his views on this subject and this paper is a very able presentation of them. The philosophy is a good one and is applicable in many circumstances, especially in the electronics/telephone industry which the author represents. The emphasis on people being involved in all of the processes is very good, for none of these concepts effect themselves—they are all carried out by people. Not until near the end of the paper does the author point out that many of his categories have no knowledge in them and that while this may upset the rational following of a preordained plan, the unfilled categories do show us where work needs to be done. Indeed, if there is any objection to the paper it is that it reads so smoothly that impressionable people may not realize that in actual practice rarely do things move as smoothly, neatly, and categorically as they do in the pages of the paper. For those who are not yet acquainted with the concepts contained herein, the paper is well worth reading.

R69-14237 ASQC 831
USE OF ERROR CORRECTING CODES ON MEMORY WORDS FOR IMPROVED RELIABILITY.
Thammavarapu R. N. Rao (Maryland University, Dept. of Electrical Engineering, College Park, Md.).
IEEE Transactions of Reliability, vol. R-17, Jun. 1968, p. 91–96. 7 refs.
(NSF Grant GK-1543)
(A68-35155)

Discussion of the effect of error-correcting coding of memory words on the overall reliability of the system. Introduction or error-correcting facilities will generally have three significant effects on the system: (1) increased hardware, which is also subject to failures and hence tends to lower reliability; (2) the system's ability to function in the presence of a certain class of failures; and (3) quicker detection of errors, which also means an improved repair rate. To illustrate the extent to which these three factors govern the reliability improvement due to coding, three types of systems are considered. These systems use the same basic processor and memory units but differ in their structure and complexity. IAA

Review: This is generally a good tutorial paper. Some of the terminology is unfortunate, especially in an IEEE journal, since it does not conform to the standards the IEEE is trying to promulgate. Thus, the words "reliability" and "reliability gain" are used in quite unusual senses. While the title deals with error *correcting* codes much of the paper discusses error *checking* codes and it should be noted that these are not at all the same thing. (The author does state that he means "error detecting and/or correcting codes" by the phrase "error checking codes," but this does not alleviate the confusion.) The assumption in the duplex-system analysis, that the extra circuits are a small fraction of the total process or memory circuits, is a very convenient, tractable one but may well not often be true. In Eq. 11, the first two f's should be enclosed in parentheses, i.e., the total expression to the left of the slash is the numerator. Inequalities 12 and 13 are identical, so that satisfying one satisfies the other. The conclusions are quite good; in fact, for the casual reader they will probably be better than reading the entire paper. Figures 10 and 11 may well be difficult to understand unless one is quite familiar with this kind of work. All in all, the paper has many good points, albeit some of them are poorly expressed.

R69-14242 ASQC 833; 815
HOW RELIABLE ARE PLASTIC ENCAPSULATED SEMICONDUCTORS?
V. J. Lukach (Radio Corp. of America, Electronic Components and Devices, Somerville, N. J.).
Insulation, Sep. 1968, p. 14, 15.

In comparing the reliability of plastic encapsulated semiconductors with hermetically sealed devices, two views are offered: (1) The intended application of plastic devices is of prime importance in determining its reliability. The environmental areas that are relatively more troublesome are identified as long-term operation under high humidity, high temperature conditions, or multicycle temperature cycling exposure. It is suggested that meaningful qualification tests should be developed that are mutually acceptable to both vendor and user, and that more than one set of standard tests might be necessary to broadly categorize the reliability levels of the plastic product which would be generally correlated with environmental applications. (2) The economic and reliability advantages offered by plastic encapsulation are cited, along with the disadvantages of hermetic sealing. Of the three methods of encapsulation (coating, transfer molding, and liquid potting), transfer molding is considered the most production oriented and probably the most economical. M.G.J.

Review: The topic in this month's Insulation Forum is interesting because of the subject matter and also because of the fact that there are only two letters concerning it, whereas there are usually many more. Unfortunately, neither letter answers the question, "How reliable are plastic encapsulated semiconductors?" Both of the letters essentially talk around the question, and there does not appear to be agreement on how reliable these devices really are for military uses. The main interest in this paper to reliability and semiconductor specialists will be in what is not said more than what has been said.

R69-14250 ASQC 838
Lincoln Lab., Mass. Inst. of Tech., Lexington.
MICROPOWER ERROR-CORRECTING REDUNDANT CIRCUIT DESIGN
Robert E. McMahon and Nathaniel B. Childs 23 Aug. 1967 28 p refs
(Contract AF 19(628)-5167)
(AD-659750; ESD-TR-67-483; TN-1967-27; N68-11273)

A simple error-correcting circuit design employing a majority charge technique is described. Use of a pulse-powered design, conventional integrated circuits, and a majority charge technique provides a reliable error-correction method for redundant digital networks at micropower levels. The design procedure is described in terms of operating margins. Practical system implementation is also provided. Author (TAB)

Review: This paper clearly shows the proposed technique for redundancy. The principle involved can be put in more conventional language by pointing out that the capacitor interconnections are the majority voter. The circuit operating description was not fully checked but appears reasonable. The use of a single integrated circuit containing the redundant elements should be pursued with extreme caution since the failure events on a single chip are likely not to be statistically independent under the conditions ordinarily expected; therefore, the gain from redundancy will not be as great as predicted. Even though power reduction by a factor of 100 to 1000 is predicted by using the pulsed power supply, there are many computer applications wherein the duty cycle is likely to be relatively high and thus the power savings by pulsing the power supply will be small. Further, one should be aware that the design of the logic system may be more complicated. Experienced design engineers also know that any breathing room they get from using an advance in the state of the art like integrated circuits (which save weight, space, etc.) is quickly removed by the customer; he now wants to use the advance as standard procedure and go on to push the state of the art again. A companion article written somewhat earlier was published in *Electronics*, February 6, 1967, pp. 66–69.

R69-14259 ASQC 832
Operations Research, Inc., Silver Spring, Md.
HUMAN RELIABILITY RESEARCH Final Report, May 1966–Aug. 1967
Charles Beek, Kenneth Haynam, and Gabriel Markisohn Sep. 1967 40 p refs
(Contract Nonr-4451(00))
(AD-664495; PRR-67-2; TR-430; N68-18468)

The research effort focused on two major areas, a survey and analysis of existing failure reporting systems, and the investigation of alternative indirect approaches to determining human performance and quantifying the human reliability contribution to weapon system effectiveness. It was found that existing failure reporting systems do not yield meaningful data on human-initiated malfunctions. In most cases, a strong reluctance to report all failures was noted, particularly human errors. In attempting to develop an indirect approach to human reliability analysis, two techniques were investigated, both of which rely on equipment failure reporting rather than human error reporting. One technique is ERUPT. This approach, by grouping the components of a weapon system into elementary reliability units, provides a means of inferring two human performance parameters from available equipment reliability and maintenance data. The second approach relates certain personnel characteristics of individuals operating and maintaining the equipment to number of failures and equipment repair times by the application of multivariate correlation analysis techniques. Author (TAB)

Review: This is generally a good report, especially in view of the frankness with which research in the field of human reliability is evaluated. It is an excellent source of information on the problems and difficulties commonly encountered (whether recognized or not). These problems and difficulties are horrendous, and so it is reasonable that the conclusions and efforts on this project are not definitive. The following examples and comments should not be interpreted as deprecating this work compared to that of others. (1) The prediction of hardware reliability is straightforward only when compared to that of human reliability. When viewed as an exercise in itself, it is extremely difficult. (2) The authors show practical knowledge of what goes on in reporting systems and the reasons why people do what they do. It would be difficult to enforce the use of failure reports, which contain human reliability comments, only for equipment improvement (rather than for personnel evaluation) no matter how many pious promises to the contrary are involved. Even the courts sometimes allow illegally-obtained evidence. (3) The system for inferring human reliability appears satisfactory on its face, but the derivation was not checked thoroughly. One must be very careful about having the assumptions explicitly stated in a derivation for two reasons: it makes the derivation easier to follow by someone else, and one is likely not to lead oneself astray. (4) The utility of multiple correlation analysis is often suspect; and it has numerous controversial forms. Where a good model is not available to begin with, the results should be used at most only to generate ideas which look good enough to check further. One big difficulty is that no matter what correlation or multiple correlation shows up, one can virtually always invent plausible reasons for it.

R69-14260 ASQC 831
OPTIMIZING PRODUCT ASSURANCE THROUGH THE SYSTEM EFFECTIVENESS APPROACH.
Edward T. Parascos (Columbia Broadcasting System, Inc., CBS Laboratories, Stamford, Conn.).
In: Utilization of Reliability; Annual West Coast Reliability Symposium, 9th, Century City, Calif., Feb. 16, 1968, Papers. Symposium sponsored by the Los Angeles Section of the American Society for Quality Control. North Hollywood, Calif., Western Periodicals Co., 1968, p. 1–18. 42 refs.
(A68-23835)

Evaluation of the basic system effectiveness objectives and of the tasks which must be accomplished in order to optimize the development, manufacture, and testing of systems, subsystems, and mission critical ground-support equipment. The system-effectiveness aspects related to product assurance of the entire spectrum of an equipment's life cycle "from the cradle to the grave" are reviewed. IAA

Review: Except for a different title and somewhat shorter introduction, this paper is the same as the one covered by R69-14201.

R69-14280 ASQC 838; 821
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
INFLUENCE OF REDUNDANCY ON RELIABILITY OF SYSTEMS [VLIYANIYE REZERVIROVANIYA NA NADEZHNOST'SISTEM]
V. V. Naumchenko *In its* Ind. Telemech. 8 Sep. 1967 p 1–7 refs
(N68-22143)

The problem of system reliability with various degrees of redundancy represented by "cold" or "hot" reserve elements is briefly reviewed. A linear relationship between the average system lifetime and the relative redundancy is established for an ideal case with "cold" or "hot" reserve elements. The required redundancy is about the same for the "cold" and "hot" cases if $m \leq 1$; however, with $m > 1$, the required "hot" redundancy increases rapidly; $T_s = mT_O$, where T_s is the specified lifetime and T_O is the average lifetime of an element under working conditions. Formulas for reliability and average lifetime are written for a system whose each element has "cold" or "hot" reserve. Mean time to failure of Shannon–Moor lw-networks is discussed. Author

Review: This paper is quite similar to that covered by R67-13230 except that the author spends less time deriving equations and a little more discussing them. That review can be consulted for more details, but the substance is that when mean time between failures is the criterion for reliability, then active redundancy (reserve elements are deteriorating at the same rate as active ones) buys one very little, whereas passive redundancy (reserve elements do not deteriorate at all) is effective. It should be noted that if there are other criteria for reliability, these conclusions will undoubtedly be modified. Such is the case where hazard rate at short times is of interest.

84 METHODS OF RELIABILITY ANALYSIS

R69-14241 ASQC 844
DETERMINATION OF SEMICONDUCTOR JUNCTION OPERATING TEMPERATURE.
Charles Y. Bartholomew, Quentin T. Jarrett, and Connell F. Maguire (Bell Telephone Labs., Inc., Allentown, Pa.).
The Western Electric Engineer, vol. 12, Jul. 1968, p. 8–10. 1 ref.

Either junction-to-ambient or junction-to-case thermal resistance can be used in the determination of semiconductor junction operating temperature. To establish which of these two resistances provides the more accurate determination, experimental work was performed to measure the effects of radiation, air conduction, air convection, lead conduction, and of wafer resistivity, area, thickness, and bonding area on these resistances. The results of this work indicate that junction-to-case thermal resistance gives a more accurate determination provided wafer bonding area is monitored during manufacture. Author

Review: The operating temperature of junctions in semiconductors is important from the reliability point of view because of the generally drastic increase in hazard rate with an increase in junction temperature. Thus, better ways of estimating junction temperature are always being looked for by reliability engineers. It is not clear what the contribution of this paper is; apparently it is not intended to present a new "thermometer" since it uses the variation of forward voltage drop with temperature. The facts (a) thermal resistance from junction to case is a variable, (b) thermal resistance from case to ambient is another variable with an even larger uncertainty, and (c) one can write a linear constitutive equation relating power flow and temperature drop, are not new; yet the paper does not appear tutorial. The fact that one is getting an average junction temperature (because, at least one large-junction transistors, the entire junction is not all at the same temperature) seems to be disregarded. In short, this paper appears to give information that is already reasonably well known.

R69-14243 ASQC 844
DISTRIBUTION ANALYSIS FOR RELIABILITY IMPROVEMENT.
Janez J. Barlič (Iskra-Kranj, Semiconductor Div., Trbovlje, Yugoslavia).
Microelectronics and Reliability, vol. 7, Aug. 1968, p. 237–240. 3 refs.
(A68-38978)

Description of a method for detecting semiconductor devices showing poor performances in later life by selection according to electrical parameters. It is shown how to obtain the limits of selection by analysis of the initial parameter distribution. The subject of the investigation was silicon diffused plastic encapsulated diodes. In the case studied, it was found that from the initial parameters distribution it is possible to predict which devices will fail in early period of life. With appropriate selection, it is possible to separate the devices which have poor performance in later life. IAA

Review: This paper is difficult to read and is unclear in many places, due apparently to the language problem. The data themselves are interesting, but since the interpretations are not clear it is difficult to evaluate them. Apparently screening was effective. Those who are very closely concerned with the problem of screening of silicon diodes may wish to take the time to figure out exactly what the author was trying to say, but even so, the conclusions should be very critically examined before being accepted (as is mentioned by the author). In a private communication the author has indicated that the sentence in the text immediately following Fig. 3 on p. 238 is incorrect. It should read as follows: "The 2nd class of diodes shows quite irregular behavior under step stress test and the failure distribution is like the failure distribution of BC class, presented in Fig. 4."

R69-14245 ASQC 844; 851
FAILURE MODES OF INTEGRATED CIRCUITS AND THEIR RELATIONSHIP TO RELIABILITY.
W. Workman (Texas Instruments, Inc., Dallas, Tex.).
Microelectronics and Reliability, vol. 7, Aug. 1968, p. 257–264. 5 refs.
(A68-38980)

Survey of the process oriented failure modes of integrated circuits—i.e., cracks in silicon dice, diffusion and oxide faults, and metallization faults. Cases of extreme high reliability proven by application successes in the field are listed, and the economic futility of proving reliability by mass-life testing techniques is demonstrated. The high stress testing concept is discussed, and mathematical models utilized for reliability prediction are described. Ways of proving reliability by field performance are suggested. It is pointed that a relative figure of "demerit" can be assigned on the basis of observed failure occurrence rates. IAA

Review: This is a good paper—it is limited in scope and treats its topic briefly and well. Unfortunately the pictures which illustrate the faults, even though they are clear pictures, do not make the faults obvious to the untrained eye. This discussion of accelerated testing is interesting, especially the maximum acceleration factor. It should be remembered that this is *an* upper bound and that the actual maximum may be somewhat less due to other circumstances. The information retrieval portion of the paper is partly wishful thinking. While in some way one does use qualitative field experience, trying to get good field reports is an extremely difficult task. Many papers appear on this topic in the literature each year. Regardless of this, the idea may be worth pursuing. Unfortunately, evidence collected in this way often has to be treated as virtually worthless by those who are not familiar with how the data were *actually* obtained, as opposed as to how they were nominally obtained.

R69-14248 ASQC 844

HOW TO PREVENT FATIGUE FAILURE: PART 1–DECREASE STRESS; PART 2–INCREASE STRENGTH.

Robert E. Little (Michigan University, Dearborn, Mich.).

Machine Design, vol. 39, Jun. 8 and Jul. 6, 1967, p. 154–159 and 130–137.

(A67-30098; A67-32824)

Discussion of methods for increasing the strength of a part or system to prevent fatigue failure. The methods discussed include increasing bulk strength, increasing local strength, eliminating fretting, scoring, and corrosion, eliminating sharp corners, improving the surface finish, and improving ductility and impact strength. Nominal fatigue stresses are decreased by redistributing loads and stresses as uniformly as possible among components. Local fatigue stresses are reduced by decreasing stress concentrations–i.e., the local stresses are redistributed more uniformly in the vicinity of stress raisers. Other methods of decreasing stress are discussed, including increasing the size of critical sections, reducing mean stress, increasing the natural frequency, and changing the shape of critical sections. IAA

Review: This is a very good introductory discussion on the problems of fatigue failures and is well worth reading by anyone in need of such tutorial material. Fatigue failures are one of the biggest causes of non-electronic failures and many electronics designers give insufficient attention to the mechanical aspects of the design. In very critical situations, viz., those in which unexpected failure of the part has severe repercussions, these hints should be used only as a general guide; metallurgists or engineers professionally competent in this area should be asked to approve the design. Nevertheless, even under those circumstances, the more the original designer understands about fatigue, the better the final design will be. Some qualifications are worthwhile on several of the points made in the text. Examples are the following: (1) The fatigue strength usually found in the literature is a median strength. One may wish to design to a probability other than 50 percent, e.g., one-percent failure, and use a factor of safety from there. This is not necessarily equivalent to applying a larger factor of safety to the median strength. (2) Proof testing may not always increase the "strength" of a system. There are some circumstances in which it will do damage. (3) When increasing the fatigue strength of a material, one must be careful to watch out for the other material properties. For example, some of the other strengths such as corrosion fatigue resistance or impact may be severely reduced. There has been an unfortunate tendency in this regard with respect to the so-called high-strength steels. (4) When applying a plating to improve fatigue properties, associated effects such as hydrogen embrittlement should be carefully considered. Many have found that their actual plating process did not help but in fact hindered.

R69-14251 ASQC 844; 836; 838; 851

McDonnell Aircraft Corp., St. Louis, Mo.

VOYAGER CAPSULE PHASE B. VOLUME 2: CAPSULE BUS SYSTEM. PART E: RELIABILITY Final Report

31 Aug. 1967 102 p refs Prepared for JPL

(Contract NAS7-100; JPL-952000)

(NASA-CR-89690; F694, v. 2, Pt. E; N67-40051) Avail: CFSTI

Engineering reliability studies related to Voyager system design are summarized in terms of satisfying the constraints imposed by the capsule bus system, failure mode effects and criticality analysis, quantitative reliability estimates, reliability program requirements, and component part reliability. Analytical and modeling techniques used to examine the various design concepts were (1) failure modes, effect, and criticality analyses; (2) reliability-weight-effectiveness analyses; (3) mission effectiveness model; and (4) conceptual tradeoff studies. The single-point failure modes, failure effect, and failure criticality analyses indicated specific redundancies so that no single failure mode could have a catastrophic effect on the mission. Selection of functional, multichannel, or block redundancy was guided by the failure criticality of the mission event or equipment, and the reliability-weight-effectiveness analyses resulted in the use of redundancy to best meet the mission objectives. Probability of success for the Voyager capsule bus preferred concept is estimated at 0.830. General specifications for Voyager flight capsule semiconductors, transistors, diodes, and integrated circuits are included. M.W.R.

Review: This review is limited to the part of the final report dealing explicitly with reliability of the capsule bus system. The report is useful to reliability engineers outside the program largely for showing the kinds of details that must receive attention in order to achieve good reliability. It will be noted that the very conventional constant-hazard-rate analysis is used for reliability prediction and that undue emphasis is not placed on the result. A major emphasis has been placed on failure modes, effects, and criticality analyses which is good since it shows an appreciation for the predominantly engineering aspects of reliability. Some of the screening techniques are interesting; for example, requiring a 100x color photograph of each integrated circuit just before final packaging. It is noteworthy that the probability of success for the capsule bus preferred concept was estimated to be "only" 0.83. The report does use some jargon which may not be familiar to other reliability engineers but this does not seriously detract from the report's value.

R69-14252 ASQC 844; 775

FAILURE DETECTION BY MECHANICAL IMPEDANCE TECHNIQUES.

R. B. Tatge (General Electric Co., Research and Development Center, Schenectady, N. Y.).

Journal of the Acoustical Society of America, vol. 41, 1967, p. 1196–1200. 5 refs.

In present practice, the decision as to whether a device has suffered damage as a result of exposure to a severe environment is generally based on operability during and after exposure, and visual inspection. Since these measures do not necessarily disclose the presence of mechanical faults, particularly in sealed units that are to see service, a need exists for a purely structural test to tell if a failure has occurred. Mechanical impedance techniques offer an opportunity for structural characterization to determine whether or not a device conforms to a predetermined standard or has suffered a change as a result of its history. From reference to network theory, it can be shown that changes in the resonant and antiresonant frequencies are sensitive indicators of change in a structure; these have the advantage of being relatively easy to measure with accuracy. The length of time that the structure must be excited in order to make the necessary measurements for such a test can be minimized by using random-noise rather than swept-sine excitation. With proper instrumentation, the results obtained with the two are equivalent. Author

Review: This paper calls attention to a useful nondestructive test method for mechanical devices and, as the author points out, ultimately all devices are mechanical in nature. Two methods of measuring mechanical impedance are given, one using the swept sine wave, the other using random-noise excitation. The analysis is in the frequency domain for both techniques. If one is going to use random-noise excitation, he should consider the possibility of analysis in the time domain as opposed to the frequency domain. This is especially true if the recording of data can be done, for example, on a two-track magnetic tape and the analysis performed elsewhere so as not to tie up the shaker. This involves the cross- and auto-correlation techniques that are very standard for getting the signatures of systems. (As is usual in papers contrasting mechanical versus electrical equipment, the grass appears greener on the other side of the fence. Both kinds of analyses are equally difficult, if for no other reason than everyone is trying to push the state of the art as hard as he can.) Nevertheless the signature techniques shown in the text are good and those involved in nondestructive testing and screening should be familiar with them.

R69-14253 ASQC 844; 851

DETERMINATION OF THERMAL LIFE EXPECTANCY OF OVERHEAD DISTRIBUTION TRANSFORMERS.

Donald O. Craghead and William A. Erskine (Southern California Edison Co., Los Angeles, Calif.).

(IEEE Summer Power Meeting, New Orleans, La., Jul. 10–15, 1966.)
IEEE Transactions on Power Apparatus and Systems, vol. PAS-86, Sep. 1967, p. 1066–1072. 3 refs.
(Paper 31 TP-66-428)

The calculated thermal life expectancy of distribution transformers is used as part of an evaluation program to develop a comparative basis for the economic purchase of annual transformer requirements. The test procedure utilized in accelerating the thermal aging of the transformers, the pre-test measurements, the test measurements, and the mathematical derivation of the transformer aging rate as demonstrated by its performance on the accelerated test are described. In addition to the test procedure, a simulated residential loading schedule has been developed and is used to calculate the expected life of each test transformer. A tabulation is used to demonstrate how the calculations are made and to provide a comparison of the life expectancy of two typical transformers. Author

Review: This paper is reviewed from the point of view of reliability engineers rather than of utility engineers. It should be read along with the comments of the two discussants which bring out several points in the paper. Basically the assumptions in the paper are the following: The insulation system has a deterioration rate which is independent of time and obeys the Arrhenius Law with an activation energy of 0.63eV/molecule. Knowledge of the hot-spot temperatures on accelerated test and during conditions of use allows the ratio between the life-on-test and the life-in-use to be calculated. The duty cycle in use is 1/6; therefore, the elapsed calendar time in use can be calculated readily from the life-on-test. It is presumed that nominally-alike transformers have the same life, i.e., there is no randomness. (The text goes through somewhat different calculations involving some reference times. But these are not necessary and actually cancel out, as shown above. Not all of the assumptions are stated explicitly in the text, at least in a form easy for the reliability engineer to find. Apparently the utility engineers have their own reasons for "going around Robin Hood's barn".) The main interest of reliability engineers in this paper will be to know that the Arrhenius equation and the results of tests based solely thereon are used to extrapolate to use-conditions. Important economic decisions are based on those results. Care is taken to make sure that other failure modes have not intruded on the results; apparently if they have, the transformer is considered defective. The funds and other resources available for these tests are strictly limited, so that here is another example for reliability engineers of people doing the best they can with what they have. Some of the discussion of the paper (which is appended to it) is evolved with (a) trying to calculate the activation energy for each insulation system, or, perhaps more explicitly, for each transformer type, and (b) the question of non-randomness of life. The lack of "suitable" answers for the questions is related to limited resources for tests.

R69-14254 ASQC 844

THE ISOLATION OF A FAILURE MODE IN SILICON PLANAR TRANSISTORS CAUSED BY ORGANIC RESIDUES ASSOCIATED WITH ALUMINUM WIRE.

R. J. D. Scarbrough and J. Auchterlonie (Post Office Engineering Dept., Research Branch, London, England).

Microelectronics and Reliability, vol. 6, 1967, p. 319–321. 2 refs.

The later stages of transistor processing are described briefly in relation to their importance in determining the final performance of completed transistors. Particular attention is given to the level of contamination deleterious to the encapsulated transistor, and a study was made of header and can cleaning, environment and transfer associated with wafer and wire bonding, and gas ambient during the pre-bake and subsequent encapsulation. It was established that a bakeable ultrahigh vacuum system with getter-ion pumping is preferable to an average high vacuum system. As device instability still existed, an experiment was devised to examine several combinations by carrying out electrical measurements before, intermediately, and after an 8-hour bake at 350°C in a nitrogen atmosphere. It was concluded that contamination was being introduced by wire bonding and was possibly associated with the aluminum wire. The aluminum wire was cleaned in ethanol before wind bonding with excellent results. Chemical analyses of the contamination confirmed the presence of traces of long-chain fatty acid, probably stearic, and of aluminum stearate. M.G.J.

Review: This paper is an excellent example of physics-of-failure analysis wherein an entirely unsuspected cause of failure was unearthed. This failure mode for silicon planar devices does not appear to have been discussed previously in literature; so this paper is an excellent contribution. It is not necessarily to be presumed that all aluminum wire will have this difficulty since there may be various methods of processing. Nevertheless, for high-reliability, long-life devices, this organic residue on aluminum wire should be watched out for.

R69-14255 ASQC 844

MEASUREMENT OF THE SOLDERABILITY OF COMPONENTS.

J. A. Ten Duis and E. van der Meulen (Philips Gloeilampenfabrieken, Electronic Components and Materials Div. (Elcoma), Eindhoven, Netherlands).

Philips Technical Review, vol. 28, 1967, p. 362–364. 3 refs.

Details are given on a test device which makes it possible to record the wetting process quickly and simply, thus providing a figure of merit which is closely connected with practical soldering. The method is based on the principle that if a sample is solderable, it becomes wetted shortly after immersion. If the sample is not wetted, an additional quantity of solder is displaced, thereby increasing the upward force; when the sample is wetted, a collar of solder forms whose weight exerts a downward force. The test device consists of a balance arm to which the sample, coated with flux, is attached; a solder bath which can be raised until the sample is immersed to an adjustable depth; a displacement gauge for measuring the change in force during the dipping process; and a weak spring for compensating the weight of the arm and sample and for providing initial pressure for the measuring pin of the gauge. The amplified signal from the displacement gauge is fed to a fast pen recorder. Schematic diagrams depicting practical examples of wetting are included. M.G.J.

Review: Many papers have been written on the proper techniques for soldering, on inspection of soldered joints, etc. There are several NASA publications dealing with this important phase of electronic reliability. This paper describes a device for analyzing the wetting of terminations of components by molten solder. It can be used in the development stages of equipment and finishes, as well as for the routine inspection of components. It appears, on its face, to be a worthwhile tool for this purpose. It is apparently intended for components to be soldered on printed wiring boards. Those involved with high-reliability soldering processes should be familiar with the technique in this paper.

R69-14256 ASQC 844
EFFECTS OF CONDITIONING ON LIFE AND RELIABILITY OF CAPACITORS.
Wendell T. Starr (General Electric Co., Philadelphia, Pa.) and Lawrence J. Hogue (General Electric Co., Schenectady, N. Y.).
IEEE Transactions on Electrical Insulation, vol. EI-2, Aug. 1967, p. 102–107. 7 refs.

The results of a study of the life behavior of a developmental capacitor of the synthetic film type are presented. The life is shown to be extremely sensitive to thermal history of the capacitor. Heating at 85°C for 100 days increased the life by at least 40 to 1. Progressive stress testing in which voltage is increased with time aided materially in defining this effect as well as in showing that two mechanisms of failure were present. The purpose in this presentation is to present an example of the conditioning effect because it is not generally recognized that its effect on life can be as serious as it often is. Author

Review: This is a preliminary paper and one does not expect the theory to be well worked out; and in fact, it is not. The authors propose several working hypotheses and tentative methods of analyzing the data. In a paper such as this the methods of analysis and hypotheses are useful for generating and comparing ideas and there is no need to belabor them in detail in a review. The authors are probably too gracious in presuming that the effects of conditioning on life and reliability are common knowledge, since it has not appeared in the reliability literature on capacitors. The effects are very large as the authors point out—large enough so that it behooves the reliability community to give serious consideration to this effect.

R69-14257 ASQC 844; 711; 713
EVALUATING ALLOYS FOR FAILURE-SAFE STRUCTURES.
Robert J. Goode (U. S. Navy, Office of Naval Research, Naval Research Laboratory, Metallurgy Div., Strength of Metals Branch, Washington, D. C.).
Metal Progress, vol. 92, Jul. 1967, p. 95–100, 102, 104.
(A67-33048)

Determination of the fracture toughness, fatigue strength, and resistance to stress-corrosion cracking in alloys for failure-safe structures. Explosion tear tests are shown to confirm that most steels above 200,000 psi yield strength lie in regions where brittle fracture should be expected; also indicated is that many of the conventional steels with yield strengths of 180,000 to 220,000 psi are also characterized by low resistance to fracture. The tests described have one important feature in common; all specimens contain cracks or flaws. As such, they give information about the growth of fractures, an important consideration in large welded structures. Because such structures have complex forms, failure-safe application of materials in them requires that plastic strains be attainable before crack growth will occur. Thus these tests have a broad use for studying structural materials. IAA

Review: A failsafe structure is one in which a localized failure does not propagate itself (under subsequent loadings) to cause failure of the entire system. It is generally hoped that this localized failure will become obvious upon the next routine inspection. It is also sometimes hoped that in a failsafe structure, what would otherwise be a localized failure, is not actually such a failure. This paper is a good one. The examples are directed largely toward undersea vessels, but the principles are applicable to any kind of structure. This article is directed more toward the metallurgists than the general designer (in view of the journal in which it appears), but much of the article is understandable to mechanical engineering designers and the contents should be known to them. If they understand the general principles involved, they can converse much more intelligently with the specialists who will perform some of the detailed calculations and give explicit advice and approval for the final bill of materials. The limitations of some of the conventional fracture analysis are well brought out. One main idea is worthy of remembering by all of those who are trying for the optimum design; namely that, as a matter of practical fact, we rarely know all the stresses and strains to which the structure will be subject and it pays to use a material that will be forgiving of our miscalculations. Some of the newer, super-strength alloys that are being developed have this kind of property less than many of the old stand-bys (the reason they are old stand-bys is that they have this desirable property).

R69-14258 ASQC 844; 775
Navy Electronics Lab., San Diego, Calif.
RELIABILITY SCREENING AND STEP-STRESS TESTING OF DIGITAL-TYPE MICROCIRCUITS Research Report, Dec. 1966–Jun. 1967
H. F. Dean and K. F. Harper 1 Sep. 1967 70 p refs
(AD-662197; NELC-1512; N68-15692)

The effectiveness of thermal infrared mapping and nondestructive electrical tests for reliability screening was tested on 100 specimens of an industrial grade digital-type microcircuit. It was shown that more effective screening tests are needed, as a number of early failures were not predictable by the test methods employed. It was also shown that microcircuit containers may be opened for inspection and testing without degrading their reliability. Author (TAB)

Review: This report essentially consists of the results of a set of screening tests and subsequent step-stress tests on a group of 100 integrated circuits (Motorola, MC-255F—a medium power line driver). The results are interesting (albeit they should be narrowly construed) and the authors disagree with many of the allegedly published properties of integrated circuits. It has been obvious for some years that when people say that silicon transistors have no degradation mechanisms, they are speaking loosely and are referring to some kind of "ideal" transistor which often does not exist. There are many known degradation mechanisms in silicon integrated devices. The authors also assert that many of the characteristics associated with rise-, fall-, etc. times change as the unit warms up. Considerable evidence was found of grossly defective circuits being shipped. There was also evidence that the emissivities of the "silicon" in the active areas had distinctly different values from chip to chip while in the inactive areas, the emissivities were the same (no explanation of this apparent anomaly was available). Even though the results are interesting and will be useful, one has to be extremely careful in interpreting them without carefully reading the report, since several arbitrary unusual definitions are tucked away in various places. Some of the difficulties are the following: (1) The Normal Distribution is not a "...statistically perfect distribution..." (p. 58). (2) The authors *define* reliability by the behavior "strength" in the step-stress test. This could be different from the life behavior. (3) In the course of the analysis, it is asserted that the dividing line between good and bad units will be the median behavior. It is not at all clear that this is reasonable; for example, one might hope that 90% of the units were good. (4) In the conclusions, the authors come out against the burn-in since it presumably degrades the units. The question of how much degradation is bad and the level at which devices should be burned in is not clear-cut. Furthermore, this conclusion is based only on the particular circuits being tested and the particular definitions of degradation chosen. This conclusion is not universally accepted. In contrast see [1].

Reference: [1] "Reliability characteristics of integrated circuits," by B. Tiger and D. I. Troxel, Paper No. MES20, presented at the Microelectronics Comes of Age Symposium, 1967 WESCON, 23–24 Aug. 67.

R69-14272 ASQC 844; 775

Southwest Research Inst., San Antonio, Tex. Dept. of Instrumentation Research.

NONDESTRUCTIVE EVALUATION OF METAL FATIGUE Scientific Report, 1966–1967

Felix N. Kusenberger, Byron E. Leonard, John R. Barton, and W. Lyle Donaldson Apr. 1967 92 p refs

(Contract AF 49(638)-1502)

(AD-653587; Rept.-15-1688-2; AFOSR-67-1288; N67-34867)

The purposes of this program were threefold: to design and fabricate a vacuum chamber such that specimens can be stress cycled and nondestructively monitored while in a controlled atmosphere; to develop electric current equipment for nondestructive evaluation of fatigue in nonferromagnetic metals under controlled atmosphere; and to modify existing ultrasonic and magnetic perturbation equipments such that nondestructive evaluations can be conducted in a controlled atmosphere using these techniques; to stress cycle specimens and conduct nondestructive evaluations of fatigue damage in these specimens. Photographs of the fatigue damage evaluation facility are shown including the vacuum chamber and associated equipment. Features and capabilities of the vacuum system are discussed. A description of the electric current nondestructive evaluation apparatus is given including photographs and a discussion of the technique. Modification of existing ultrasonic surface wave and magnetic perturbation equipments so that they can be used for fatigue damage evaluation in a vacuum are also described. Fatigue evaluation experiments on a steel specimen stress cycled in the laboratory ambient atmosphere are described. The results obtained utilizing the ultrasonic and magnetic nondestructive monitoring instrumentation are presented. Author (TAB)

Review: This paper describes the testing of specialized electrical current, acoustical, and magnetic fatigue detection equipment which is to be used in futuristic environments such as those encountered in the Supersonic Transport and Manned Orbiting Laboratory operations. The data are clearly presented; and, even though the specialized "environments" were limited to only high vacuum, fatigue detection capability was concluded to be good. The mechanism used for scanning the part may be somewhat costly if the part has a complex shape. Only simple specimens were evaluated in this study. As is often the case, some of the secondary findings may be of greater benefit to fatigue research than those related to the original objectives of the program. The work was well performed and the results should be of benefit to those involved with non-destructive monitoring of fatigue, especially those working with a vacuum environment. Earlier reports on this program were covered by R65-12148 and R67-13518.

R69-14273 ASQC 844

Illinois Univ., Urbana. Dept. of Theoretical and Applied Mechanics.

NEUBER'S RULE APPLIED TO FATIGUE OF NOTCHED SPECIMENS Final Report, 1 Feb. 1966–30 Apr. 1967

T. H. Topper, R. M. Wetzel, and Jo Dean Morrow Philadelphia NAEC Jun. 1967 23 p refs

(Contract N156-46083)

(AD-659550; NAEC-ASL-1114; N68-10577) Avail: CFSTI

A method is presented for predicting the fatigue life of notched members from smooth specimen fatigue data. Inelastic behavior of the material at the notch root is treated using Neuber's rule which states that the theoretical stress concentration factor is equal to the geometric mean of the actual stress and strain concentration factors. This provides indices of equal fatigue damage for notched and unnotched members. Experimental results for notched aluminum alloy plates subjected to one or two levels of completely reversed loading are compared with predictions based on these indices. Measured notched fatigue lives and lives predicted from smooth specimens agree within a factor of two. Author (TAB)

Review: This paper presents an analysis, based on Neuber's rule, for converting smooth specimen fatigue data into a master life plot which can be used to estimate the fatigue life of a notched member produced from the same metal. The approach presented is different from that of other investigators in that it is not necessary to solve for the actual stress or strain at the notch's root. This work is a part of a broad program which may ultimately lead to the prediction of fatigue failure in structural elements based on fatigue data derived from smooth specimens. The analysis assumes that the mean stress at the root of the notch is zero; furthermore, it is limited to the prediction of crack initiation (or final failure when the crack propagation stage is negligible). The paper is short, well written, and well documented. The mathematics appears to be correct. Some qualitative design information is presented for 2024 and 7075 aluminum alloys. The paper will be of more value, however, to research engineers than to design engineers. The paper covered by R69-14185 is a useful supplementary reference.

R69-14274 ASQC 844; 775

Bettis Atomic Power Lab., Pittsburgh, Pa.

PROCEDURE FOR THE FATIGUE EVALUATION OF DEFECTIVE PIPE BUTT WELDS

E. J. Mc Gowan and A. L. Snow May 1967 33 p refs

(Contracts NObs-90029; AT(11-1)-GEN-14)

(WAPD-TM-560; N67-37945) Avail: CFSTI

An evaluation procedure for determining the acceptability of a weld joint containing defects and subjected to cyclic loading is presented. A method of classifying different types of defects is given and the δ concept of notched fatigue damage is used to assign fatigue strength reduction factors to the different types of defects. The calculation of peak stresses is discussed and determination of stress differences for fatigue evaluation is outlined. Form sheets are included to facilitate the efforts required by the procedure. Author (NSA)

Review: This paper does a good job of evaluating the effects of defective butt welds on the fatigue life of welded pipe joints. The authors have categorized various defects so that design and reliability engineers can use the results with minimum effort–if they can fit actual defects to one of the categories. The detection, identification, and the location of defects may well be the biggest deterrent to the use of any such concept. Various non-destructive testing techniques are available for detecting and locating defects, but they rely on standard reference techniques and materials which may not be available. The authors do not discuss this problem, but they use very conservative analysis techniques which may avoid some of these difficulties. There are several annoyances in the paper, e.g., (a) the letter "N" is used to indicate axial thrust, number of cycles, and number of transients, (b) there is a typographical error in the explanation of the example P_{ij} near the center of page 6, and (c) the explanation of how the superposed values of 300 cycles and 600 cycles in the table on page 8 were obtained is inadequate. The mathematics of the paper, although not completely checked, appears to be correct. The analytic technique would be useful to design and reliability engineers who are concerned with butt welds in tubular and piping structures. One example would be engineers who are concerned with the design, construction and reliability of the hollow welded struts for crane booms.

R69-14279 ASQC 844; 838

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

OPERATIONAL RELIABILITY OF RADIO RELAY LINES [EKSPLUATATSIONNAYA NADEZHNOST' RADIORELEYNYKH LINIY]

D. A. Bunin 19 Sep. 1967 14 p Transl. into ENGLISH from Avtomat., Telemekh. i Svyaz' (Moscow), no. 1, 1966 p 12–15

(Contract AF 33(657)-16410)

(AD-665985; FTD-HT-67-68; N68-21427)

Statistical data on the reliability of 15 radio-relay lines (RRL) totaling 4000 km and having 96 stations with RM-24 type equipment and one 272-km RRL having 21 stations with RTA-24 type equipment is reported; all lines are serving railroads. Equipment failures are responsible for 40–55% of the total number of failures; power-supply failures, for 27–41%; strong fadings, for 5–33%. The above figures testify to the low reliability of Soviet railroad-serving RRLs. Steps for enhancing the reliability by various reserving techniques are discussed. Author (TAB)

Review: This paper gives some statistics on the breakdowns of radio relay apparatus used on railroads and thus is of some interest to those engaged in similar work in this country. The author states that the reliability is very poor and suggests redundancy on an equipment basis as a cure for the problem. While the general level of reliability in this country may be higher, the causes of complaints are similar (manufacturers should pay more attention to reliability, and the quality of servicing tends to be poor). Apparently most of the equipment is not transistorized but uses vacuum tubes. The table in the abstract in the report should not be used since it is incomplete and misleading; the similar one in the body of the text offers more accurate information. There is a misleading statement in the text (perhaps due to translation): "However, the quality of the apparatus produced by industry is not dependent on designers and operators... the operational reliability... can be increased by the use of equipment redundancy." One would expect that the quality would be directly dependent on designers of that equipment but perhaps not on the designers of the radio relay system. The theory implied by the formulas is extremely simple; there is no need for esoteric analyses.

85 DEMONSTRATION/MEASUREMENT

R69-14244 ASQC 851; 844

SOME RESULTS OF LONG TERM LIFE TESTS WITH P-N-P ALLOYED GE-TRANSISTORS.

M. J. O. Strutt and C. Villalaz (Swiss Federal Institute of Technology, Dept. of Advanced Electrical Engineering, Zurich, Switzerland).

Microelectronics and Reliability, vol. 7, Aug. 1968, p. 241–256. 30 refs.

(A68-38979)

Results of long term life tests carried out with 2400 pieces of one transistor type. It is shown that by severe 0-hr selection of different characteristics, a remarkable reduction of the number of devices showing an extreme behavior can result. The results analyzed with respect to the "effects of random fluctuations of the manufacturing process" have shown that the method of analyzing from curve patterns has given an effective and sensitive indication. The comparison of the results of specially prepared experimental groups has shown contradictory information. The information has been obtained by analysis of the numbers of long term life test outsiders and by analysis of the curve forms. The results show a strong and specifically directed possibility of influencing the initial parameters of the products by the use of additives. IAA

Review: This paper contains a very detailed analysis of the test results in a poorly-organized form; therefore it is difficult to find out from reading the text just what the conclusions and trends were, if any. There are a great many suggestions for anyone planning to undertake similar tests. A language problem may make the paper seem more difficult to read than it really is. After one has studied all the results presented in this paper, it is not clear at all what he will have in terms of designing better equipment. Unfortunately, the authors do not tell anything about the transistor other than that given in the title, so that one has no idea whether it is low- or high-frequency, low- or high-power, etc. The market for high-reliability germanium-alloy transistors is probably very low. People building entertainment devices would probably not be interested in all of these data, nor even in obtaining similar data for their own transistors. Thus, it is not clear to whom the results of this study are addressed. This appears to be a classic kind of study: non-accelerated tests are run and when they are finished, the part being tested is obsolete. In short, while the detailed discussion and presentation of the results should be good for something, it is extremely difficult to find out what it is.

R69-14249 ASQC 851

LIFE OR DEATH FOR TRANSISTORS.

Ronald M. Mann (Texas Instruments, Inc., Semiconductor Components Div., Dallas, Tex.).

EDN, vol. 12, Aug. 1967, p. 72–81. 11 refs.

The most frequently encountered causes of transistor failure are outlined, and test methods for determining end-of-life point are evaluated. Four methods are discussed: (1) The storage at elevated temperature method is employed to show up a degradation type of failure. (2) The operating method is used to detect failures of the type that might occur in actual use. (3) The step-stress operating method, because of its stringency, will show up degradation and device failures in a shorter period of time. (4) The power cycling method, because of its thermal stressing, will detect any mechanical failures at weak bonding points in the unit, as well as structural flaws in the wafer. Basic measurement requirements and procedures are defined. Factors which may influence accuracy are cited as handling damage, damage due to uneven oven temperatures, results of oscillation, damage resulting from transients, the effects of insufficient limiting in power supplies, and the damaging effects of static discharges. Stress is placed on the importance of properly calibrated test equipment, and precautions in handling, biasing, and temperature control. M.G.J.

Review: This easily-read article gives practical hints on how to conduct life tests of transistors. The idea is that when you have finished running a critical life test on some transistors, and the results differ from those you would like or expect (and the expense of those tests was considerable), do you try and figure out what went wrong with the testing procedure or do you have confidence in that testing procedure and know that the results are accurate? The hints for good life testing are practical and worthwhile. There is enough discussion so that one knows the chances he is taking by using the inexpensive set-up as opposed to the expensive one. There are no checklists per se, but a budding test engineer can easily make his own (from this and other articles and from his own judgment) on the basis of the kinds of things that can go wrong and what measures have been or should be taken to prevent them. (Some of the introductory material should be used only for flavor, not for exact adherence to details.)

SUBJECT INDEX

Typical Subject Index Listing

PROBABILITY
Procedures for applying sequential probability ratio tests in analyzing checkout and support equipment
TR-3 c84 R69-12733

SUBJECT TERM | REPORT NUMBER | NOTATION OF CONTENT | CATEGORY NUMBER | *RATR* ACCESSION NUMBER

The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

S

PERSONAL AUTHOR INDEX

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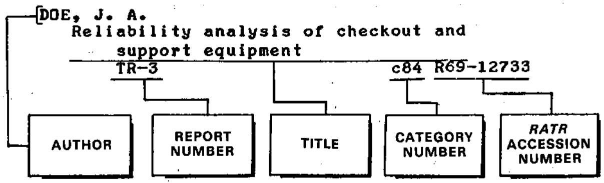

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REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 2

List of Report Numbers

This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB*, *STAR*, and *IAA*, respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 2

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This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each accession number is the category number for locating the abstract-review in the abstract section of *RATR*.

Reliability Abstracts and Technical Reviews

MARCH 1969

Volume 9
Number 3

R69-14281—R69-14330

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

RATR **ACCESSION NUMBER**	R69-12733 ASQC 844; 413	**ASQC CODES**
TITLE	General Equipment Company, Banville, Calif.	**CORPORATE SOURCE**
	RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT	**PUBLICATION DATE**
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	***TAB*** **AND** ***STAR*** **ACCESSION NUMBERS**
REPORT NUMBER	(TR-3; AD-629305; N69-15098) CFSTI: HC $3.00/MF $0.65	**SALES AGENCY AND PRICE**

RATR **ACCESSION NUMBER**	R69-12739 ASQC 814	**ASQC CODE**
TITLE	**SEMICONDUCTOR RELIABILITY**	
	Joseph A. Smith (Eastern University, Arlington, Penn.)	**AUTHOR AND AFFILIATION**
JOURNAL REFERENCE	*Electric Journal*, vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	***IAA*** **ACCESSION NUMBER**

RATR **ACCESSION NUMBER**	R69-12765 ASQC 773; 221; 823	**ASQC CODES**
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)	**AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968 8 p*	
	Available from Assoc. of Reliability Eng., New York: $1.00	**AVAILABILITY AND PRICE**
IAA **ACCESSION NUMBER**	(A69-12407)	

VOLUME 9 NUMBER 3

Reliability Abstracts and Technical Reviews

A Monthly Publication of the National Aeronautics and Space Administration

March 1969

80 RELIABILITY

R69-14305 ASQC 800
RELIABILITY—110 YEARS OF INCREASING COMPLEXITY AND VALUE.
Lee R. Webster (Radiation Inc., Reliability and Quality Dept., Melbourne, Fla.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference Sponsored by the American Society of Mechanical Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 90–93. 4 refs.

The evolution of the system approach is discussed, with this approach defined as a process used in generating a completely integrated system design to accomplish objectives which, in turn, result from needs. As the trend of technological development is clearly toward an increasing integration of the engineering and management functions, the use of the system approach can be considered the first major milestone in this trend. With the formalization of the system approach, the role of reliability engineering has taken on a more centralized role in the system design function. It appears that the system reliability and/or cost effectiveness model, supported by reliability engineering, can be made to function as an analytical tool which accurately presents the engineering and management status of a design effort. The view is offered that in the future reliability will remain a regulatory function in the sense of formulating and implementing an optimum system design and management strategy. M.G.J.

Review: This paper would have been more suitable for introducing the session in which it appeared than as one of the contributions toward that session. It probably had more value as an oral presentation than it does as semi-archival material. The paper is largely a loose, historical, qualitative narrative about the way man's engineering sophistication has been increasing over the past centuries. Managers and neophytes, i.e., those without technical background in this field, may find the paper of some value.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14283 ASQC 810; 720; 760
RELIABLE SOLDERING OF HYBRID CIRCUITS.
Howard H. Manko (Alpha Metals, Inc., Research and Development, Jersey City, N. J.).
Solid State Technology, vol. 11, Aug. 1968, 2 p. 4 refs.

The reliability of an assembly using hybrid circuits depends, among other things, on the quality of the interconnection between the hybrid circuit and the general assembly. In those cases where soldering is used, simple recommendations are made to ensure high reliability at low cost. Design considerations, materials selection, equipment, and final inspection methods are covered. Some of the more common pitfalls encountered in this industry are outlined, and methods are suggested to circumvent them. Author

Review: This is a very qualitative paper which discusses the general principles and basic techniques involved in soldering the hybrid circuits onto a printed circuit board. It mentions some difficulties associated with this soldering and inspection process. Several references are given for more detailed information. The main effect of the paper is to bring to the attention of managers and others the fact that these problems can exist and that soldering is not the simple process many of them think it is. Straightforward solutions to all of these problems are available in the references cited.

R69-14301 ASQC 815
WHAT IS WRONG WITH EMI SPECIFICATIONS?
Carl B. Pearlston, Jr. (Aerospace Corp., Los Angeles, Calif.).
The Electronic Engineer, July 1968, p. 66–70. 21 refs.

The problems associated with various electromagnetic compatibility specs for airborne equipment are discussed and graphically depicted. This historical development of some of the interference limits is illustrated, with the trend toward allowing increasing amounts of radiated interference from the test sample noted. The specific problems considered include the lack of agreement as to tolerable levels of radiated interference both for broadband and continuous wave (CW); the variations in allowable conducted broadband and CW interference limits; conducted interference limits from 30 Hz to 150 kHz; and the levels of susceptibility voltage which equipments are required to withstand on their power leads over a range of 20 Hz to 10 GHz. The radiated field susceptibility test levels for various specifications in use are compared. It is pointed out that these data show no correlation between the susceptibility and interference limits of any current military interference specification. Emphasis is placed on the need for a thorough study on the rationale and the correlation for interference and susceptibility test limits based on operational system experience. M.G.J.

Review: If a piece of electronic equipment is to be reliable, it must not be susceptible to malfunction because of the RF fields in its environment (radiated or conducted). In addition, if it is to make life easier for other electronic equipments operating in its own vicinity, then it must be careful how it pollutes the RF environment. Naturally, there are DoD specifications to control this electromagnetic interference (EMI) and the difficulty the author is complaining about is in part that there are too many such specifications with widely differing requirements and covering too few of the necessities. Unfortunately, this situation occurs in other fields as well, and is due at least in part to the lack of resources to resolve the problems in all areas at once, not to mention the difficulty of getting everyone to agree on what should be done. The author, again naturally enough, suggests that something be done about this (and the editor states that presumably the DoD is working on it), e.g., that realistic limits be developed for how much EMI the equipment can stand, and how the sources of this RF pollution should be allocated. Even though this research ought to be done, much of it probably never will be. One of the largest difficulties in writing a good specification on EMI is the same as that in writing almost any specification: there just is not and will not be enough knowledge to write an extremely well-based specification which can be vigorously defended against all critics. Many of the provisions will be somewhat arbitrary; unfortunately, their effectiveness is not known until after they have been used for an appreciable period of time. Those reliability engineers who are involved with electronic equipment should be sure that they understand the problems of EMI and are prepared to deal with them on the same basis as some of the difficulties more familiar to them.

R69-14306 ASQC 810; 813

THE ROLE OF RELIABILITY AND QUALITY ASSURANCE IN ADVANCED SYSTEMS.

A. J. Kullas and Ward Bishop (Martin Marietta Corp., Aerospace Group, Denver, Colo.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco. Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 94–99. 3 refs.

(A68-37603)

Discussion of a management view at some of the things learned from the reliability and quality assurance work in space programs. The experience is applied to advanced systems and its effects on the role of reliability and quality assurance in the advanced systems are discussed. A broad look is taken at the reliability and quality assurance programs and a detailed look at some of the problems. A theme is developed for the approach to future programs which is presented with supporting logic and data. The emphasis is on the management aspects of the reliability and quality assurance program and not the technical aspects. Author (IAA)

Review: This paper is concerned with the management aspects of Reliability and Quality Assurance in advanced systems, and emphasizes the need to establish disciplines which will result in the greatest engineering confidence in mission success for the resources expended. A one-paragraph reference to statistical confidence on p. 94 is too brief to make clear precisely what the authors mean, but it is only incidental, as the main concern is with engineering confidence. Advanced systems are usually produced in very small numbers. Thus it is important to identify potential problems and make significant decisions during conceptual phases. Reliability and Quality must be proven through early testing, involving the smallest piece parts up through the full system, during development and design phases. This paper is a clear and concise discussion of the subject, with the most important points in each section tabulated and/or numbered for easy assimilation. Illustrative charts and figures are included. The paper will be easy and worthwhile reading for those concerned with the management of Reliability and Quality Assurance programs on advanced spacecraft systems.

R69-14307 ASQC 810

THE ROLE OF RELIABILITY AND QUALITY ASSURANCE IN PROGRAM MANAGEMENT.

M. N. Olsen and W. H. Shaw (TRW Systems Group, Systems Engineering and Integration Div., Redondo Beach, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968, Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 100–107.

(A68-37604)

For maximum effectiveness, line reliability and quality assurance activities require coordinated central management from the program office just as do the other line functions more commonly associated with program office direction. To understand this, the paper first traces in the broadest terms the place of the assurance disciplines in the life cycle of a typical product. The focus is then narrowed to examine the work-package concept which brings the efforts of skill centers to bear on the program objectives. These objectives, generally stated, are the creation and supply of an end product which inherently and in fact satisfies expressed customer needs. The paper describes the work package mechanism whereby the reliability and quality assurance effort throughout the program is coordinated, budgeted and directed. Author (IAA)

Review: The authors introduce the topic indicated in the title by first discussing what a product is in terms of the processes that produce it, and in broad terms the roles which Reliability and Quality Assurance (R&QA) play in the management of those processes. They then go on to say that R&QA have the following roles in program management: contract interpretation, policy-making, planning, negotiation, monitoring, assessing, and reporting. They explain each of these roles in some detail. This makes for quite effective organization of a paper on this subject, and it is easy to read and to interpret. While some managers may differ with the authors' points (it looks as if R&QA have been assigned the role of complete program management), they will still find the paper worthwhile reading for the ideas which it contains. The discussion is well illustrated with figures which were apparently used as slides in the oral presentation.

R69-14308 ASQC 814

IMPLICATIONS OF RELIABILITY MODELS AND INDICES USED IN UTILITY POWER GENERATION SYSTEM PLANNING.

C. D. Galloway, L. L. Garver, R. J. Ringlee and A. J. Wood (General Electric Co., Schenectady, N. Y.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 112–118. 24 refs.

The models and indices employed in planning generation reserves for power systems are discussed, with consideration given to the effects of generating unit sizes, probability of forced outage, effects of interconnections, and deviations from forecasts. An overview is presented on the models and indices used during the past three decades as an indication of the data base available. The three vital problems for future planning of a generation plant are cited as long range load forecasting, capital requirement prediction for additions and replacement of generating plant, and assessment of risk of generating capacity deficiency. Results are given for several investigations on the effects of unit sizes, forced outage rates, and interconnection capacity upon the required reserve margin and the present worth of future capital requirements. Two examples are included to show how generation reliability models can be used in parametric studies to determine the influence of forced outage rate and unit size on system reliability and costs. M.G.J.

Review: An overview of the application of engineering economic analyses to electric utility planning is given in this paper. This is a substantive presentation which is well-illustrated with figures, outlines, and references. Those who are involved with cost effectiveness analyses for rapidly-changing commodities such as some aerospace items will view with envy the story which is presented. The electric utility industry, in general, has a large data base from which to operate, and has achieved an enviable reliability record. For instance, the authors note that the availability in the northeast sector of the country over the past decade was 0.9998. Some quotes are included in this paper from utility engineering economic papers of three decades ago which use such words as "effectiveness," "cost," and in general the quotes are typical of many recent ones in cost effectiveness. Some reliability indices explicitly appear in several figures and the discussion tells how they fit into the analyses, but no equations are shown. The authors note that the present worth method of economic analysis is the preferred one for utility power planning. This is a preferred method in general and is finding increases applications in commercial analyses in fields other than utilities, as well as in Government cost-benefit studies such as those in transportation areas.

R69-14309 ASQC 810; 612; 844

PROGRAMMING IS ALSO A RELIABILITY PROBLEM.

J. Sauter (International Business Machines Corp., San Jose, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 128–132. 13 refs.

The need for program reliability is emphasized via the example of a program error that caused unreliable operation of reliable hardware. Recommendations are offered for an approach to be taken in attempting to solve the problem. The need for future research before a tangible solution can be found is stressed. Author

Review: This is largely an exhortative paper. It contains a few general guidelines for action but no specifics. The general guidelines are well taken and undoubtedly are being put into effect in some places. Programmers have developed some techniques for improving the reliability of their programs, for example, flow charts and subroutining procedures. While it is tempting to agree with the author that much more money and effort should be spent on techniques to improve the reliability of computer programs, it is probably true that in many small cases, present procedures are the most cost-effective. The fact that each computer seems to have a personality of its own (small deviations from the performance it is supposed to have) makes the task of the programmer even more difficult. Some very large and complicated programs are accompanied by corresponding checkout programs; that is, various kinds of data are generated by the checkout program and compared with the answers given by the original program. Another source of difficulty in generating reliable programs follows the author's analogy to hardware reliability: when one pushes performance to the limit, one is likely to suffer a reliability debilitation. Similarly, when one pushes the efficiency of a program to the limit, it is likely to be less accessible to easy debugging. The development of a higher-level language, which itself can be debugged once and for all, will obviously allow programs to be simpler and thus presumably to have less chance for error.

R69-14311 ASQC 810; 871

RELIABILITY AND MAINTAINABILITY PROVISIONS FOR A RAPID TRANSIT INTERURBAN SYSTEM.

H. Hjortsvang and J. P. Van Overveen (Bay Area Rapid Transit District, San Francisco, Calif.)

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 153 166. 5 refs.

The considerations behind the reliability and maintainability specifications established for the San Francisco Bay Area Rapid Transit (BART) are discussed. Presently under construction, the BART will be a rail network with trains operating under automatic control at speeds up to 80 mph and minimum headways of 90 seconds. The general safety requirement is based on the fail-safe principle, which requires a careful failure mode analysis. Equipment reliability is discussed in terms of control and communication equipment; correlation between train delay and other inconveniences and subsystem reliability; degradation of train control system; magnitude of the delays; control equipment classified as to failure consequence; central supervision; the functional relationship of automatic train control and traction systems; environmental influences; relation between reliability and maintenance; diagnostic checkout; the specific separation of the servicing and inspection of the equipment, and of the repair and overhaul operation; and reliability of operation in the system. M.G.J.

Review: The emphasis in the forthcoming San Francisco Bay Area Rapid Transit (BART) system on schedule (average delay of 5 seconds), comfort, convenience, and safety have compelled the explicit consideration of reliability and maintainability factors. A sensible and appropriate program for such reliability and maintainability considerations is described in this paper. The concepts are the basic ones developed in recent years, principally in military applications; the new aspect is their application to the high-speed interurban rapid transit system. The paper does not go into much analytical detail but rather is generally descriptive and includes an overview of the BART system.

R69-14313 ASQC 810; 871

MAINTAINABILITY AND RELIABILITY CONSIDERATIONS FOR THE NEXT GENERATION SUBSONIC TRANSPORT.

E. C. Frost and A. B. Stacey (Lockheed Aircraft Corp., Lockheed-California Co., Burbank, Calif.)

In: Annals of Assurance Sciences: Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 177 182. 11 refs. (A68-37608)

Discussion of maintainability and reliability considerations for SST aircraft with a view to reducing costly maintenance delays and cancellations. It is suggested that the downtime cost for the L-1011 and the DC-10 aircraft will be nearly twice that of the B-707, and for a B-747 it will be more than three times the cost established for the B-707. Criteria are set forth for achieving minimum maintenance downtime. Several suggestions are given for increasing dispatch reliability: (1) fault isolation and incipient failure detection techniques can be improved, (2) system reliability can be improved, (3) component reliability can be improved, and (4) the minimum equipment list can be expanded. Computer programs which develop predicted maintainability and reliability values and provide printout of desired parameters are discussed. IAA

Review: This paper is an overview of efforts to obtain high reliability and maintainability in a forthcoming high-capacity commercial aircraft. The need for the high reliability and maintainability is a result of the extremely high down-time costs for such aircraft. The authors use the term "rambling thoughts" to describe their paper, but it is hardly so. Although nothing unique from a technical viewpoint is presented, the paper is nevertheless informative about a service used by many people. The reliability and maintainability gains which can be made with moderate efforts are sometimes surprising, yet on other occasions dramatic gains in reliability and maintainability such as those for some of the space and missile systems have required extremely large expenditures. However, since the high-capacity aircraft is a commercial commodity, the amount of money to be spent for improving reliability and maintainability is best determined by techniques of business investment analysis, once the safety requirements of the aircraft are met. The expenditures for reliability and maintainability would seem to be a large consideration in determining the optimal size of the aircraft, but this paper does not acknowledge or pursue this point. In a private communication the first author has commented on this as follows. "In fact, reliability and maintainability expenditures are not especially sensitive to aircraft size but are more a function of system complexity. Aircraft size, of course, is based on optimization of payload, range, power, passenger comfort and sometimes airport limitations."

R69-14319 ASQC 815; 813

INCENTIVE CONTRACTING—ITS IMPACT ON SYSTEM ENGINEERING AND RELIABILITY.

Walter D. Smith (Martin Marietta Corp., Aerospace Group, Denver, Colo.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Automotive Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 234–237.

(A68-37612)

Review of the effective utilization of incentive contracting to achieve program objectives, using the Gemini Launch Vehicle (GLV) as an example to show the interrelationship of the incentive provisions and their effect on the system design. Effective techniques by which in-flight reliability was achieved are presented.

IAA

Review: This paper describes an apparently very successful program on the Gemini launch vehicles, and the author classes it as "an example that reliability can be obtained without adversely affecting schedule and that high reliability actually saves money." The paper gives a very brief description of the kinds of testing and analyses which were performed ahead of time in order to implement this high reliability. There was apparently big emphasis on over-stress testing and the search for a cause of every failure. The paper gives only an overview of this program. The description of the incentive contract is not easy to understand, although the author sums up the incentive contract by saying that the customer was demanding in-flight reliability by a factor of 10 to 1 over all other considerations and also that the incentive contract clearly spelled out that both the manufacturer and the customer were after the same objective total success "in-flight." To have the customer and supplier both have the same objective is of course the main purpose of an incentive contract. From the description given in the paper, it appears that the contract was well and realistically written, that schedules were determined by people who had been there before, and that the reliability approach was determined by someone who wanted results rather than excuses.

R69-14320 ASQC 815; 814; 816

PURCHASING AND CONTRACTING PROBLEMS IN THE SYSTEM EFFECTIVENESS FIELD FOR WEAPON SYSTEM DEVELOPMENT (INCENTIVES).

J. Frederick Medford (Walter V. Sterling, Inc., Claremont, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 238–249. 10 refs.

The view is offered that there is a way to improve profitability for defense contractors and at the same time improve system effectiveness of weapon systems, based on the government's new approach to incentives, warranties, and guarantees which also promotes disengagement between the military–industrial complex. The Total Package Procurement contract influence in the development of new weapon systems is discussed. Given as examples are the C-5A aircraft contract (Air Force), and the FDL ship contract (Navy). Total life cycle costing and the basic cost effectiveness measure are explained. Maintenance and repair warranty clauses are also discussed, with emphasis placed on the proposed warranties for performance, maintainability, and reliability which are to be good for five years after acceptance of the vessel by the Navy. An incentive for maintenance and repair costs, including bonus and range of incentives and penalty, is proposed. M.G.J.

Review: A good feature of this paper is that it relates incentive contracting and cost effectiveness; that is, it presents incentive contracting as a means for achieving cost effectiveness. This is a solid paper containing thoughtful discussion, some timely references, and two actual examples (with emphasis on the one about ships). It also includes some ships' data. It would be of most value to those who must cope with incentive contracting and cost effectiveness in a substantive manner; namely, management and those analysts who are pursuing the details. For most technical persons in the Government/Industry complex, this topic is one of only background interest, as the subject will affect them indirectly. This paper brings out the implementation problems, mainly lack of experience, and difficulty of measuring cost and effectiveness indexes. The measurement problem appears as a large one with regard to measuring total lifetime costs of naval ships, as the military will operate and maintain the ships. Involved in the costs are thus the efficiency of the Government at this task, and the accuracy of their measures. It would hardly seem that contractors would be willing to risk much money on such a situation; however, it is difficult to judge how these things will come out. Although the paper does not cite any space-oriented systems such as rockets or satellites, incentive contracts are finding increased application there, and are working out satisfactorily. This outcome was not predictable some years back. The trend is apparent that large systems contractors doing Government business will have to compete in this environment, for a while anyway. The paper touches on a key point which Government persons seem to conveniently miss—that industries' cost effectiveness objective is to make the highest monetary return on investment according to the rules set forth by the Government. Thus industries' best cost effectiveness may not be the best cost effectiveness to the Government. Here is where reliability comes in. If it is profitable for industry to strive for reliable products or even for an optimum reliability level considering total life cycle support trade-offs, then industry will strive for this. However, if it is necessary for industry to produce unreliable equipment in order to compete successfully, as in the case for electronics in the years following World War II, then industry will do so.

R69-14321 ASQC 810; 813; 815

MANAGEMENT OF SYSTEMS EFFECTIVENESS ASPECTS OF SATURN V CONTRACTING AND PROCUREMENT.

Frank L. Hale and W. Bruce Dalrymple (Boeing Co., Aero-Space Div., Launch Systems Branch, Huntsville, Ala.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 250–255. 7 refs.
(A68-37613)

Description of the techniques for Apollo/Saturn V management of the systems effectiveness aspects of the contracting and the procurement of components critical to the Saturn V mission. One of the salient systems effectiveness parameters of the Saturn V launch vehicle is the overall reliability level which must equal or exceed 0.85. The Saturn V management plan and typical Saturn V contractor's program are described. IAA

Review: This paper describes the management techniques used for assuring systems effectiveness through the contracting and procurement on the Apollo/Saturn V program. The following are identified as the ingredients of a successful program: (1) highly motivated people to perform all critical activities, (2) mature management systems, (3) tightly managed surveillance and analytical activities, (4) rapid feedback of information and corrective action to improve the hardware, and (5) continual management visibility of all critical activities. These and other relevant points are brought out in a concise and readable paper which is supported by a number of illustrative figures. The seven references which are cited will be of assistance to those who wish to read further on some of these points. The paper itself will be very worthwhile reading for those who are concerned with the management of the contracting and procurement activities on future large government programs.

R69-14322 ASQC 810; 814
APPRAISAL OF GUARANTEED MTBD WARRANTY PROGRAMS.
Igor Bazovsky, Jr. (Boeing Co., Aerospace Group, Seattle, Wash.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 256–265. 9 refs.
(A68-37614)

Indication of a method of appraising warranty policies by determining their effect on the overall system lifetime costs. The approach is to calculate the expected restitution by using either the cumulative remuneration function or the incremental remuneration function. An attempt is made to illustrate some cost tradeoffs leading to system specification crystallization, or involved in actual design with guaranteed MTBF warranty programs. Some methods of evaluating the expected remuneration under different circumstances with some fairly general remuneration functions are presented as a necessary but only partial contribution to the cost-effectiveness optimization and tradeoff problem. IAA

Review: (The title is misleading in that the paper does not deal with the problem of actually guaranteeing the MTBF parameter. It deals instead with the costs of guaranteeing to compensate for failures.) Total lifetime costs are used as the basis for developing a variety of warranty equations. The various models result from different commodities with different intended uses. The situations are all hypothetical and no data or specific applications are noted. Reliability enters in, since typically some reliability index appears as a parameter in the warranty-cost models. Those readers who are interested in such currently-popular concepts as life-cycle costing and total lifetime costs will want to see this paper, as well as those interested in warranty and incentive concepts. The array of warranty-cost models presented in this paper illustrates why there is no such thing as a single cost model with general applicability. This paper is adapted from a thesis which most likely contains more detail than is presented here.

R69-14324 ASQC 810; 833
INTERCONNECTING RELIABILITY.
Carl H. Stuart (Amphenol Corp., Connector Div., Design Assurance, Broadview, Ill.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 278–285. 2 refs.

The techniques used in insuring and determining the repeated performance of electrical connectors are described. Six programs illustrating the techniques of reliability are discussed: (1) The design evaluation function is comprised of reliability engineers who have the versatility to combine information from different functions into complete empirical and mathematical analysis. (2) Three significant advances in quality assurance are described: an automatic contact retention device designed and built to perform the task of applying a force on the contact retention clip as directed by specification, an automatic pin contact sorting machine, and an automated mechanical device for socket contacts. (3) The Fields Applications Engineering function supplies training films, pattern indicators, and on the spot assembly assistance programs to correct misinterpretation of the assembly instructions. (4) Field failure data are provided to show the failure rates according to modes for two different airplanes. (5) Human factors studies are being initiated to prevent loss of reliability in connectors due to assembly. (6) Dynamic life tests are discussed in relation to establishing failure rates. M.G.J.

Review: This paper undoubtedly made a much better talk than an archival paper. It is an enthusiastic, largely qualitative presentation of items associated with reliability. Figure 7 is not labeled well; the data 1966 apparently refers to the 727 aircraft and 1963 apparently refers to the 707/720 aircraft. Figure 6 which gives some formulas for triple-classification analysis of variance serves no useful purpose since no numbers are involved (no one would look here to find this formula if he wanted it), and the discussion is not clear. (Apparently a sample difference between two contacts was detected but it was not statistically significant.) Figure 8, a failure-rate chart, is not clear until one realizes that the head of the last column (C-0) is C-zero, i.e., the number of cycles allowed for zero failures. All in all, few people will want to refer to this paper, even though they enjoyed the talk.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14288 ASQC 824; 844
Australian Aeronautical Research Committee, Melbourne. Dept. of Supply.
SOME THOUGHTS ON CUMULATIVE FATIGUE DAMAGE THEORY
F. H. Hooke Apr. 1967, 25 p refs
(ARL/SM-315; N68-22702) Avail: CFSTI

The concept of fatigue damage is examined with particular reference to the problem of accumulating damage from load cycles of different amplitude. A damage parameter is defined, which represents the state of a fatigued component at a particular stage, and a damage capacity which specifies its tolerance to fatigue cycling. The damage capacity distribution of a set of identical components may be defined in several different ways, one of which is in terms of life distribution. Some non-interactive damage accumulation rules are examined, including the simple Miner rule, a generalised Miner rule, and a generalised form of a concept due to Bastenaire, by which the resulting life distributions may be established. It is shown that the simple Miner rule requires constancy of distribution shape at all stress levels —a condition frequently not fulfilled in practice. In several varieties of step and program test, life distributions are predicted and compared with experiment. The predictions are satisfactory for program but not for step tests.

Author

Review: With an innocuous title such as appears on this paper, the author cannot be faulted for any lack of completeness. He is concerned largely with one-parameter theories of damage and with their logical consequences in terms of relative distributions at various constant stress levels. Some popular cumulative damage theories such as the Corten–Dolan theory are not included nor is the theory discussed by Heller and Heller in the paper covered by R68-13564 (because they do not deal with the distribution of fatigue lives). The application to some pre-existing experimental data is interesting although not definitive. The truth of two of the assertions is not at all obvious. The first concerns chance events producing the exponential distribution. If by chance event the author means a Poisson process, then of course the exponential distribution follows inexorably. If he does not, then his conclusion is incorrect. In a one-parameter damage theory, it is not obvious that a specimen which would be weak at one stress must be correspondingly weak at another, no matter how complicated that single damage parameter might be. In summary, this paper is for the theoretician and experimentalist doing research in the theory of cumulative fatigue damage rather than for design engineers.

R69-14289 ASQC 820

California Univ., Berkeley Dept. of Industrial Engineering and Operations Research.

RELIABILITY THEORY

Richard E. Barlow *In* Am. Math. Soc. Math. of the Decision Sci. 1967 18 p refs

(N69-70607)

Reliability theory is discussed in the context of closure under the formation of coherent structures. The most common structures for reliability consideration are identified as the series structures with Boolean structure function. Definitions are given for the coherent structure and the reliability function of the coherent structure. Theorems are stated and proved for the increasing failure rate average (IFRA) class of distributions. Bounds on failure distributions are also considered. It is pointed out that the IFRA failure distributions are theoretically attractive because of their closure property with respect to coherent structures, and that they possess an interesting graphical property which is useful in theoretical investigations.

M.G.J.

Review: This paper consists of 16 pages of notes pertaining to a lecture on Reliability theory, a topic to which this author and his associates have been principal contributors. A coherent structure and its reliability function are defined and illustrated. Some theorems regarding the increasing-failure-rate-average class of distributions are proved. The paper will serve a useful purpose for those who wish to get a quick picture of some of the developments in this field. For those who wish to pursue these matters in more detail, seven pertinent references are cited.

R69-14290 ASQC 824

Research Analysis Corp., McLean, Va.

ON THE MAXIMUM-LIKELIHOOD ESTIMATION OF FAILURE PROBABILITIES IN THE PRESENCE OF COMPETING RISKS

Charles Anello Feb. 1968, 29 p. refs

(Contract DA-44-188-ARO-1)

(AD-666400; RAC-TP-291; N69-11770) Avail: CFSTI

The paper is concerned with the statistical problem of estimating failure rates of a population exposed to several simultaneous hazards or risks. Two distinct models are discussed: (a) a model that is appropriate when the risk-specific hazard rates can be assumed constant over the study period, and (b) a model that assumes the risk-specific hazard rates are linear functions of time. For both models the method of finding the maximum-likelihood estimators is developed. The linear model situation includes a discussion of how a nonlinear programming procedure can be used to obtain estimates of the parameters. The paper investigates the statistical properties of these estimators using a suitable simulation technique.

Author (TAB)

Review: This report presents a good discussion of failure rate estimation when a population is exposed to several different independent risks. The approach is parametric and consideration is given only to the cases in which the failure rates are constant or, at most, linear in time. In the last section some Monte Carlo results are presented illustrating the potential bias of maximum likelihood estimators for small samples. These results are based on only thirty replications of the experiments for each sample size considered; consequently, the computed estimates of bias are themselves subject to considerable sample variation.

R69-14296 ASQC 824

A COMPARISON OF SOME OLD AND NEW METHODS IN ESTABLISHING CONFIDENCE INTERVALS OF SERIALLY CONNECTED SYSTEMS.

George J. Schick (University of Southern California, Dept. of Business Economics and Qualitative Analysis, Los Angeles, Calif.). *Journal of Industrial Engineering*, vol. 18, Aug. 1967, p. 489–494. 23 refs.

It is shown how component reliabilities at different or identical confidence levels can be combined, in serially connected systems, to find a system reliability at a chosen confidence level. Two primary approaches, approximate and exact, for calculating the confidence limits for system reliability from component data are discussed.

Author

Review: There are many difficulties with this paper. The first striking example is the unevenness of mathematical level. On the first page it is assumed that the reader knows about likelihood functions but yet the author explains in detail the product notation. The most blatant errors occur in the author's incorrect statistical usage. He continually confuses population parameters and estimates thereof. It is impossible to test (or form for that matter) a statistical hypothesis about an estimate of a parameter. In a similar vein, confidence intervals are treated unsatisfactorily. The author does not present an accurate account of the results in Madansky's paper, Reference 14 in the paper. Thus the reader interested in the mathematical details should refer to the Madansky paper. While the remaining portion of the paper is a more accurate presentation of results published by other authors, its only contribution is that of comparing the several techniques. In general, the reader should look to the referenced literature for more precise details. (Part of this paper appeared in the one covered by R68-13857.)

R69-14298 ASQC 824; 431

TRANSMISSION SYSTEM RELIABILITY EVALUATION USING MARK V PROCESSES.

R. Billinton and K. E. Bollinger (University of Saskatchewan, Saskatoon, Saskatchewan, Canada).

IEEE Summer Power Meeting, Portland, Oregon, July 9–14, 1967, Paper. 19 p 8 refs.

(IEEE Paper 31 TP 67-407) $1.00.

Basic concepts of Markov processes are discussed with respect to their applications to power system reliability and, in particular, to the two-state fluctuating environment respect for simple configurations. The results obtained by the Markov approach are compared to those obtained using an approximate method. Author

Review: This paper shows how the equations for the Markov process can be applied directly to reasonably simple situations of power system availability. The results in this paper are worthwhile reading for anyone doing theoretical work in this area. Since only the steady state probability (availability) is desired, the equations are quite simple compared to the total system of equations. Even in this situation, as the authors point out, numerical solution is necessary unless the case is quite simple. Not all of the mathematics was checked but it appears competent. (Except for the minor situation in the case of normal weather only, one should let $m \rightarrow \infty$ rather than $\lambda = 0$, $m = 1$, $n = 0$; in this particular situation, the two are equivalent but the first is what one really wants to do.) The comparisons the authors make with the approximate method introduced several years ago are of interest and the differences are shown to be important under some considerations, i.e., the approximation can be off by a factor of 2. In many situations, the error is not this much and since the original data are probably known only within a factor of 2 or so, the fact that the calculations are approximate introduces no serious error. The same principles, of course, hold true in aerospace engineering as in power systems engineering–except that in the former, if one knows the failure rate to within a factor of 2, he is doing extremely well.

R69-14299 ASQC 824

AUTOMATION AND REMOTE CONTROL.

V. V. Naumchenko

(Avtomatika i Telemekhanika, no. 10, p. 169–174, Oct. 1966.) Automation and Remote Control, no. 10, Oct. 1966, p. 1813–1818. 2 refs. Translation.

Two methods of estimating the average time of trouble-free operation of complex unrestorable systems in the presence of an arbitrary law of component reliability are examined. The first method consists in replacing the component reliability function p(t) by another function; it is not required that this function give a good approximation of the law of component reliability over the entire range of determination but it must satisfy certain conditions. Sufficient but not necessary conditions are given by a lemma. The other approach to estimating the life of complex systems leads to determination of inverse functions of p(t) and of the probability of trouble-free operation of a component. Used as an example is a system with a component-by-component loaded reserve whose component reliability is described by any law p(t). M.G.J.

Review: This paper lists two methods of approximating the integral used to calculate the mean time-to-failure of a system. The approximation techniques involve finding functions other than the exact one which are more readily integrable and which satisfy certain conditions. In the general situation, obviously, one may spend a considerable amount of time trying to find reasonable such functions. Nevertheless, the methods are of interest, both upper and lower bound approximations are given, and those doing theoretical work in this area should be familiar with the material. To make them useful to practicing design and reliability engineers, the suitable approximations would have to be found by theoreticians and then published in a form usable by engineers. The mathematics was not all checked but it appears quite reasonable.

R69-14318 ASQC 824; 882

MEASURING AND OPTIMIZING DORMANT WEAPON SYSTEM AVAILABILITY.

Norman E. Tipton (General Dynamics/Convair Div., San Diego, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 221–228. 2 refs.

Equations are derived for measuring weapon system availability as a function of deployed time (service life) and checkout frequency. Availability is defined as the probability that a system will be in an operational state at any random time. The equations for measuring availability include the measurement of availability when (1) the system is monitored continuously, (2) the system is checked at periodic intervals, and (3) the system is not checked out at any point in its deployed life. A graph is provided as an aid in rapidly determining the availability of nonchecked systems. A hypothetical post-boost propulsion system is presented, and its availability is determined using current dormant failure rate data. Changes in system availability as a function of checkout frequency are then calculated. Based on availability and maintenance cost data, an optimum checkout frequency is selected. From the analysis, generalizations are made that have applications to other weapon systems. Author

Review: This paper is concerned mainly with a realistic example; viz., applying a simple availability equation concerning missile checkout. The availability equation is presented at the beginning of the paper without much explanation or any references. Thus the reader is largely left to figure out for himself the basis of the equation. It is suggested that those who are curious about the source of the equation and want some orientation see the paper by Doshay and Shube, pp. 203–209 in the same Proceedings. Note that the availability equation is for a serial system of nonredundant items and if any redundancy is present, then this equation will change significantly. Some dormant and active failure rate data are presented for propulsion system components; such numerical values are always of interest.

R69-14329 ASQC 822

Systems Development Corp., Santa Monica, Calif.

FAILURE DISTRIBUTIONS WITH DECREASING MEAN RESIDUAL LIFE

Vrudhula K. Murthy and V. R. Rao Uppuluri 10 Oct. 1967, 20 p refs

(AD-661663; SP-2964/000/00; N69-70933)

It is well known that the class of distributions with decreasing mean residual life (DMR) contains the class of distributions with increasing hazard rate (IHR). The study of DMR distributions has received little attention in the literature. Starting with a random variable $T > 0$, which has all its moments, and with distribution function $F_0(x)$, a sequence of distribution functions with the following properties is constructed. (1) $F_0(x)$ is DMR implies that $F_k(x)$ is DMR, $k=1,2,\ldots$. (2) $F_0(x)$ is DMR implies that $F_k(x)$ converges either to a singular distribution or to an exponential distribution. (3) The members of the sequence $\{F_k(x)\}$ are all identically exponentially distributed if and only if for some $k \geq 1$, $F_k(t) = F_{k-1}(t)$. Author TAB)

Review: This report presents some interesting mathematical manipulations, but is totally devoid of motivation. In fact, one wonders why the particular sequence of distributions considered is of interest. It should also be pointed out that the author's use of the term "singular distribution" is somewhat nonstandard in that they mean "degenerate distribution." The "proof" of the final inequality is very confusing due to typographical errors and poor wording.

83 DESIGN

R69-14293 ASQC 830; 713; 844
DESIGNING TO COMBAT FATIGUE.
D. M. McElhinney (British Aircraft Corp./Operating/, Ltd., Weybridge Div., Weybridge, Surrey, England).
(International Committee on Aeronautical Fatigue, Symposium, 5th Melbourne, Australia, May 1967, paper).
Aircraft Engineering, vol. 39, Oct. 1967, p. 6–13.
(A67-42441)

Observations of design methods adopted to combat fatigue and its effects on the economics of civil transport aircraft. From the operational point of view, the increased structural weight required because of fatigue has an adverse effect on direct operational costs, as well as reducing the payload. Capital investments are balanced by benefits, the most important of which are passenger and crew safety, and an enhanced service life. In improving the structure to give greater confidence in the overall service life, direct benefits are the reduction in the amount of maintenance and inspection, delaying of the fail-safe repair threshold, and extension of the amortization period. Attention is given to the design, manufacturing, development testing, and operational stages. IAA

Review: This is a descriptive, tutorial paper concerning the economic and structural problems of fatigue in aircraft. It will serve that purpose well for beginners in the field and for managers who wish an overview of the situation. The paper helps to define the state of the art in the open literature, so that everyone has some idea of what everyone else is doing. Experienced designers can profit from this type of paper.

R69-14304 ASQC 831; 552; 821
SYSTEM ANALYSIS VIA PROBABILITY DIAGRAMS.
R. W. Stoffel (Martin Marietta Corp., Denver, Colo.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 82–89. 7 refs.

A detailed description is presented on the steps required for using the probability diagram as a graphical method of modeling the reliability of relatively complex networks. The method requires that the elements which comprise the network are statistically independent. A second constraint is that each possible state in which each element may exist must be expressed in terms of mutually exclusive probabilities. The five steps required for modeling with the probability diagram are cited: (1) construct the diagram, (2) determine which of the diagram cells result in each desired network state, (3) write a probability description for each desired network state, (4) simplify the probability description by algebraic methods, and (5) check the mutual exclusiveness of the generated functions by a numerical example. The advantages are cited as the ability to provide an exhaustive solution to the combinational probability problem, and a method of handling network elements which have more than one failure mode. A typical example of using the technique is included. M.G.J.

Review: This paper calls attention to using graphical probability diagrams for aiding in the structuring of reliability equations, with emphasis on applications to items with more than one failure mode. It is at an introductory level and would be of value mainly to persons such as those with little probability and statistics background who find themselves involved with reliability analyses. As the author notes, as a system becomes larger (and realistic) a level is reached where such diagrams are not feasible. It is always desirable for persons to whom this type of paper would be of interest also to see some standard introductory texts on probability and statistics, none of which are cited among the references in this paper. Another convenient type of diagram not cited in this paper and useful in a similar manner is the tree diagram. The part of the diagram of Figure 8 which is labeled "correct" is incorrect, as the lower B in the first column should have a dash over it.

R69-14315 ASQC 831; 824; 882
SERVICE LIFE PREDICTION PROGRAM FOR THE MINUTEMAN LGM 30 PROPULSION SYSTEM.
J. L. Myers and E. L. Moon (TRW Systems Group, Redondo Beach, Calif.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 194–202. 3 refs.
(A68-37609)

The life prediction studies and the overall approach to system life analysis developed in the Minuteman LGM 30 aging program are outlined. In the Minuteman, approach advance knowledge on aging behavior is essential for the assessment of operational readiness and the formulation of timely replacement and maintenance planning. The methodology for predicting service life includes (1) analytical procedures for identifying possible life limiting design features, (2) early establishment of experimental data, controlled environment aging programs at the material, component and full system level to provide advance information, (3) establishment of failure criteria whereby aging trend data can be interpreted in terms of system requirements, (4) standardization of trend analysis techniques to minimize engineering judgment, and (5) development of improved procedures for utilizing aging data. Each of these techniques is discussed, and the advantages are detailed. Author (IAA)

Review: This paper gives a summary of what appears to be a well-thought-out program for predicting degradation failures in some of the Minuteman solid fuel motors. One of the main efforts of this program is to get pre-production samples far enough ahead of time so that their degradation can reasonably be assessed before production of the motors is in full swing. The various phases of the program appear to be well planned, and the places where engineering judgments are made are clearly identified. The standardized procedure for extrapolating the aging data is not clear. It appears that the mean trend together with a tolerance interval (fraction of the population included within the lines) are calculated but that no account is taken of the statistical uncertainty in the mean line itself. For large extrapolations, this uncertainty can easily be larger than the tolerance interval. Those who are involved in programs of a similar nature will find the ideas useful and the references to more detailed treatments helpful.

R69-14316 ASQC 831; 824; 882

ADVANCED MISSILE MODELS AND METHODS FOR AVAILABILITY PREDICTION.

Irving Doshay and David P. Shube (Douglas Aircraft Co., Santa Monica, Calif.)

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 203–213. 5 refs.

Consideration is given to the need for establishing a course of action which may be used to minimize dormant failure effects and attain desired availability of a missile system with minimum maintenance costs. An example of how this is accomplished with the use of a simulation model is given, along with results of evaluation for various concepts. Analytical models are also considered, with hypothetical systems evaluated using computer mechanized programs. Results of the described availability analyses are presented in families of curves covering a wide spectrum of missile standby mean time between failures as well as possible checkout schedules. It is suggested that these data and/or techniques may be used to establish a minimum cost maintenance and checkout policy compatible with attaining desired system availability. Author

Review: A sense of realism exists in this well-done paper. Essentially, it is a discussion of simulation and analytical approaches for missile availability modeling. The appendix is a concise presentation of availability models featuring checkout considerations for missile applications. This appendix is a permanent reference item for persons interested in availability modeling, as it concerns some derivations for model simplifications as well as corrections to some availability models which were published some years ago. The applications of the analyses are for determining minimum cost missile maintenance and checkout procedures. Although the paper is apparently based on actual application, it does not cite what influence if any the analyses had on the actual operating plans. (The first author in a private communication has stated that they had a great deal of influence.) No data are presented, but this was probably because of security classification (the first author has subsequently corroborated this). Although not mentioned in the paper, the approximate availability models which are developed would be more feasible than the exact ones for utilization with literal optimization techniques for minimum cost while attaining some desired availability. If feasible, the use of the approximate availability models would, of course, be much more efficient than changing parameters and re-running simulations, as apparently was the main approach used here as well as elsewhere in similar studies.

R69-14323 ASQC 833

DESIGN FACTORS AFFECTING RELIABILITY AND PERFORMANCE OF MOLDED SOLID ELECTROLYTE TANTALUM CAPACITORS.

P. J. Christiansen, H. Nieders, and A. W. H. Smith (P. R. Mallory & Co., Inc., Indianapolis, Ind.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 268–271.

Design factors and construction details are discussed in relation to their effects on the performance and reliability of transfer molded plastic encapsulated solid electrolyte tantalum capacitors. It is concluded that highly reliable capacitors can be produced if the following points are taken into account: (1) Initial careful consideration must be given to the device's mechanical and dimensional compatibility with the finished end product packaging. (2) Materials compatibility must be assessed, along with the chemical, electrochemical, and physical reactions between materials. (3) End product environmental use has to be investigated and a relationship developed between optimum product performance and actual use conditions. (4) Further correlation work is needed to develop short, quick, relevant test techniques usable for inspection, production process controls, and fast evaluation of new materials or contemplated changes of production techniques. Author

Review: This paper is only of general interest to those who are not engaged in the manufacture of similar capacitors, since it deals only slightly with the reliability discipline per se. The description of the capacitor development is not too clear, especially with regard to the encapsulating resins. On page 269, it is concluded that the encapsulating resins will not provide the required capacitance stability, and on page 270, it is stated that the encapsulating resins provide a comparatively good moisture barrier but the latter is the item that determines capacitance stability. The hazard rate of 1%/1000 hr is high compared to semiconductor hazard rates. No detailed discussion of the hazard rate calculations is given nor are any derating factors given (MIL-HDBK-217 is referenced). From the two conditions at which tests were run and from MIL-HDBK-217, it was concluded that half of the failures at the high humidity level are caused by the high humidity. In the absence of any other information, this is perhaps the best that can be done but MIL-HDBK-217 is at best a very rough guide. All in all, the paper is of passing interest; those engaged in the manufacture of similar capacitors may find some of the discussion useful.

R69-14326 ASQC 832; 844

MEASUREMENT OF HUMAN ERRORS WITH EXISTING DATA.

K. Inaba and R. Matson (Serendipity Associates, Chatsworth, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 301–307.

An error analysis technique is developed, based on the vast pool of available maintenance data. The data were found to be particularly useful in isolating the basic source of problems. Emphasis was placed on first determining the major changes of states required within the maintenance system, and on objectivity, consistency, and efficiency of analysis. Four types of errors are identified and defined: (1) erroneously declaring state of system or equipment as bad; (2) erroneously declaring state of system or equipment as good; (3) erroneously isolating the cause of a problem; and (4) damaging or incapacitating the system. A functional flow logic diagram of a maintenance system is included, which depicts all the major functions and provides sufficient guidelines for tracing errors. The extent to which system performance can be improved by reducing the error rate is graphed. M.G.J.

Review: There is a sparsity of references on the quantification of human factors in reliability, as compared to the vast number which are hardware-oriented. This paper will thus be of value. It contains some concepts which are more advanced than those usually found in discussions on the quantification of the human factor in reliability, and some associated data are presented. It treats certain detailed aspects of reliability analysis which are often not explicitly identified. Possible applications of the findings are as inputs for reliability and maintainability prediction models and as a basis for corrective actions to reduce human errors of the types considered. The paper is well illustrated; however, no references are given and presumably a related report will be forthcoming.

R69-14327 ASQC 832; 863
POTENTIAL DAMAGE EVALUATION—A METHOD FOR DETERMINING THE POTENTIAL FOR HUMAN-CAUSED DAMAGE IN OPERATING SYSTEMS.
Paul. F. Muller (Lockheed Missiles and Space Co., Missile Systems Div., Human Factors Staff, Sunnyvale, Calif.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 308–311.

A human engineering study of the Polaris logistics system was initiated in order to determine the causes of damage to missiles and missile components. The logistics flow by function–facility was determined; 45 functions were selected for evaluation and detailed step-by-step charts of the basic operations performed in each were prepared. These charts were transferred to potential damage evaluation sheets (PODAMEVASH). Five experienced persons, knowledgeable in given operational areas, were selected as raters. They were given the applicable PODAMEVASH and written instructions to rate those steps of which they had knowledge as high, medium, or low in potential damage. The completed ratings were then totaled for each of the three ratings for each step. Any step total which did not equal 10 was arithmetically transformed to equal 10. The ratings were then summed by steps and graphs. A cutting score was selected and only those steps above that score were selected. Human engineers then investigated high damage potential steps; numerous instances of poor man–machine interface and inadequate and improper procedures were found. Author

Review: This is a short paper which describes an apparently very worthwhile project in applying the human factors discipline to the reduction of handling damage. Unfortunately, the paper is not clear when discussing the quantitative aspects of the rating. The biggest unclear point is whether each step winds up with a single number (a weighted average of the high, medium, and low ratings) or three numbers (one each for the fraction of high, medium, and low ratings the step received). Thus the paper is useful largely for the kind of thing it shows can be done and the general method used for achieving it. It is always wise, as this project typifies, to try and make the biggest improvement for the least expenditure of resources that one can at first. As the author points out, among other things, this involves consuming the least possible amount of resources in finding out what the trouble is and most of the resources in actually solving the problems.

R69-14328 ASQC 832
EFFECTS OF ASSEMBLY ERROR ON PRODUCT ACCEPTABILITY AND RELIABILITY.
L. V. Rigby and A. D. Swain (Sandia Lab., Systems Reliability Div., Albuquerque, N. Mex.).
In: Annals of Assurance Sciences: Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1958, p. 312–319. 10 refs.

Data from inspection reject tags were used to determine the probability that human errors would occur in the assembly of two different electronic modules. Consideration was given to the probability that these errors would (1) cause functional failure if not detected in acceptance inspections, (2) cause rejection of the modules in those inspections, and (3) remain undetected to cause future functional failure of accepted modules. Although the inspection process was effective in removing nearly all defects, it was not nearly as efficient as it could be, as manifested by a near-zero correlation between probabilities (1) and (2). The results suggest that real improvements in inspection efficiency and further reduction of the already low functional failure rates of units passed by inspection could be expected from corrective action based on systematic human error analysis. The need for such analyses is demonstrated, techniques whereby they can be accomplished are presented, and some improvements that could result from the applications of these techniques are discussed. Author

Review: Another contribution is made by the authors of this paper as they continue to pursue and to report on the area of human error in manufacture and its effect on reliability. This contribution is not a breakthrough, but a step forward in concepts, definitions, and data; it will be useful to apply and to build on. Since explicit consideration of human factors is not extensively included in conventional reliability analyses, this paper deserves the label of a contribution. The models and data restrict themselves to manufacturing, inspecting, and testing. There is no attempt in the paper to bridge the gap between this and conventional reliability analyses. However, the concluding discussion in the paper does give some sage advice from the practical action viewpoint: "As components become more reliable, improvements in reliability via component design and selection are more difficult to achieve; and efforts to improve reliability may be more successful if they concentrate on reducing the effects of assembly errors."

84 METHODS OF RELIABILITY ANALYSIS

R69-14281 ASQC 844; 775
DYNAMIC MECHANICAL COMPONENTS EVALUATED WITH INFRARED OPTICS.
William J. Quinn (Hughes Aircraft Co., Research and Development Div., Culver City, Calif.).
Space/Aeronautics, no. 4, Sept. 1968, p. 88, 90, 93.

Infrared radiometry techniques are discussed in relation to measuring surface temperature variations to provide a reliable indication of the performance of dynamic mechanical components. Unless the emissivity of a surface is known, IR radiometry is impossible without a black-body radiation source as a reference. Therefore, a portion of the component is turned into a black body either by applying a special black paint of high absorptivity and emissivity, or by machining a small, nonreflecting cavity into the surface under study. The instrumentation used for the IR radiometry is arranged around a microscope unit that combines a visible-light channel and an IR channel. The device being monitored is mounted on a traversing table with micrometer adjustments for two orthogonal axes in a plane perpendicular to the target-detector axis. The table permits precise tracking across the target surface for the rapid determination of thermal profiles. Typical bearing and face temperature profiles of a servomotor, using black body cavities as references, are given as examples of the technique. M.G.J.

Review: The advantages of infrared radiometry in evaluating dynamic mechanical components are pointed out. The mechanism by which temperature is measured by infrared radiometry is indicated. This brief paper will serve a useful purpose in calling attention to the value of this method for the qualitative evaluation of complex assemblies. Its possible suitability for the detection of fatigue cracks in dynamic components is worthy of further investigation.

R69-14282 ASQC 844; 820

Advisory Group for Aerospace Research and Development, Paris (France).

THE POTENTIAL USE OF MATHEMATICAL MODELS IN MATERIALS DATA PRESENTATION WITH PARTICULAR REFERENCE TO THE AGARD MATERIAL PROPERTIES HANDBOOKS

A. G. R. Thomson Oct. 1966, 41 p Presented at the 23d AGARD Meeting, Paris, 4–12 Oct. 1966.

(AGARD-510; N68-21153) Avail: CFSTI

Creep data in the AGARD material properties handbooks are reviewed and means are discussed of improving the scope and usefulness of the data. Ambiguities in the definitions of creep extension and other material properties and the need for consistency in the presentation of data are discussed. Advantages of using mathematical models for the correlation and presentation of various kinds of material properties data are considered. Author

Review: The title of this monograph is more general than the material inside. The major emphasis is on the presentation of creep data for metals although some of the other properties of metals are treated. The material will be of value to those who are concerned with acquiring enough data for use in reliability analyses especially of the "stress-strength" type. Little mention is made in these models of the statistical scatter except that it interferes with the orderly analysis and acquisition of data. Any models which are developed should distinguish between median parameters and some appropriately low level of probability of failure. Just how to do this will be almost as difficult as getting the median data in the first place, but it is important. When the data selected for publication are screened by the rule of plausibility, there is always the danger that very valid and accurate data will be dismissed because they do not agree with the generally accepted range of values. It is unfortunate that this kind of report is so late in finding its way into wide distribution; one of the crying needs designers have is for applications-information on the materials they would like to use. The situation is becoming worse, undoubtedly due to the rapid introduction of newer materials, especially the very high-strength ones whose properties other than tensile strengths are likely to be difficult to find. The paper itself is well written and anyone involved in the administration of this kind of task should certainly be aware of this publication. In a private communication the author has stated that replies to the questionnaire (included in the report) are still most welcome.

R69-14284 ASQC 844; 836

CONTROLLING CORROSION.

Jack Schmidt (Lockheed Aircraft Corp., Product Evaluation Section, Sunnyvale, Calif.). and Ronald G. Neswald (Conover-Mast Publications, Inc., New York, N. Y.).

Space/Aeronautics, no. 5, Oct. 1968, p. 64–73. 12 refs.

The costs of over $12 billion and the loss-of-use revenues due to corrosion problems are discussed, in relation to the need for basic research into the actual mechanisms of intergranular and stress corrosion. Electrochemical models of corrosion, which explain the phenomenon in terms of an anodic region from which metal is lost and a cathodic region toward which material is drawn, are examined. Methods of designing around stress corrosion are assessed, along with techniques for minimizing residual stresses. Variability in corrosion test results is considered a major problem. The question of corrosion versus ultimate strength is treated in the context of metallurgical processing. M.G.J.

Review: The discipline of reliability has three main functions: (1) predict life in the presence of uncertainty, (2) extend that life, and (3) reduce that uncertainty. This paper on controlling corrosion deals with the first two aspects. It is a paper designed to bring forcibly to the attention of the reader (hopefully both managers and designers) the fact that corrosion has both economic and safety aspects which an intelligent far-sighted management will consider in all phases of the product cycle. It seems that designers and/or management are usually incapable of optimizing in the presence of more than a very few constraints. To rectify this, various kinds of design reviews have been instituted to make sure that the oft-neglected constraints are in fact considered. One difficulty of this procedure is that the designer is virtually forced to become a front man for a myriad of specialists and is unable to function properly in this situation. It may be that our traditional methods of design will have to be changed to overcome this problem. The authors very wisely point out that it is not very satisfying to own an extremely efficient vehicle that does not work. This is one of the traditional battles that good reliability engineers have to fight, i.e., force management to state its views on trade-offs between performance and availability/reliability. The authors also fruitfully finger the new breed of stress analysts and high-strength alloys at their disposal as unwitting culprits in causing corrosion problems. This article is not difficult to read nor overly-jargonized, so that it gives to the non-metallurgical specialist an excellent appreciation for corrosion difficulties, especially stress corrosion, and the kinds of things that are being done to inhibit corrosion. There are two important aspects to inhibiting corrosion during the design phase (as with most reliability efforts): (1) do as well as we now know how and (2) push the state-of-the-art. It is the first category where reliability/metallurgical engineers and design reviews can have their greatest impact. It is an area also where management needs to devote a greater share of its attention, because employees are usually reasonably adept at giving the same kind of priority to problems that management *really* wants. The basic tool of reliability is essentially "infinite attention to detail." This paper is a good exposition on one set of those details. Designers and managers should be aware of its contents. A valuable help for designers is the selected bibliography at the end of the paper just in case they should become converts.

R69-14285 ASQC 844

FAILURE ANALYSIS: KEY TO MORE RELIABLE SEMICONDUCTORS.

Michael D. Emelianoff (Transitron Electronic Corp., Wakefield, Mass.).

The Electronic Engineer, no. 10, Oct. 1968, p. 49–56.

The basic equipment needed to set up a failure analysis laboratory is discussed in terms of requirements for electrical testing, visual examination, environmental testing, hermeticity testing, decapping facilities, a chemical laboratory, metallurgical and microsectioning facilities, and photographic facilities. A generalized procedure for transistor failure analysis is graphed. It is pointed out that failure analysis consists of both non-destructive and destructive tests and that the sequence in which they are performed is critical. The typical causes of failure are identified as misapplication, manufacturing imperfections, and mishandling. The need to thoroughly understand device operation, technology, and physiochemical properties as a step toward further product improvement is emphasized. M.G.J.

Review: This is a good paper on failure analysis of semiconductor devices; it is not a manual for performing each step, but rather a listing and explanation of the steps. It should be emphasized that on as-received commercial material, many of the tests will not need to be run since the failures may be reasonably obvious. The check lists in this paper are good and are in a form easy to use. Not all analysts agree on the exact details, so that the charts need not be followed slavishly. An important point brought out by the author is that if failures are generated during a test, one needs to be very sure that the test equipment itself is not causing these failures because of actual operating conditions' being different from the nominal intended operating conditions. The statement "Many engineers blame all failures either on poor quality assurance equipment or on unrealistic testing procedures" is not quite accurate. They tend to blame the failures on poor quality assurance procedures, and that covers two of the three main causes of failure. That such is the case is attested to by many articles written by users of these devices. The equipment for setting up a failure analysis laboratory is asserted to be quite expensive but no estimates of this cost are given in the paper.

R69-14286 ASQC 844
WHY RELAYS FAIL: PLAYING SAFE CAN BE DANGEROUS.
John L. Latour (Associated Testing Laboratories, Inc., Special Projects, Wayne, N. J.).
The Electronic Engineer, no. 10, Oct. 1968, p. 69–72.

The most common troubles in relay operation are cited as contact wear-out, make–break problems, low current switching, bounce, sticky contacts, inductive load effects, and insulation breakdown. Each of these problems is examined to show why published relay specifications for worst case conditions frequently fail to indicate performance in an actual operating system. Critical criteria in either buying or custom-designing relays for a particular application are defined as (1) determing the performance needed under system conditions, (2) deciding which of these conditions are really important in the application, and (3) testing, by subjecting the relay to actual system conditions and looking for changes in the relay's performance. M.G.J.

Review: The ubiquitous relay often gives designers and users trouble because the worst-case conditions do not come at either end of a rating but somewhere in between. This is the reason one has to be very careful when applying the theory of derating to relays. The severity of exposure may be increased by a nominal derating. This paper explains again to engineers why this is so. It does not list all of the difficulties one can experience with the relay but it does list many. Designers should be familiar with the contents of this article. Relays offer many advantages in design over the semiconductors that one might otherwise use and thus are often a good choice if they can be applied well. The relay industry is working on the problem of adequately specifying relay performance and characteristics, but this is a difficult and argumentative task. Nevertheless, as this article shows, it is one to which more attention must be immediately devoted if more and more engineers are not to be converted away from relays toward substitute devices.

R69-14294 ASQC 844; 775
THE IMPORTANCE OF SERVICE INSPECTION IN AIRCRAFT FATIGUE.
J. A. B. Lambert (Hawker Siddeley Aviation, Ltd., Hatfield, Herts., England) and A. J. Troughton (Hawker Siddeley Aviation, Ltd., Woodford, Essex, England).
(International Committee on Aeronautical Fatigue, Symposium, 5th, Melbourne, Australia, May 1967, paper.) Aircraft Engineering, vol. 39 Oct. 1967 p. 14, 17–20, 25–28, 31, 32.
(A67-42442)

Examination of the advantages of fail-safe design and present nondestructive testing techniques, and the importance of facilitating inspection at the design stage. All the available nondestructive testing (NDT) methods for aircraft structures in service, including visual methods, magnetic crack detection, X-ray methods, eddy-current detectors and the use of ultrasonics, are reviewed. The limitations and effectiveness of each method are discussed and are illustrated by various examples from aircraft in service. It is considered vital in a fail-safe aircraft to design a structure which can genuinely be inspected visually. It is preferable that the design of the stressed skin structure should be kept simple, relying primarily on low crack-propagation rates to achieve a fail-safe structure. The use of safe-life stress levels for fail-safe structures to decrease inspection is considered, together with the economic use of safe-life features in a fail-safe design. IAA

Review: This is a cross between a tutorial and an argumentative paper. The authors are presenting in a tutorial manner a point of view which is controversial. The presentation is effective, avowedly partisan, and usefully tutorial. This is not to say that everyone will agree with all of the conclusions reached, but it helps to get the reasoning down in print. While early in the paper, the authors dichotomize safe-life versus fail-safe, later they point out that it is partly a matter of degree and that many structures are fail-safe even though deliberately not intended to be so. Further, the designer of a safe-life aircraft can intentionally build in many fail-safe elements. By this means, he can probably design to somewhat higher probability of failure of some elements. The discussion of non-destructive test methods is conventional and worthwhile. A newer inspection method now appearing is infrared transmission, although it is applied mostly during developmental phases. The authors wisely put extreme stress on making critical parts of the aircraft readily available for easy inspection and on eliminating design and fabrication techniques which encourage corrosion. It should be pointed out, though, that the exactness of the discussion in this paper belies the tremendous uncertainties involved in designing an aircraft, especially those uncertainties concerning ignorance of failure modes and mechanisms. These appear all too frequently (from a user's viewpoint) on both commercial and military aircraft. This paper was also presented at the 5th I.C.A.F. Symposium "Aircraft Fatigue—Design, Operational and Economic Aspects," Melbourne, Australia, 22–24 May, 1967, and is available in pre-publication form as N68-27849.

R69-14295 ASQC 844
RELIABILITY CHARACTERISTICS OF INTEGRATED CIRCUITS.
B. Tiger and D. I. Troxel (Radio Corp. of America, Defense Electronic Products, Central Engineering, Camden, N. J.).
Microelectronics Comes of Age – Symposium Summaries, 1967 Western Electronic Show and Convention, San Francisco, Aug. 23–24, 1967. Convention sponsored by the IEEE Group on Parts, Materials, and Packaging. 1967, 4 p. 3 refs.
(MES-20)

Summary data are presented on a study conducted to identify the significant factors relating to reliability and effectiveness of integrated circuits as used in equipments and systems, and to formulate techniques to relate these factors in a quantitative evaluation of the reliability of integrated circuits in system applications. An evaluation of the results indicates that reliability of suitably used integrated circuits, rather than being related to degradation, is much more dependent on (1) screening effectiveness (2) the failure mechanisms which exist in field use units, and (3) the life distribution and environmental susceptibilities of the units which have these failure mechanisms. Author

Review: This paper is a very brief outline of the work done by these authors and reported elsewhere (as mentioned in the text; see, for example, R68-13838 and R68-13914). The results are somewhat controversial in that they differ from those also presented in the literature, although these authors are by no means alone in their viewpoint. One of the difficulties in presenting this viewpoint, viz., a large population of microcircuits consists of mostly good items with some defectives, is that the English language tends to be imprecise. Therefore many sentences wind up not being assertions but definitions of some of the terms involved. It is difficult to write what one really means, and the result often loses impact if one has done so. Examples of this difficulty are the following: (1) "Failure occurs when the applied stress level exceeds the strength capability of the device." This sentence defines strength capability. (2) "The good units fail only if and when overstressed." This defines either good units and/or overstressed. Developing this concept into a clear precise theory is a difficult task, but the authors have made a good start on it.

R69-14297 ASQC 844; 884

A METHOD FOR CALCULATING TRANSMISSION SYSTEM RELIABILITY.

Stephen A. Mallard and Virginia C. Thomas (Public Service Electric and Gas Co., Newark, N. J.). *IEEE Summer Power Meeting, Portland, Oregon,* July 9–14, 1967, Paper. 14 p. 8 refs.
(IEEE Paper 31 TP 67-501) $1.00.

A method applying probability techniques is presented for analyzing the reliability of a transmission system. The method considers generation and transmission equipment performance, weather conditions, load cycles, generation dispatch, interconnections, and the effect of scheduled outages. A mathematical model was developed to simulate the operation of a transmission system and to evaluate reliability. This model was applied to study several specific portions of a system. The reliability of the transmission supply to several stations and the reliability of the station supply to low voltage buses are calculated. Included in the analysis is the effect on system reliability of performing scheduled outages according to certain specified policies. Author

Review: This paper deals with what is often called Availability rather than Reliability per se (Availability is the fraction of time the system is up in the steady-state situation). The algebra was not checked in detail but appears competent. The paper is of value to aerospace reliability engineers because it is a good idea to see what someone in another field is doing with the techniques–one can look at them somewhat more objectively then. It is not clear from the paper how many of the parameters are calculated on the computer from a basic set of data, and how many must be figured afresh at each situation. In a private communication the first author has provided the following information: "The reliability calculations are performed on a computer for a two-path parallel system. The calculation of three-path parallel systems or the calculation of the frequency and duration of overload outages resulting from overlapping forced and scheduled outages are only partially computerized." Reference 2 (of the text) is an important part of the paper and should be available if the paper is going to be studied. As is usual (but nevertheless awkward) in the literature, the phrase at-random is used to imply a Poisson distribution or a uniform distribution. This paper will be of more value to Reliability engineers than to aerospace design engineers. The Availability techniques themselves appear to be very straightforward.

R69-14300 ASQC 844

SOME RESULTS ON OPERATIONAL INTEGRATED CIRCUIT RELIABILITY IN A PROTOTYPE DATA ENCODER.

T. H. Shepertycki (National Research Council, Radio and Electrical Engineering Div., Ottawa, Canada).
Microelectronics and Reliability, no. 7, Nov. 1967, p. 317, 318. 1 ref.

Operational reliability data, obtained during two year's operation of a prototype data encoder, are presented. The encoder contains a mixture of 433 screened and unscreened silicon integrated circuits. Two grades of military quality units, Types A and B, were used; both belong to the same generic family which is a low power digital RCTL line employing a triple-diffused planar structure in a TO-87 and TO-89 package. The Type B circuits were subjected to the following additional testing and processing conducted by the manufacturer: (1) centrifugal acceleration at 20,000 g perpendicular to the plane of the chip; (2) dynamic operation, burning in each unit at 125° C for 168 hr; and (3) radiographic inspection. Upon completion of the encoder, it was subjected to 220 hr of testing between −50° and +70° C. Five Type A and one Type B units failed. Since the encoder was integrated into the prototype model of the ISIS-A satellite, one additional Type A circuit failed. The time distribution of the failures with calculated failure rates is depicted. M.G.J.

Review: This very short note compares the failure experience of some screened circuits with unscreened circuits. Presumably, both types were allocated so that each kind (screened and unscreened) had an equal chance of appearing in a given location. The unscreened units had several very early failures. Beyond that, the performance has been about the same. This is not a definitive report in any sense, but it does contain useful data. The paper will be of more value to reliability engineers than to circuit designers.

R69-14302 ASQC 844; 851

SURVEY OF RELIABILITY PREDICTION TECHNIQUES.

C. M. Ryerson (Hughes Aircraft Co., Culver City, Calif.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 70–74.
(A68-37601)

Discussion of the accuracy that can be expected from various types of reliability prediction techniques and the timing for their optimum use. Comparison of similar systems, standardized typical system, comparison of similar circuits, active element group count, generic type part count, simulated operation, and environmental testing are among the prediction techniques discussed. Each technique has a preferred application depending on the stage of program completion, the prediction information available, and the intended uses of the prediction figures. The preferred application of each technique is described. IAA

Review: This is a tutorial paper and handles the topics contained therein well enough for the space available. Almost any experienced reliability engineer would have his own personal set of topics which he would like to see covered under the title of the paper; so it is difficult to fault the author for his particular choice. The paper will be helpful to the neophyte who is trying to get his feet firmly established on the ground. There are two deficiencies in the discussion of the selected topics. (1) Under reliability prediction accuracy, absolutely no numbers are mentioned. Thus, the novice has no idea whether a hazard rate prediction is good to ± 10% or to a factor of ten. (2) In several places, it is mentioned that the information to be used can be obtained by actual measurements. The novice may get the idea here that the hazard rates and reliabilities of many parts can be obtained by actual measurement in a reasonably short time. Unfortunately, this is not true for high-reliability parts, so that (as has been pointed out extensively in the literature and probably by this author elsewhere) one cannot *measure* the reliability of many of the parts.

R69-14310 ASQC 844; 881
POWER SYSTEM RELIABILITY IN PETROLEUM AND PETROCHEMICAL PLANTS.
George H. St. Onge (ESSO Research and Engineering Co., Florham Park, N. J.)
Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 133 141. 8 refs.

As selection of the optimum system for a particular plant requires comparison of reliability levels and costs of alternative designs, consideration is given to the reliability requirements of power supply sources whether purchased power or plant generation, the plant distribution system, and the power supply for process control systems. Information is presented on typical systems and design features. Sources of reliability data are cited which can aid the engineer responsible for the system design. Importance of equipment reliability, as well as the need for additional work in reliability data collection, is stressed. Author

Review: It is worthwhile for reliability engineers in the aerospace industries to consider the problems of reliability engineers in other industries and thus see what is going on in the wider world. It is common for many reliability engineers to feel that the DoD invented reliability, whereas, of course, many industries, notably the telephone and electric power ones, have been concerned about it for years (not only reliability per se but associated characteristics such as availability, maintainability, cost effectiveness, and life-cycle costing). This paper is largely concerned with what aerospace engineers call availability, this being made up of the reliability (time between failures) and maintainability (time to get on the air after a failure). The watchword, of course, no matter what the industry, is *infinite attention to detail*; this paper spells out many of those details which must receive attention in electric power systems. One of the often-neglected details, as became apparent in the Northeast power blackout, is that start-up power after a shutdown may depend on sources which are themselves shut down by the emergency. This should be especially checked out. The details requiring attention are given in as much exactness as the length of the paper allows. Redundancy is suggested as a method for improving reliability (a method well known to aerospace engineers). There is not enough explicit emphasis in the paper that in order for redundancy to have its full beneficial effect, the failure events must be statistically independent. This is in no wise as simple a calculation as it may at first appear, since, for example, failures may have a common cause which is not readily apparent. Needless to say, the planning of such a system as described by the author is not a job for a neophyte since, for example, many sources of power which we take for granted depend ultimately on a source of electricity. The plea for more failure data on hardware is certainly a familiar one to aerospace engineers. In general, while the plea is well taken, the results are often not forthcoming and one must do the best he can with what he has (perhaps this is the essence of engineering).

R69-14312 ASQC 844; 552; 874
EVOLUTIONARY GROWTH OF HELICOPTER MAINTAINABILITY, RELIABILITY, AND SAFETY.
Earl T. Ireton (Boeing Co., Vertol Div., Philadelphia, Pa.).
In: Annals of Assurance Sciences: Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 167 176.
(A68-37607)

Discussion of the data collection systems in use in the three military services concerning helicopter maintainability, reliability, and safety. An analysis is presented which shows the evolution of these factors in helicopter design, and identifies design improvements which will allow the establishment of significantly improved performance goals in these areas in future aircraft. Data are presented which show improvements obtained through in-service development and modification programs. Examples are presented to show how this background can be extended to future designs. In addition areas which need additional understanding are identified. The effect of these improvements on direct operating costs is indicated. I.A.A.

Review: Many graphical illustrations concerning maintenance, performance, reliability, safety, etc., and based on actual data provide the material on which this paper is based. It is a readable overview of helicopter systems analysis factors at the big-picture level. The trends concerning performance, reliability, maintainability, etc., are almost all in the desired direction. Of high interest is some discussion illustrating that the costs of increased efforts for reliability and maintainability during design are more than recouped through reduction in later manpower and spares support costs. Oddly, the only undesirable trend which is noted concerns accidents of commercial helicopter carriers. The accident rate chart shown concerning air carrier passenger service shows essentially no change for the past six years or so. In a private communication the author has stated that the sample size for commercial carriers was so small that he prefers to interpret the trend as a plateau, thus indicating a need for system's safety emphasis. An interesting conclusion from the overall data is that materiel failures are decreasing nicely, but pilot and human-factors failures are not (thus showing where more effort is needed).

R69-14314 ASQC 844; 541; 714; 716; 775
AGING CHARACTERISTICS IDENTIFIED BY INSTRUMENTAL ANALYTICAL METHODS.
J. A. Levisky and C. W. Rogers (Hill AFB, Service Engineering Div., Reliability Branch, Utah).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 186–193, refs.

The aging characteristics and suspected weak link materials of a variety of electrical, mechanical, and chemical components are presented. Attention is focused on the instrumental methods of analysis used to follow chemical changes at the molecular level. In the approach discussed, aging is treated as a slow rate chemical reaction process. Techniques for reaction rate studies are incorporated in these aging studies. The methods considered are infrared spectrophotometry, ultraviolet spectrophotometry, gas-liquid chromatography, X-ray diffraction, atomic absorption spectrophotometry, and particulate counter. Each is discussed in relation to the associated aging program. The variable data are examined statistically through regression analysis techniques. Confidence limits, correlation coefficients, and significance of slope statements are calculated. Lifetime predictions are made on the results of the statistical analysis. Author

Review: This paper treats what is often called physics-of-failure or reliability physics by the electronics industry. This involves the search for the underlying degradation and its causes. Three testing methods are explained: gas-liquid chromatography, atomic absorption spectroscopy, and X-ray diffraction, the major portion of the paper being given over to X-ray diffraction. The paper uses a minimum of jargon so that the explanations are accessible to the neophyte in these fields (a class into which most reliability engineers fall). It is especially pleasing that the authors have considered the statistical uncertainties in their extrapolations, a virtue very often found lacking in reliability engineers. The one curve which illustrates this statistical uncertainty is unfortunately not sufficiently descriptive for the untutored. Since the regression curve presumably gives the mean behavior of the samples and the confidence limits are those on the mean value, there is nothing on the curve which indicates the tolerance interval (that interval which will contain a certain fraction of the population). In most cases, this will be much wider than the confidence interval.

R69-14317 ASQC 844; 851

TESTING FOR SPACECRAFT RELIABILITY A MANAGEMENT OVERVIEW.

A. M. Smith and W. R. Waltz (General Electric Co., Philadelphia, Pa.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 214–220. 1 ref. (A68-37610)

Discussion of the optimal allocation of funds for typical spacecraft testing through the use of a "test to find defects" philosophy. Observations are drawn from five previous spacecraft programs which are suggested as useful guidelines in developing test policies that impact on the quality of spacecraft systems. Defect occurrence vs level of assembly, component vs system level testing, and qualification vs acceptance testing are discussed. It is suggested that tests and related test activities do, in themselves, generate defects. While design and workmanship type defects are about equal in magnitude in vehicles entering system acceptance test, tests are much more effective at finding the workmanship defect. As a result, the primary cause of equipment failures in flight seems to consistently be the design-caused defect. IAA

Review: The study of what went wrong in the past can often help us to avoid similar mistakes in the future and this paper is devoted to just that task. The situation is complicated by correlation's not being equivalent to cause and effect and several hypotheses' being able to explain the same situation. The authors' discussion is good and raises valid points which should be considered; but specifications are treated only in terms of system requirements (what the original top-level customer wanted). Specifications can also mean all the documents by which buyer and seller communicate and is used in that sense in this review (for example, it includes equipment requirements for intended end use, and test design and procedures). If all of the requirements for a subsystem or component are in fact specified, and if a test does in fact cover all of those attributes, and the proper dividing lines are known between good and bad, then the only kinds of defects that would be found in subsystem and system tests would be interface defects and those caused by previous tests. A specification as complete as this may often be much too expensive and time-consuming. But lack of completeness tends to generate the problems so well described by the authors. Part of the way to improve the testing situation would be to improve specifications. Difficulties in comprehension of the philosophy also arise from such questions as: If a design characteristic caused by incompleteness in a design only rarely causes a failure, is it in fact a design defect? Qualification tests (in the sense used by the authors) are deprecated and with good reason. It is wise to point out that qualification tests are most effective where there is very little variability and least effective where there is much variability in the system and its parts (this is one of the reasons why qualification tests are so ineffective with regard to the life of a system). In the discussion about escapes, it is not always clear whether the test specification for the part was violated or not and if not, whether it was because the test specification was too loosely drawn. The authors have performed a good service in raising the questions, providing data on them, and giving their initial discussion. This will be a very fruitful field for more work to be done.

R69-14325 ASQC 844; 815; 851

ELIMINATE POWER TRANSISTOR SECOND BREAKDOWN FAILURES.

John K. Morris (NASA, Marshall Space Flight Center, Huntsville, Ala.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 286–299. 3 refs. (A68-37615)

Consideration of second breakdown, one of the most critical parameters and failure modes that limits the power-handling capabilities of power transistors. Second breakdown is a condition where the output impedance of a transistor changes almost instantaneously from a large value to a small limiting value. An attempt is made to explain the characteristics of second breakdown, ways to specify transistor characteristics through safe operating areas to avoid second breakdown. With proper consideration of the second breakdown parameters, it is felt that a significant improvement could be attained in the reliability of systems using power transistors. IAA

Review: The significant message of this paper is that second breakdown failures have now been recognized to be of sufficient importance to warrant the inclusion of new tests in power transistor specifications and to be covered by additional standard tests in MIL-STD-750 (Military Standard Test Methods for Semiconductor Devices). These changes are only recommendations at present, but the course is clear. These changes or others similar to them will become a part of transistor ratings in the future. There has been sentiment growing in this direction for several years; this latest step forward must be welcome news to most transistor users. The first part of the paper illustrates the use of transistor Safe Operating Areas (hopefully to be furnished by the manufacturer in the future, but at present determinable by the user). The treatment follows that of Schiff and Wilson [1] and Turner [2]. The present discussion is more detailed and specific, and succeeds in communicating both the complexity of the problem and the soundness of the solution proposed.

References: [1] P. Schiff and R. L. Wilson, "Detection Techniques for Nondestructive Second-Breakdown Testing", IEEE Transactions on Electron Devices, vol. ED-13, Nov 66, p. 770–776. [2] C. Turner, "Carl Turner of RCA Explores Selection of Second-Breakdown-Resistant Transistors," EEE, vol. 15, Jul. 67, p. 82–95 (see R67-13498).

R69-14330 ASQC 844; 833
MICROELECTRONICS RELIABILITY.
Eldon C. Hall (M.I.T. Instrumentation Laboratory, Cambridge, Mass.). *Microelectronics Comes of Age --Symposium Summaries. 1967 Western Electronic Show and Convention, San Francisco, Aug. 23–24, 1967.* Convention sponsored by the IEEE Group on Parts, Materials, and Packaging. 1967, 4 p.
(MES-19)

Various techniques that can be used to evaluate a component using short term tests are discussed. It is pointed out that the results of these tests indicate strong correlation with the results of long term failure history. If a failure rate of less than .01%/1000 hours is a requirement, then extreme care must be taken at all levels of component manufacture and system assembly since the reliability of any system is dependent upon the design, assembly, and inspection of each element of a system. Maintenance of tight process controls, accurate failure analysis, and rapid feedback at each step of a process are cited as major requirements. As an example of the value of maintaining such controls, the processing procedure used on the microcircuit elements of the Apollo guidance computer is discussed. Figures depict the types of failure modes, the percent failures at incoming electrical test before stress tests, the percent failures following stress test, and the field failure rate data. M.G.J.

Review: This is a rather brief paper which has two major parts: (1) a discreetly harsh attack on the reliability information of microcircuits put out by manufacturers and (2) a brief description of the inspection screening procedures used for the Apollo guidance computer. The latter repeats information given by this author and others of his group in other publications --see for example, R66-12467 and R68-14068. The first part indicates that (a) reliability is not a prime consideration in the design and manufacture of microcircuits, (b) much of the advertising and descriptive literature is misleading in this regard, and (c) "let the buyer beware" is very appropriate for off-the-shelf items. The inspection screening philosophy expressed here is one of several extant in the field and has considerable merit. This is not to say that others do not have equal merit; for example, one group insists on using off-the-shelf items that are made in very large volume and then imposes its own screening procedures over and above the ones usually used by the manufacturer. As has been said many times in these reviews, there is a wide disparity between articles on reliability of microcircuits written by users and those written by manufacturers. In the discussion on accelerated-stress testing and consequent extrapolation to operating conditions, the author is pointing out that rarely is the mathematical model known well enough for making accurate predictions. There is a much more readily assessable uncertainty involved in such extrapolation, viz., the statistical uncertainty in the result. This is rarely calculated and often of tremendous magnitude so that even if the model were exact, the extrapolation is very uncertain.

85 DEMONSTRATION/MEASUREMENT

R69-14287 ASQC 851
ACCELERATED LIFE TESTING OF STATIONARY BATTERIES.
E. Willihnganz (ELTRA Corp. C & D Batteries Div., Conshohocken, Pa.).
Reprinted from *Electrochemical Technology,* no. 9–10, Sep./Oct. 1968, p. 338–341.

Details are given on the procedures used to test 500 cells at temperatures of 100° to 160° F and voltages between 2.10 and 2.50. The findings indicate that float operation of lead–calcium stationary batteries at an elevated temperature appears to be a useful tool in quality control of factories and for evaluating proposed changes in materials and design, without waiting 20 to 40 years for field results. Author

Review: Accelerated life testing is one of those human activities which generally fails to survive a nominally-rigorous examination but yet is done by virtually everyone because he needs to. This article describes a carefully-done series of tests which have extended down in severity to about one quarter the life at usual conditions. The points appear to lie on an Arrhenius straight line and so have been extrapolated on that basis to the low temperatures. There is remarkably little scatter. It is not clear if the points are averages, nor is there any indication of what the statistical scatter in the predicted life would be. (In a private communication the author has stated that in both Fig 6 and Table II the points are for single items.) It should be remembered that the Arrhenius equation predicts the life only for the particular failure mechanism under consideration. If others should come into play at longer lives, they may of course take precedence.

R69-14291 ASQC 851
ACCELERATED PRODUCT DETERIORATION.
Benson G. Brand (Battelle Memorial Institute, Columbus, Ohio). *Industrial Research,* Sept. 1968, p. 70–76.

Accelerated test methods, representative of the actual service environment to be encountered by the product, are discussed. It is pointed out that any testing program must be designed carefully to furnish needed information, must yield information that can be related to some phase of the product's performance under end-use conditions, and that interpretation of the results is a critical factor in the usefulness and reliability of the testing procedure. The assumptions involved when employing the rate process equations of Arrhenius or Eyring are defined, and the advantages of each are assessed. A balance between deteriorative influences and failure modes is considered necessary to obtain a satisfactory degree of reliability. Caution must be observed in order not to exceed any critical limit of the object being tested and thus produce failure by a different mechanism that would not occur at all in actual service. Procedures for corrosion testing are discussed, along with techniques for determining the expected service life for plastics and the new test methods developed for evaluating materials for the space environment. M.G.J.

Review: This is a qualitative article as befits the magazine in which it appears and is written to cover an extremely broad range of applications, although the examples are largely from chemical corrosion and paint film deterioration. The cautions about the difficulties of accelerated testing are well taken. For practical engineering systems, there is rarely any difference between the Arrhenius and Eyring models. Only in the most elementary chemical combinations does the Eyring model provide a clear superiority. In connection with extrapolating from the Arrhenius/Eyring models, the author omits (as is unfortunately customary in the literature) any discussion of the statistical uncertainty in such extrapolations. It is easy to infer from the figure that the temperature at 20,000 hours is easily calculated, whereas one may not know it within 20°–40°. The extrapolated life at a given temperature may not be known to within a factor of 100. The examples dealing with accelerated corrosion studies may not make sufficiently clear to some people that corrosion tests are some of the most difficult tests to truly-accelerate; for example, the corrosion of plating on automotive parts is extremely difficult to accelerate properly. If all one wishes is a brief qualitative background to get some feel for accelerated tests and the difficulties associated therewith, this is a good article.

R69-14292 ASQC 851
CHOOSING SILICON RECTIFIER DIODE LIFE TESTS.
David L. Mohn (General Instrument Corp., Semiconductor Components Div., Application Engineering, Hicksville, N. Y.).
Evaluation Engineering, no. 5, Sept./Oct. 1968, p. 10–12, 14, 16, 21.

The method of maximizing system reliability by early elimination of potential part failures through life test screening is discussed in relation to silicon rectifier diodes. Five life test methods are considered: (1) steady-state operational life test by system simulation or brute force method; (2) operational thermal fatigue life test; (3) elevated temperature half-sine wave blocking voltage life test; (4) elevated temperature dc blocking voltage life test; and (5) nonoperating (storage life test). Examples for typical applications of each method are given, along with the required equipment and cost comparison ratings. The major cost factors are identified as size of sample, i.e., number of test positions, equipment required for the test, and power usage. It is pointed out that by properly combining the entire life test program with both the appropriate parametric method(s) of life test and the straight operational, full stress, life test method, an optimized equipment/reliability program can be realized. M.G.J.

Review: This paper will be helpful to engineers who are responsible for selecting testing methods for silicon diodes and similar devices. Even though the article is brief, it gives useful information, especially to the newcomer. The paper is, as implied by the title, a series of tips, not an extended explanation; so it should not be considered complete.

R69-14303 ASQC 851; 875
SURVEY OF RELIABILITY AND MAINTAINABILITY DEMONSTRATION TECHNIQUES.
Gerald B. Cohen (Sylvania Electric Products, Inc., Electronic Systems Div., Waltham, Mass.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conf., San Francisco, Calif., July 14-17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 75–81. 7 refs.
(A68-37602)

Discussion of several reliability/maintainability demonstration tests, the variety of ways they may be specified, and the comparative advantages, and risks involved. The following types of reliability demonstrations are discussed: (1) sequential tests which assume an underlying Poisson process and allow for the selection of a variety of different test plans, discrimination ratios, and test environments; (2) tests designed for "one-shot" devices which operate just once and therefore do not accumulate significant operating time; (3) "on-paper" demonstration tests designed for equipments with unusually high MTBF requirements or for cases where the time available for demonstration tests is very limited; and (4) tests conducted while the equipment is in actual operation by the user. A similar discussion is presented for several maintainability demonstration tests which correspond to the reliability demonstration tests. IAA

Review: This is a short paper as implied by the title and is reasonably good for the amount of space allotted. The author makes the excellent point in several places that if any such tests are agreed upon, there should be clear understanding between both parties on all of the ground rules (including what happens when the outcome of the test is "not covered" by the ground rules). The discussion of the various kinds of tests is straightforward and usual. The author is perhaps too optimistic about the attitude of engineers toward maintainability—he obviously has not been adversely influenced by the horror stories expounded in some papers about poor maintainability. The discussion of tests for one-shot devices leaves much to be desired. It is not clear if the author is presuming (incorrectly) that all variables are Normally distributed (it turns out that he is not), but it is the only assumption he makes and it is without qualification. He further arrives at a probability for a defective of less than 10^{-6} which is completely outside the range of applicability of any such distribution. If this kind of test (the measurement of variables) is going to be performed contractually on one-shot devices, it would be wise to specify (all values derived from the sample) the number of standard deviations from the mean for the measured quantity. If one is going to assume the Normal distribution to calculate probabilities, there should be awareness of the applicability of Student's t distribution, especially if probabilities less than 10^{-2} are being considered. The author mentions that on-paper tests are not clean-cut and are often the subject of controversy. The description is perhaps too generous since they offer the possibility of downright cheating (and anything less than that) and would be expected to be very inaccurate unless comparisons were made from quite similar equipment made by the same company, etc.

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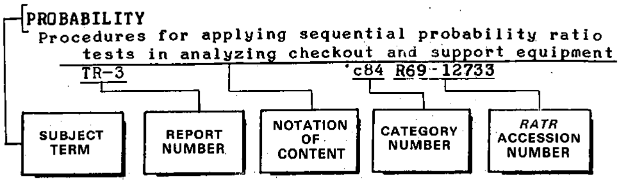

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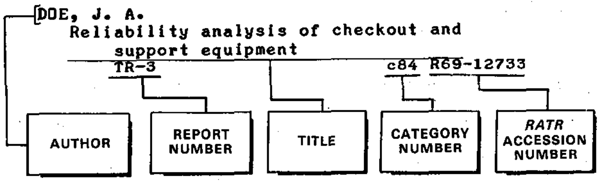

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The Contents of
Reliability Abstracts and Technical Reviews

The first section of *RATR* contains bibliographic citations, abstracts, and reviews. The items (each identified by an *RATR* accession number) are arranged in subject categories based on the first two digits of the codes developed by the American Society for Quality Control. The complete listing of these ASQC codes appears on the inside back cover. Examples of citations of reports, journal articles, and conference papers are shown below. The principal subject field of the item (and therefore the category in which the item appears in the journal) is indicated by the first ASQC code number; related subject fields are indicated by additional code numbers. The appearance of a *TAB, STAR,* or *IAA* accession number indicates that the item has been announced in, respectively, *Technical Abstract Bulletin, Scientific and Technical Aerospace Reports,* or *International Aerospace Abstracts.*

The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

RATR ACCESSION NUMBER
TITLE
AUTHOR
CONTRACT OR GRANT
REPORT NUMBER

R69-12733 ASQC 844; 413
General Equipment Company, Banville, Calif.
RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT
John A. Doe 23 Sep. 1968 27 p refs
(Contract NAS15-13411)
(TR-3; AD-629305; N69-15098) CFSTI: HC $3.00/MF $0.65

ASQC CODES
CORPORATE SOURCE
PUBLICATION DATE
TAB AND *STAR* ACCESSION NUMBERS
SALES AGENCY AND PRICE

RATR ACCESSION NUMBER
TITLE
JOURNAL REFERENCE

R69-12739 ASQC 814
SEMICONDUCTOR RELIABILITY
Joseph A. Smith (Eastern University, Arlington, Penn.)
Electric Journal, vol. 8, Apr. 1968, p 478–492.
(A69-12569)

ASQC CODE
AUTHOR AND AFFILIATION
IAA ACCESSION NUMBER

RATR ACCESSION NUMBER
TITLE
CONFERENCE OR SYMPOSIUM REFERENCE
IAA ACCESSION NUMBER

R69-12765 ASQC 773; 221; 823
TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES
Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)
Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p
Available from Assoc. of Reliability Eng., New York: $1.00
(A69-12407)

ASQC CODES
AUTHORS AND AFFILIATIONS
AVAILABILITY AND PRICE

VOLUME 9 NUMBER 4

Reliability Abstracts and Technical Reviews

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80 RELIABILITY

R69-14355 ASQC 800; 815
THE STATUS OF RELIABILITY ENGINEERING IN THE UNITED KINGDOM.
William P. Cole (G.E.C. (Electronics) Ltd., Aerospace and Defence Div., Stanmore, Middlesex, England).
(1968 Annual Symposium on Reliability, Boston, Jan. 16–18.) IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 117–121.

A survey of reliability activities in the United Kingdom with particular emphasis on the electronics industry is given. A survey of the status of reliability engineers is presented with a discussion of the training facilities that are available for them. Reliability processes relevant mainly to military procurement are given, detailing specific activities and the emphasis which the procuring agency places on such activities. Some of the differences between the United Kingdom and the United States on such matters of policy are highlighted. Author

Review: As a survey of reliability activities in the United Kingdom, this paper will be of general interest rather than of technical consequence to American readers. Section II, which deals with reliability requirements in military procurement and occupies over one-half of the paper, will be of the most interest. However, it is too brief and sketchy to provide more than general impressions. The other sections consist of some introductory remarks and some comments on the reliability of commercial products. (This paper was presented at the 1968 Annual Symposium on Reliability but does not appear in the symposium proceedings. Papers on the status of reliability engineering in Canada, France, and the Netherlands which appear in the symposium proceedings were covered by R68-13839, R68-13841, and R68-13842 respectively. Another paper appearing in the International Perspective section of the proceedings is "A new approach to reliability assurance testing in U. K.", by L. W. F. Lukis, covered by R68-13840.)

R69-14380 ASQC 800
SYSTEMS ENGINEERING—THE ROLE OF RELIABILITY.
Lee R. Webster (Radiation, Inc., Reliability and Quality Dept., Melbourne, Fla.).
Mechanical Engineering, vol. 91, Jan. 1969, p. 10–13 4 refs.

Approaches to product design are discussed with emphasis on system engineering and the increasing role of reliability analysis. The system approach to design is defined as a process used in generating a completely integrated system design to accomplish objectives which, in turn, result from needs. System effectiveness is given as the single figure of merit used in the design selection process to measure the ability of the design to accomplish the specified objectives. While the initial function associated with a formalized reliability effort was that of failure data collection and evaluation, it is indicated that with the formalization of the system approach, reliability engineering has taken on a more centralized role in the system design function. A sample of some of the more recently evolved reliability engineering functions not directly related to hardware design includes mission analysis to establish reliability and availability requirements; and system effectiveness and cost effectiveness analysis and optimization with respect to cost, weight, and volume. S.P.G.

Review: Although it has a different title, this paper is essentially the same as the one covered by R69-14305.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14335 ASQC 815
RELIABILITY REQUIREMENTS FOR SAFE ALL WEATHER LANDINGS.
L. A. Adkins, Jr. and M. C. Thatro (Lockheed Aircraft Corp., Lockheed-Georgia Co., Marietta, Ga.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 328–335. 7 refs. (A68-37619)

In discussing the reliability of a complex system, the major reliability concerns to date have been in terms of cost, system effectiveness, and availability. With the advent of Category III all weather landing systems, however, reliability is an important element in determining the safety of the system. For Category III operations, there is a brief time period during which the safety of the aircraft becomes completely dependent upon the integrity of the electronic system. As it is impossible to achieve a system with infinite reliability and safety, it becomes necessary that some safety/reliability goal be established to enable the relative safety of the all weather landing system to be determined. In addition to the establishment of this criterion, this paper will discuss the human error elements contributing to overall system failure, and outline a Boolean algebra technique for relating the hardware and human factor elements into a composite picture. Author (IAA)

Review: This paper gets close to the philosophic foundation of probabilities and to the relationship of engineering judgment to probability. In these philosophic problem areas, the treatment is good. In the actual discussion of numerical probabilities and formulas thereon, it appears that the authors have fallen into the trap they were avoiding earlier, namely, the calculation of probabilities by unrealistic formulas. By implication and directly, the authors are using formulas which apply to statistically independent events, yet in a catastrophy of extremely low probability the events are likely to be anything but statistically independent. (This is undoubtedly one of the sources of error in the probability of failure of an electrical system that they mentioned.) There are some inconsistencies and ambiguities scattered throughout. Examples are the following: (a) Where several items are necessary, it is very difficult to point out the most important one. (b) The calculations on the left column, page 331, for the ground system are not clear. (c) The term "theoretical failure rate" as used in the fail-operative system is not clear. (d) Some of the discussions on page 332 of safety, reliability and availability are not clear, especially in regard to what is logically in series and what is not. In spite of these, the paper does perform a useful service in presenting the dilemmas in rather clear form.

R69-14343 ASQC 810; 863; 871

SPARE ENGINE MANAGEMENT—AN EXAMPLE OF CURRENT AIRLINE PRACTICE IN LOGISTICS PLANNING AND MANAGEMENT.

F. S. Nowlan (United Air Lines, Inc., San Francisco, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 405–410. 2 refs. (A68-37627)

Discussion of the techniques employed by a typical airline for spare-engine management. The high unit cost associated with spare engines has resulted in relatively deep analysis of engine support requirements, and engine management is therefore typical of current trends in airline logistics planning and management. A simple mathematical model is presented which can be used both for planning and management purposes. The uncertainty associated with the elements of this model is discussed, as well as the interaction between elements of the model. Methods by which uncertainty can be reduced and elemental trends identified are illustrated. IAA

Review: Background and allied considerations related to spare-engine planning are treated in this paper. The contents are thus broader than the title might suggest, as is usually the situation for real-world applications. The only mathematical model which is noted is a rather simple one. The desirable trends in recent years toward the use of several indexes, such as the percentage of engines in overhaul, lend support to the applicability of such simplified models. Those interested in maintenance planning for any modern-day complex system will find this paper to be useful, or interesting background reading at the least. The inseparable interaction between reliability and maintainability considerations is illustrated in this paper.

R69-14345 ASQC 810; 831

SYSTEMS AVAILABILITY—A MANAGEMENT APPROACH TO RELIABILITY AND MAINTAINABILITY.

George K. Davenport (Bendix Corp., Aerospace Systems Div., Launch Support Div., Kennedy Space Center, Fla.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 453–479. 14 refs. (A68-37630)

Estimation of the reliability of a given system, and examination of the minimum requirements which might be imposed by management planning in procurement of spares, in design goals, and in maintenance manloading. The purpose of systems availability and the scope of the program are outlined. The techniques are discussed with reference to reliability, maintainability, and availability; weighted reliability and criticality; the classification of items according to problem areas; minimum maintenance personnel manloading; and critical spares identification and estimation. An appendix deals with Bendix reliability calculations in terms of the FORTRAN IV and Mathatron-APS programs, and with Bendix maintainability and availability calculations in terms of the Mathatron-APS program. IAA

Review: This paper describes in considerable detail the techniques which are used in the preparation of a Systems Operational Reliability Analysis (SORA) by the Bendix Launch Support Division at Kennedy Space Center. The purpose and scope of the program is described, listing the seven stages in the accomplishment of the SORA. Mathematical techniques are discussed, indicating the usefulness of the exponential distribution in situations involving the constant hazard rate and suggesting the Weibull distribution for situations in which variable failure rates are involved. Also considered are weighted reliability and criticality, classification of items according to problem areas, maintenance personnel requirements, and critical spares identification and estimation. Illustrative material pertaining to a pneumatic supply system is included in the paper. Ten pages of computer printout of reliability calculations are given in the appendix. Fourteen references are cited. This paper has a wealth of information for those who may wish to study it closely, but may also be scanned quickly by those who wish to get a bird's-eye view of what is involved in this first phase of the total reliability program of the Bendix Launch Support Division. It will be worthwhile reading for those concerned with the planning and/or implementation of similar programs.

R69-14346 ASQC 810

SESSION SUMMARY: RELIABILITY IN THE COMPETITIVE MARKET.

A. R. Townsend (General Motors Corp., Allison Div., Reliability Dept., Indianapolis, Ind.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 480, 481.

In an introduction to a conference session on reliability in nonmilitary competitive industries, note is made of current Federal responsibility to the consumer, safety requirements, and testing and evaluation procedures. Many limitations in reliability are attributed to a communication problem. The objectives of the session are thus established as (1) to expose the design reliability problems and implications of the commerical and consumer market; (2) to stimulate communication on mutual problems between military and commercial engineering and management people; and (3) to challenge the reliability profession to apply its concepts to the benefit of our basic economy. L.B.H.

Review: Approximately one third of this paper is devoted to extolling the benefits of the local economic/political system, and thus has little direct bearing on the title. The next portion of the paper seems to imply that reliability is new to the competitive market. But papers on this discipline have been given by automotive companies and appliance manufacturers for several years, although it is true that many consumers think they would like to see management paying more attention to it. The balance of the paper is largely introductory material describing the papers in the session. The author seems to forget that life-cycle costing and similar concepts have traditionally been applicable only to very mature industries, such as the utilities. Trying to apply it to the volatile armament industry is very difficult. This paper has no value as an archival document.

R69-14354 ASQC 813; 844
IMPROVING THE CONTRIBUTION OF MATERIAL AND PROCESS TECHNOLOGY TO PROGRAM RELIABILITY.
A. J. Giguere, H. J. Brown, and K. R. Mills (Martin Marietta Corp., Aerospace Group, Denver, Colo.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July – 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 554–562. 4 refs.
(A68-37638)

Discussion of the need for early support of aerospace hardware programs by materials and process personnel. Since programs are currently austere in funding, it is necessary that material and process personnel be in on the initiation of programs. Discussed, herein, are several problems which might have been avoided had materials and process support been provided in the design phase. Also discussed are ways in which the required support is possibly attained in the systematic analysis of a design problem which provides continuing visibility through definition, test, and qualification.
Author (IAA)

Review: The thesis of this paper is that material and process control is essential to high reliability. From this, it follows that there must be an organized program to be sure that materials and processes will not be detrimental to the product. The existence of such a program can be endangered by budget cuts. The authors illustrate the need for this kind of program with case histories involving several materials, and urge that designers call upon material/process specialists at an early stage in the design. The authors' points are well taken, but sooner or later someone is going to have to take pity on the designer. He is in the position of a patient when the doctor said, "If I made all the tests on you that all of the various specialists recommend, you would spend the rest of life in my office and the hospital." Everyone (value engineers, reliability engineers, safety engineers, material specialists, statisticians, etc.) is saying that the designer must consult the appropriate specialist in any area; i.e., the designer's knowledge is insufficient. While what they say is true, the designer has other problems and perhaps our system of engineering needs to be modified to relieve the designer of the almost unworkable burdens that everyone wishes to put on him.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14337 ASQC 824; 433
BAYESIAN RELIABILITY EVALUATION?
W. Thomas Weir (General Electric Co., Aerospace Group, Missile and Space Div., Re-Entry Systems Dept., Philadelphia, Pa.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 344–346. 3 refs.
(A68-37621)

Brief introduction of the Bayes theorem, with comment on the use of subjective information. While the classical and subjective schools are irreconcilable on theoretical grounds, they achieve similar results in a variety of practical situations, one framework being simpler in certain instances, the second in others.
IAA

Review: This paper is an introduction to the Bayesian section of the Proceedings and of necessity is short. It is nevertheless a very good introduction to subjective probability (degree of belief). It shows what areas are matters of controversy and what areas are not. It is important to remember that not all statisticians can be allocated exclusively to one of two groups: classical and subjective. Many good practicing statisticians realize that probability theory is an abstract mathematical concept and, like any such abstract concept, can be applied where the professional feels the situation fits the theoretical assumptions well enough. Unfortunately, the example chosen here (and in most elementary discussions) chooses the uniform distribution as typifying the knowledge before an experiment is performed. Rarely, if ever, will the uniform distribution really typify an engineer's degree of belief in a situation. There will be some values, not necessarily close together, that he will consider quite likely and other values that he will consider quite unlikely. Another way of putting it is that the uniform distribution can represent an engineer's knowledge; it cannot represent his complete ignorance—nothing can (otherwise it is not *complete* ignorance). Furthermore, space undoubtedly prevented the author from going into the subject in this much detail, when using continuous distributions to express one's degree of belief, great caution is needed because such curves lend themselves to misinterpretation by the unwary. As engineers, we tend to think in terms of probabilities, not probability densities, and that little differential on the end can make a great deal of difference. These comments should not be construed as deprecating the article (it is a very good presentation for beginners—understandable with a minimum of jargon), but rather as supplying additional information. Unfortunately, some of the information one gets elsewhere on the Bayesian approach tends to be misleading. The application of degree of belief is not well enough advanced to have clear-cut uncontroversial (even to subjectivists) approaches and description.

R69-14338 ASQC 824; 433
BAYESIAN ESTIMATION OF TIME-VARYING RELIABILITY.
Arthur M. Breipohl (Oklahoma State University, Stillwater, Okla.) and W. C. McCormick, Jr. (USAF, Systems Command, Holloman AFB, N. Mex.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 347–351. 8 refs. AEC-supported research.
(A68-37622)

Description of how the Bayes' rule together with an engineering model can be used to estimate reliability when the reliability changes with time. It is assumed that samples of equipment are subjected to pass-fail tests at prescribed points in time. Since reliability is changing, the results of the samples tested at different times cannot be combined directly. However, a model of the time variation and Bayes' rule do allow combining the data. The basic idea is to form an estimate of some sampling time, project this estimate via an engineering model, and combine the projected estimate with the data taken at the next sampling time via the Bayes' theorem. The paper describes the results of applying this basic idea. There is a discussion of the model of time variation of reliability, a development of the results obtained with various assumptions, some discussion of the assumptions, and analysis of the results. Author (IAA)

Review: This paper is not for the novice in Bayesian statistics but rather requires some sophistication in the handling of formulas. The algebra was not checked in detail but appears to be competent. The term "time-varying reliability" would be clearer to many people if it had been called "time-varying fraction-defective" It all amounts to the same thing in the end and the authors cannot actually be faulted for their choice of words. The beta distribution is chosen here for the prior distribution because it is tractable. In the present situation, of course, one cannot say offhand whether the choice is good, bad, or indifferent; but in many practical situations, one may wish to forego the tractability to gain increased correspondence between the model and reality. One of the problems that some Bayesians run into is that after running the experiment, they do not like the looks of the posterior distribution and so go back and change the prior. When choosing a prior, one should consider the logical consequences of any experimental outcome to be sure he agrees that the posterior is a reasonable description of his degree of belief after the experiment. If not, he should change the prior *before* running his actual experiment. Thus it can be seen that simulation is an important part of subjective probability. The immediately foregoing discussion is not meant to deprecate the authors' choice, but to warn the unwary that the choice of prior distributions is not as simple as it might seem from reading some articles. The authors' approach to estimating C_n is bogged down in algebraic details and thus will take considerable study to follow. It would be wise to have the algorithm for deciding on C_n written down carefully beforehand. A simulation should be run on possible experimental outcomes to be sure that one is satisfied with this algorithm no matter what the actual experimental outcome would be.

R69-14339 ASQC 824; 433

USE OF BAYES THEOREM IN ITS DISCRETE FORMULATION FOR RELIABILITY ESTIMATION PURPOSES.

W. J. MacFarland (General Electric Co., Research and Development Center, Schenectady, N. Y.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968 p. 352–365. 4 refs.
(A68-37623)

Introduction to the Bayes theorem, which is merely a simple expression for the handling of conditional probabilities, with discussion of its use in its discrete formulation for reliability estimation purposes. The need for an inclusive prior distribution is explained, and the three basic types of Bayesian inference situations are studied. General optimal properties of the Bayesian prior distribution, and continuous formulations for Bayesian reliability estimation are examined. The beta prior and binomial data are discussed. The discrete formulation, which receives extensive attention, seems to have a variety of desirable properties not offered by the continuous formulation. IAA

Review: This paper basically has an excellent message, viz., the prior distribution should be chosen very carefully, so that no matter what the experimental outcome, the posterior distribution will also reflect your new beliefs. The author shows that this condition is much easier to achieve with a discrete prior distribution than with a continuous probability density function. He also shows that the conjugate function (in the binomial case at least) is unlikely to be an accurate reflection of a person's prior beliefs since with a particular test outcome it does not necessarily transform into his posterior beliefs. The message of this paper should be kept in mind when reading other papers on Bayesian techniques for Reliability. Some of the terminology in the earlier parts of the paper may confuse the newcomer to the philosophy of subjective probability; if in fact one is using probability to refer to degree-of-belief, then one must be careful about discussing an *incorrect* such probability function. The test data will modify one's degree-of-belief. If the degree-of-belief does not get modified according to Bayes' formula, then one is in trouble. There are roughly three choices, as follows: (1) Discontinue using probability as a measure of degree-of-belief, thus getting out from under the restrictions imposed thereby. (2) Modify the prior distribution so that together with the experimental data, the posterior distribution does accurately reflect degree-of-belief. (3) Modify one's feelings about the situation to be in accordance with the formulas; this is often done in engineering work where "intuition" turns out to be inaccurate and one prefers to believe the results of computations. (Choices (2) and (3) are by no means mutually exclusive.) While the author explicitly avoids a discussion of how to choose a prior distribution (other than insisting that the distribution have some reasonable attributes), the testing of a prior *before* running any experiments is essential. One should simulate a considerable number of test outcomes and see if the posteriors thus generated do reflect one's new degree-of-belief under those circumstances. If they do not, one should consider a reversion to steps (2) and (3) mentioned above. When one is finally satisfied with the results of the simulation, then he has an adequate prior distribution. The above remarks should not be construed as denigrating the author's main point—it is excellent. One need not sacrifice accuracy in order to gain tractability. The use of a conjugate prior may often force that sacrifice implicitly.

R69-14340 ASQC 824; 433; 512

SOME COMPARISONS OF BAYESIAN AND CLASSICAL CONFIDENCE INTERVALS IN THE EXPONENTIAL CASE.

J. J. Deely and W. J. Zimmer (Sandia Corp., Sandia Laboratory, Albuquerque, N. Mex.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 366–371. 2 refs.
AEC supported research.
(A68-37624)

The classical one-sided confidence interval on the parameter from the exponential distribution is compared to the Bayesian one-sided confidence interval based upon a prior distribution which is a particular member of the "natural conjugate" family. The Bayesian interval is not always shorter than the classical interval but the probability that the Bayesian interval is shorter can be computed. This probability is shown to depend on only one parameter of the prior distribution. Graphs which relate this parameter and the probability that the Bayesian interval is shorter are given. In addition it is shown that it is possible to save observations and still maintain a shorter Bayesian confidence interval with probability ≥ 0.5. Finally, assuming that the prior distribution is a member of the "natural conjugate" family with unknown parameters, a procedure is given for using prior observations to estimate these parameters. Approximate Bayesian confidence intervals could then be obtained from these estimates. Author

Review: The main point of this paper is that the Bayesian confidence interval for mean-time-to-failure, θ, is not necessarily shorter than the classical interval, even though the former interval is based on a complete specification of the a priori density function of θ. The controversy concerning the assumption that an a priori function can be specified is bypassed, since this is not the purpose of the paper as stated by the authors. The paper is well-written and will be of interest to those concerned with Bayesian approaches. A knowledge of probability distribution theory is necessary for understanding the detailed mathematical derivation; however, many results are given in graphical form and the main theme of the paper can be understood without pursuing the detailed manipulations.

R69-14341 ASQC 824; 433

IMPLEMENTATION OF BAYESIAN RELIABILITY MEASUREMENT PROGRAM.

John E. Olsson (General Electric Co., Aerospace Group, Missile and Space Div., Re-Entry Systems Dept., Philadelphia, Pa.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 372–379. 2 refs. (A68-37625)

Results of studies of the establishment of a Bayesian Reliability Measurement Program. The Bayes theorem and some of the various statistical models that were formulated on the basis of the theorem are reviewed. The coding of subjective knowledge on hardware before testing commences is discussed. The implementation of a Bayesian reliability measurement program on a typical subsystem is described. There is considerable reason, it is believed, for continuing this and other trial applications of a Bayesian reliability measurement program. IAA

Review: One must be careful in arguments about Bayesian statistics, especially if he is an advocate thereof, not to be led astray by classicists who are themselves confused. If the subjectivist is using probability to represent his degree of belief, then no matter how many experiments of the relative frequency variety he runs, his final probability (whether a distribution, a mean, or tolerance interval) still measures *degree of belief*— it does not assert something about the true value. In general, it is then up to the engineers and managers involved as to what contractual or official effect they wish to give to this degree of belief. The discussion on Bayesian methods per se is straightforward. It should be noted, however, that the author is concerned only with the constant hazard rate hypothesis and only with the gamma prior distribution. While the combination is tractable, it is not necessary to use a gamma prior distribution with the constant hazard rate hypothesis. See, for example, the paper appearing on pp. 352 – 365 in the same Proceedings. There are at least some misprints in some of the equations (in particular, Equation 3 needs modification), so that none of the results should be used without having checked the algebra. (The author in a private communication has acknowledged that there are misprints in some of the equations. He has offered to furnish a corrected copy of the paper to anyone requesting it.) With the gamma prior distribution and the constant hazard rate, previous knowledge can be expressed as an equivalent previous test time and an equivalent number of failures. This should not bother anyone if he is in fact satisfied with the prior distribution that he has chosen. The author wisely mentions that careful thought should go into choosing the parameters of the prior distribution. The prudent engineer will simulate possible test outcomes and see what they do to his degree of belief; he must be willing to have the posterior distribution represent his degree of belief in each case. If he is not, he should either change his priors or his wants. In many cases, tractability of a prior distribution may be too high a price to pay for the warping of one's beliefs. These comments should not be taken as deprecating subjective probability since, when properly used, it is a powerful tool. But they should caution the prospective user that their application will force on him a kind of rationality with which he may be most unfamiliar and to which he may be unwilling to submit.

R69-14342 ASQC 824; 433

A BAYESIAN APPROACH FOR ASSESSING THE RELIABILITY OF AIR FORCE RE-ENTRY SYSTEMS.

David V. Mastran (Directorate of Special Weapons, San Antonio Air Materiel Area, Kelly AFB, Tex.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 380–383. 6 refs.

Bayesian methodology is used to assess Air Force ICBM reentry systems reliability, allowing subjective information to be incorporated mathematically in the reliability statement and system confidence bounds to be obtained from component data. Mathematical reliability models for each reentry system are developed, expressing the system reliability as a function of the component reliabilities. Reliability models are used, incorporating system configuration information, and the system reliability density function is derived by Monte Carlo simulation. L.B.H.

Review: This topic (evaluating the reliability of ICBM re-entry systems) is a reasonable one for the application of Bayesian techniques. The discussion uses conjugate prior and posterior distributions as a matter of tractability. The paper is not intended for the novice since he will not have the background to evaluate the controversial points. Examples of the difficulties and controversial points are the following: (1) Even though Bayesian statistics is a loosely defined concept, a great many practitioners consider that the essence is using probability to describe degree-of-belief (when accurate relative frequencies are available, the prudent man will use them to describe his degree-of-belief). Therefore the resulting posterior distributions still describe degree-of-belief and the Bayesian confidence bounds will indicate area under this degree-of-belief curve without reference to the true reliability. (2) The uniform prior distribution is not equivalent to nothing being known. It is a statement about a specific kind of knowledge. This is illustrated by the author when he points out that a uniform prior on subsystem reliabilities is not equivalent to a uniform prior on the system reliability. A similar example is that if the reliability is assumed uniformly distributed, then the hazard rate is not uniformly distributed. Thus there are many philosophic difficulties associated with the use of the prior distribution to reflect no knowledge. It is more appropriate to select a prior distribution which does in fact have the desired properties and logical consequences that one wishes. Much of this kind of difficulty is caused by our thinking in terms of probability, but having to use probability density in the calculations. (3) The author seems to equate the best estimate of reliability to the mode of the distribution. Estimates have many properties and it is never obvious on its face what a particular person implicitly means by best. He should always state the objective criteria. Very often people use a sample median or sample mean as their best estimate; others wish unbiased estimates of the population parameters, etc. When one wishes to use probability theory to describe his degree of belief, he must be prepared to spend a reasonable amount of time and effort to make sure that the prior distribution he has chosen does in fact represent his prior beliefs. To do this, he must among other things run simulation tests by postulating the results of experiments and observing the consequent posterior distributions. Given those experimental results, he must agree that the calculated posteriors do in fact represent his degree of belief. If they do not, he must either change his intuition on the subject, change the prior distribution, or both. (He can, of course, give up representing his degree of belief by probability.) The paper appearing on pp. 352–365 in the same Proceedings illustrates some of the difficulties in choosing a prior and suggests that a discrete distribution sacrifices little in terms of tractability and gains much in terms of accuracy. This suggestion should be carefully considered by engineers who use subjective probability.

R69-14344 ASQC 824; 817; 863; 882

A TECHNIQUE OF AVAILABILITY PREDICTION FOR ADVANCED SUPPORT PROGRAM DEVELOPMENT.

M. M. Holland (North American Rockwell Corp., Aerospace and Systems Group, Autonetics Div., Anaheim, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 437–446. 2 refs.

(A68-37628)

Development of equations that would permit prediction of certain parameters in advanced support program development, allowing the operation of a program to be evaluated. The necessary variables are defined, and quantitative parameters of evaluation formulated. The equations then allow any program with an integrated support effort to be analyzed objectively. More important, they allow reliability and support to be related, with the proper emphasis placed on each. The techniques demonstrated in this study will allow a program to be optimized with relation to such factors as time, money, or effectiveness. IAA

Review: This paper presents a mathematical technique for evaluating reliability in relation to logistics support of the equipment, with the objective of permitting a support program to be optimized with relation to such factors as time, money and effectiveness. The mathematics per se is straightforward, involving the writing of mathematical expectations as appropriate sequences of terms and summing them in order to get desired results. While not all of the equations were checked in detail, a spot check indicated the mathematical work to be competent. Limitations of the technique, as well as its potential uses, are pointed out in the paper. This approach should prove to be quite useful in coordinating effort between support and reliability, in evaluating proposed program changes, and making appropriate tradeoff analyses, as well as in the prediction of support problems before they have a chance to actually affect the program. Those who might wish to use these equations to predict, for example, the number of systems operating at a given time in an absolute sense rather than for comparative purposes should note certain limitations which are not mentioned in the paper. The basic assumption underlying the derivation of the equations is that the time-to-failure of the systems considered is distributed exponentially. This assumption implies a constant hazard rate and is one commonly made in reliability studies at various levels of a system. However, the fact that individual subsystems (e.g., components) have a constant hazard rate does not imply that systems made up of them will have a constant hazard rate. While the author does not discuss this point, he does assume that the systems as they come off the production line have a constant hazard rate. The exponential assumption may not apply for another reason, namely, systems fresh off the production line are likely to suffer from a high incidence of early failures (infant mortality) and thus have a decreasing hazard rate as they are debugged. It is also assumed that all systems which come off the production line have the same hazard rate, since a single λ is used throughout the equations. These implicit assumptions are at the core of the author's entire discussion, and consequently the results are more restrictive than is implied in the paper. There is no discussion of the distinction between component failure and system failure in systems in which redundancy is involved, and this could become a factor of importance in some situations. However, as mentioned above, these limitations are less important when the equations are used for the purpose of making comparative evaluations than they would be in the case of depending on the absolute results. In the latter situation, if these limitations are ignored, the accuracy of the results relative to the real-life situation may be considerably less than an unsuspecting user might believe.

R69-14348 ASQC 821

PROBABILISTIC STRENGTH MAPPING—A RELIABILITY VERSUS LIFE PREDICTION TOOL.

M. J. Bratt, H. A. Truscott, and G. W. Weber (General Electric Co., Cincinnati, Ohio)

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July – 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 501–510. 5 refs.

(A68-37632)

Description of a probabilistic strength-mapping method embodying the principle of multidimensional statistical analysis. According to this principle, an n-dimensional surface, whose general form is based on the metallurgical phenomena involved, is fitted to data points scattered throughout the region of interest, one of the surface dimensions being cumulative probability. Such a technique makes it possible for the experimenter to explore many more relationships and interactions with a given number of tests without sacrificing the important probability dimension. IAA

Review: The thesis of this paper seems to be that if you can hypothesize a reasonably decent mathematical model for the stress-life characteristics of the component at hand, then testing can be spread throughout the applicable region of stress. Deviations from the best-fit curve can be used to guess at a reasonable tractable probability function which will fit these data, and to estimate the parameters of the chosen function. This thesis is quite true and is a valid means of incorporating prior knowledge into an analysis. Difficulties do arise when extrapolations are made in the probability plane to extremely small probabilities. At a minimum, one should calculate the statistical uncertainty involved in such extrapolation (this is equally true in the non-probabilistic planes) and should consider how likely it is that the chosen tractable expression is inaccurate in this region. Any probability less than 0.001 obtained by such extrapolations could easily be in error by a factor of 10. Furthermore, the point made in the article covered by R68-14167 must be worried about, viz., materials purchased commercially often do not have the properties nominally associated with that material. The authors' Figure 10, wherein the two plotted points have probabilities which differ from the extrapolated curve by well over a factor of 10 illustrates the latter principles. (In a private communication the third author has stated that the deviations could be due to different definitions of failure—crack initiation vs. rupture.) These comments are not meant to discourage the use of prior knowledge in this form or even discourage extrapolation. But it does pay to be very careful when walking on dangerous ground, even though one chooses to walk there.

R69-14357 ASQC 824; 433

THE PREDICTION AND MEASUREMENT OF SYSTEM AVAILABILITY—A BAYESIAN TREATMENT.

David M. Brender

IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 127–138. 21 refs.

(A68-44394)

Description of a Bayesian-oriented methodology for: (1) predicting the availability of a projected system, and (2) measuring the availability of an existing system. The approach followed is to start with familiar availability expressions containing parameters of uncertain value, and evolve point and interval estimates for these availability expressions which take into account the formation gained, initially, from an analysis of the system, and later, from a test of the system. The results obtained for measuring the steady-state point availability provide the basis for handling expressions associated with more complicated availability definitions, such as that of transient availability, mission availability, and others. IAA

Review: Those concerned with system effectiveness analysis and who have the background information to formulate a priori density functions for the failure rate and repair rate will find this paper useful. It contains a series of formulas for a priori density functions for availability and appropriate moments based on gamma-1 a priori density functions for failure rate and repair rate. The following are specific points in the text which appear to need clarification or definition. Explanations provided by the author in a private communication are given in square brackets. (1). On p. 127, second paragraph under "Literature on Availability Statistics," the last sentence is not clear. [The 'prediction problem' is defined in the last sentence in the subsection headed Prediction Problem.] (2) On p. 128, (under 2), top of second column, the meaning of "exact value" in the last sentence needs clarification. [The English seems more than clear when I contrast "the exact value of the failure rate" with "the distribution of the failure rate."] (3) On p. 128, third paragraph in second column, use of the adjective "unique" seems to be oversimplifying the approach. [The word "unique" is used in the sense of "leading to one and only one result." However, it should be pointed out that the a priori densities are assumed to be of gamma form.] (4) On p. 129, second column, equation (11), w, u, s, and r are introduced without definition; the reader must refer to (74) for this information. Also, the use of ρ_1 and ρ_2 in the first column on the same page could have been clarified for the reader: ρ_1 = (r, s), ρ_2 = (w, u). [All background information is presented in Section VIII. If a gamma distribution is assumed, then indeed ρ_1 = (r, s); however, this assumption does not apply here. In the following paper, page 143 in the same journal (where a non-gamma prior is assumed) ρ_1 = (r, s, w). (Thus ρ_1 and ρ_2 are the corresponding vectors of parameters.)]

R69-14358 ASQC 824; 433; 882

THE BAYESIAN ASSESSMENT OF SYSTEM AVAILABILITY—ADVANCED APPLICATIONS AND TECHNIQUES.

David M. Brender

IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 138–147. 12 refs.

(A68-44395)

Extension of the statistical assessment of system availability within a Bayesian framework to consider four additional areas of application. These areas include (1) applications to more complicated availability definitions than considered earlier; (2) applications to measures of performance other than availability; (3) the use of prior distributions on the failure and repair rates more general than the gamma form; and (4) the use of a model involving nonexponential repair intervals. The results obtained under all four categories can be expressed in terms of the basic measures for the Euler distribution developed earlier. IAA

Review: The general comments made for the previous paper by the same author (pp. 127–138 in the same journal) also apply to this paper. No discussion of procedures for developing the a priori distributions are given. It is implicitly assumed that these distributions are available, wheras the major problem to the user of Bayesian analysis is to justify the one he has chosen. It would seem to be very difficult to justify in practice the use of a priori distributions which are linear combinations of gamma distributions. However, in response to this comment, the author has provided one good justification as follows: "Two engineers who are considered to be of equal ability each pick a gamma prior distribution for a particular failure rate after their individual analysis of a situation. When their gamma distributions are compared they are not found to be very different one from the other. If a manager requires a single estimate immediately, he may decide to work with a new prior which is a linear combination of both gammas, each gamma weighted by 1/2. With somewhat more faith in one engineer than the other, a different weighting scheme could be used in the linear combination." The author tends to oversell Bayesian statistics in the conclusions, while downgrading the role of an orthodox approach. For example, it is stated on page 146 that: "The alternative (orthodox approach) is to deal with each statistical problem as an individual entity, developing specialized techniques for each problem variant." This is not an accurate description of the classical approach. The reader interested in Bayesian applications will find the results in the paper of limited value because (1) the analytical details are not adequately developed, and (2) the applications are limited. For example, the paper deals primarily with the steady-state point availability and transient availability expression for a single item or equipment. It treats very briefly the steady-state availability of a simple redundant system (two active identical units serviced by one repairman). In response to these comments the author has stated that this paper provides a starting point for people interested in Bayesian applications to availability. He has commented further as follows: "The purpose of the paper was to show how the Bayesian idea can be used to handle the complicated problem of estimates and confidence statements on a wide variety of availability expression. ... The availability of the redundant configuration is listed, an estimate is derived and provided, the higher moments are given, the distribution of the availability is derived and provided: there is a numerical example, the posterior problem is solved; the approach is shown to apply to triple redundancy and beyond; and mentioned is a more complicated problem to which the results apply."

R69-14360 ASQC 825; 831; 838

SYSTEMS RELIABILITY SUBJECT TO MULTIPLE NONLINEAR CONSTRAINTS.

Frank A. Tillman, Ching-Lai Hwang, Liang-Tseng San, and Shafi Balbale (Kansas State University of Agriculture and Applied Science, Manhattan, Kan.).

IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 153–157. U.S. Department of the Interior Grant 14-01-0001-1283; NSF Grant GK-818; Grant NsG-692.)

A simple computational procedure has been developed for maximizing reliability of multistage parallel systems subject to multiple nonlinear constraints. It appears that the procedure can be applied to a variety of optimization problems with separable objective and multiple constraint functions. Author (IAA)

Review: This is a theoretical paper. The derivations and proofs require a mathematical sophistication beyond that possessed by most reliability engineers. One should understand the derivations before applying the theory to his own systems. Thus the paper will have limited appeal to design and reliability engineers. The paper itself is a technically competent piece of work, but for a full appreciation of the problem considered, the reader should be familiar with the authors' earlier papers covered by R68-13580 and R68-14043 (References 1 and 4 in the paper). In particular, this paper provides a computational scheme which overcomes some of the practical limitations of the methods discussed in the authors' Reference 4. For practical systems wherein the number of parallel elements in any stage is small (probably less than 3 or 4), and the number of stages is small (say less than five), other less elegant and more brute-force calculations may be satisfactory. For example, calculate the system reliability for all feasible combinations and list them in order of decreasing reliability; the first one which satisfies all constraints is the solution.

R69-14361 ASQC 824
STABILIZING MEAN VALUES AND MINIMIZING VARIANCES OF ELECTRONIC SYSTEMS PERFORMANCE CRITERIA.
Emil C. Neu and Raj P. Misra (Newark College of Engineering, Dept. of Electrical Engineering, Newark, N. J.).
IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 157–163. 5 refs.

Mathematical statistics are used to design electronic systems in which the effects of the initial variations of the system parameters and the drift of these parameters on the system performance criteria are a minimum. This is accomplished by minimizing the initial mean values of the system parameters while constraining the means of these parameters to their required values. In addition, the drift rates of the system parameters are selected in such a manner as to prevent the drift of the mean values of the system performance criteria while reducing the tendencies of the variances of these criteria to increase with time. These techniques were applied to a number of electronic systems, including systems with both active and passive elements. Author

Review: This is a mathematical paper, albeit not esoterically so, which is amply illustrated with examples so that the technique is clear. The title and introductory remarks tend to be much more general than the actual mathematical formulation of the problem. Therefore one should be very careful in using these techniques to realize what it is he is doing, namely, he is adjusting the mean values of the parameters so that the variance of the calculated function will be a minimum at a given value of that output function, under the condition that the relative variance for a part remains constant under this variation. The method of actually solving for the values need not be followed in detail. It may be more convenient to differentiate both the constraint and the variance formula and then combine the results rather than making a substitution first. The notation gets complicated at times and there are some misprints in subscripts, but with perseverance and faith these are easily overcome. The examples are quite specific and should be taken only as illustrating the method; the results are not true in general because many of the assumptions are quite strict and in many cases will not be useful in approximating a given physical situation. Not all of the algebra in the examples was checked but it appears competent. The paper is obviously intended for design engineers. How useful they will find it, i.e., how much it will tell them about a circuit that they do not already know, is difficult to say. The technique is not as complicated as it looks and circuit designers should be aware of at least the thing the method is trying to accomplish.

R69-14362 ASQC 824; 413
ON A TEST FOR EQUALITY OF THE MEANS OF TWO INDEPENDENT POISSON DISTRIBUTIONS.
Henry L. Gray and Truman O. Lewis (Texas Technological College, Lubbock, Tex.).
IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 163–170. 3 refs.

An exact method is studied for testing the equality of means of two independent Poisson distributions. The method allows for sampling over different time durations, making possible comparison of the mean time between failures (MTBF) of an equipment, by observing it for a specified period of time, to the MTBF of another equipment which has been under observation for a second specified period of time. The purpose of the test for a given situation is discussed, and examples are given which illustrate the test. Extensive tables and graphs are included. Author

Review: This paper presents a rather good practical discussion of the use of a test for equality of the means of two independent Poisson distributions. While the test is not new (see Reference [1] in the paper), the tables and power plots given should be useful in carrying out and planning such tests. The reading could be clarified somewhat if the authors had pointed out that several of the probabilities considered are *conditional* probabilities.

R69-14363 ASQC 824; 838; 872
SOME CONSIDERATIONS FOR MULTIPLE-UNIT REDUNDANT SYSTEMS WITH GENERALIZED REPAIR TIME DISTRIBUTIONS.
Hisashi Mine, Shunji Osaki, and Tatsuyuki Asakura (Kyoto University, Kyoto, Japan).
IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 170–176. 3 refs.

The mean time to system failure (MTSF) for a 2-out-of-n system with repair is intuitively derived. The improvement factor, the ratio of the MTSF for a 2 out of n system with repair to that system without repair, is evaluated and its symptotic behavior is studied. Tables are given for the improvement factor for 2-out-of-3, 3-out-of-3, and 3-out-of-4 systems. Author

Review: As the authors point out, the derivations in this paper are intuitive. They are not rigorous mathematically, but are useful nonetheless in showing roughly how the results come about. For example, the asymptotic results obtained are clearly valid only under certain conditions on the repair time distributions, but it is also fairly clear that such conditions would usually be satisfied in practical situations. The tables given should also be of interest to the applied reliability research worker.

R69-14365 ASQC 824; 844
CORRECTION TO RELATION OF A PHYSICAL PROCESS TO THE RELIABILITY OF ELECTRONIC COMPONENTS.
Clarence F. Kooi.
IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 179.

A previously published derivation and succeeding equations are noted as erroneous, and the correct derivation is proposed. A normalized distribution of components is considered, and the reliability function is determined. The failure rate is plotted and is found to be zero at time zero and at time infinity. L.B.H.

Review: This is a correction to the paper covered by R68-13906. In that review, two erroneous equations were pointed out and this correction essentially makes the necessary changes and follows through on some of the corresponding hazard-rate calculations. Unfortunately, the author's notation in this correction is not the same as that in the original article; the differences are the following: 1. N should be defined as the number of impurity particles in potential well #2 at $t = 0$. 2. The introduction of the constant g is needless since in every essential place it is combined with a previously-introduced adjustable constant h. 3. The number of components which have not failed at a particular time have less than n_c particles in potential well #1 (not well #2 as stated). The letter has two difficulties unrelated to the original paper: (1) In the equation for Z, a factor of 2a is missing. The ordinate on the plotted graph should be $-Z/4a$. (2) The author's condition for a region where $Z \propto t^{-1}$ is incomplete (as perhaps he intended). The complete description is $b << x << 1$. In any event, the shape of these curves is extremely sensitive to the form chosen for the function x(t).

R69-14366 ASQC 824; 838
FORMULAS FOR THE MEAN LIFE OF A BINOMIAL-SERIES SYSTEM.
Carl J. Benning (Texas Instruments, Inc., Dallas, Tex.).
IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 180, 181. 1 ref.

In commenting on a previously published formula for calculating *the mean life of a binomial-series system, it is pointed out that*

the application of the formula is laborious when factorial tables are unavailable, or if the gamma function is used. To simplify the procedure, some formulas are presented for establishing upper and lower bounds on these systems with only a slide rule required to apply the results. The technique used to develop the bounds is based on a standby representation of the binomial system, and on standby systems for obtaining upper and lower bounds. The differential transition matrix is constructed for the standby representation and compared to that for a binomial system.
M.G.J.

Review: This letter is an addendum to an article by J. M. Shapiro that (a) appeared in *Evaluation Engineering* (see R67-13365) and (b) is Reference 1 of the letter. Unfortunately, the exact circuit being analyzed is not reproduced, so that one needs to look at the original reference for this information. (The original system consists of two subsystems. The first is a single exponential element with hazard rate λ_s; the second subsystem consists of N exponential elements in parallel, each with hazard rate λ of which k must work.) In the following discussion, the author's notation is used except for the ratio $\lambda_s/\lambda \equiv \nu$ and the abbreviation for $1 - \lambda_s \cdot ML \equiv \psi$. The author's Eq. (1) (copied from his Reference 1 and is the original answer to the problem) is equivalent to $\psi = N!/(k-1)! \cdot (k-1+\nu)!/(N+\nu)!$ (presumably, if the factorial notation is taken to be a substitute for the gamma notation, the formula is exact). It is shown in R67-13365 that the above formula is equivalent to $\psi^* \equiv N/N+\nu \cdot N-1/N-1+\nu \cdot N-2/N-2+\nu \cdot \cdot \cdot k/k+\nu$, which for most *practical* systems will be easy to evaluate with a slide rule. (The duplicate factors have been eliminated from ψ.) From ψ^* the author's upper and lower bounds are easily derived since he merely considers ψ as being made up of either all of the largest terms, $\psi_1 = (N/N+\nu)^{N-k+1}$ or all of the smallest terms, $\psi_2 = (k/k+\nu)^{N-K+1}$. Other better bounds can be obtained with not much extra effort by appropriately manipulating the equation for ψ^*. For example ψ_1' and ψ_2' are much closer values for use in the lower and upper bounds respectively: $\psi_1' \equiv \{(N+k/N+k+2\nu)\}^{N-k+1}$, $\psi_2' \equiv \{Nk/(N+\nu)\ (k+\nu)\}^{N-k+1/2}$. These are derived by (a) considering the numerator and denominator separately and (b) taking the factors of each in pairs, symmetrically about the center. Obvious extensions will give more complicated, but closer bounds. Another interesting set of bounds is given by: $\psi_3 \equiv (1 + \nu/k-1)^{k-0.5}/(1 + \nu/N)^{N+0.5}\ \{\nu+k-1/\nu+N\}^{\nu} \exp\{-1/12\ (\theta 1/N + \theta 2/k-1+\nu - \theta 3/k-1 - \theta 4/N+\nu)\}$, where $0 < \theta_i < 1$. This is adapted from ψ^* and Eq. 6.1.38, p. 257 in [1]. Each pair of bounds comes closer together as the ratio N/k becomes closer to 1. In the case of the Shapiro example (which contains a tremendous amount of redundancy in the redundant section), the author's upper and lower bounds are $\psi_1 = 0.0094389$ and $\psi_2 = 0.0032097$ (almost a factor of 3 apart); for the upper and lower bounds suggested above in the review, $\psi_1' = 0.0058211$ and $\psi_2' = 0.0055042$ (less than 6% spread), and $\psi_3 = 0.0057086$ (relative uncertainty is about ±0.1%). The redundant subsystem contributes very little to system failure because it is so reliable; therefore, the approximations have little effect on the final answer for mean life. In fact, if the redundant subsystem were perfectly reliable ($\psi = 0$), one gets ML = 1367.66. Therefore, the example in the text is not a true test of the closeness of the closeness of the bounds.

Reference: [1] Handbook of Mathematical Functions, AMS 55, National Bureau of Standards; Available from U.S.G.P.O.

R69-14371 ASQC 824; 822

POINT AND INTERVAL ESTIMATION PROCEDURES FOR THE TWO-PARAMETER WEIBULL AND EXTREME-VALUE DISTRIBUTIONS.

Nancy R. Mann (Rocketdyne, Canoga Park, Calif.).
Technometrics, vol. 10, May 1968, p. 231–256. 73 refs.
Sponsored by North American Rockwell Corp.

Point estimators of parameters of the first asymptotic distribution of smallest (extreme) values, or the extreme-value distribution are surveyed and compared. Those investigated are maximum-likelihood and moment estimators, inefficient estimators based on only a few ordered observations, and various linear estimation methods. A combination of Monte Carlo approximations and exact small-sample and asymptotic results has been used to compare the expected loss (with loss equal to squared error) of these various point estimators. Since the logarithms of variates having the two-parameter Weibull distribution are variates from the extreme-value distribution, the investigation is applicable to the estimation of Weibull parameters. Interval estimation procedures are also discussed.
Author

Review: This paper is a comprehensive mathematical treatment of the topic indicated in its title. Because of the fairly widespread use of the Weibull distribution in life-testing and failure analysis applications, it constitutes a worthwhile contribution to the theory of reliability estimation. It will be useful mainly to statisticians who are concerned with reliability analyses involving the Weibull distribution, and with the design of life tests in situations in which the Weibull is considered to be a suitable model. However, it is not the sort of thing which the average engineer can pick up and use directly because considerable background and maturity in statistics is required in order to assimilate the material. The paper is clearly and competently written, and cites 73 references. Among these, Items 53 and 54 are the earlier papers by the author covered respectively by R68-14099 and R68-13758.

R69-14372 ASQC 824; 412

ON THE DETERMINATION OF A SAFE LIFE FOR DISTRIBUTIONS CLASSIFIED BY FAILURE RATE.

Sam C. Saunders (Boeing Scientific Research Labs., Seattle, Wash.).
Technometrics, vol. 10, May 1968, p. 361–377. 9 refs.

When the distribution of life length is a member of a specified subset of distributions which have increasing failure rates, a method is found to determine functions of the sample data which can be used to provide lower tolerance bounds of given confidence or a service life with specified assurance of no failures among a given number of items to be produced. The method of finding such functions of the observations is shown to be optimal in a sense and the calculation of a lower bound for the probability of no failure in the future production is carried out when such functions are used. The confidence in the tolerance bound and the assurance of no failure in a production lot of specified size are compared when using bounds obtained from these functions.
Author

Review: This paper is essentially the same as the report covered by R67-13118.

R69-14373 ASQC 824; 412

A NOTE ON PREDICTION INTERVALS BASED ON PARTIAL OBSERVATIONS IN CERTAIN LIFE TEST EXPERIMENTS.

John E. Hewett (University of Missouri, Columbia).
Technometrics, vol. 10, Nov. 1968, p. 850–853. 8 refs.

Prediction intervals for certain functions of the total sample are obtained using a preliminary subsample of the total sample. In some instances these functions pertain to the total test time necessary to complete the experiment. For the simultaneous life test considered by Sobel and Epstein a prediction interval is obtained for the total unit hours of test time necessary to test all of the items as well as a prediction interval for the "remaining life." In addition the inverse binomial sampling plan discussed by Nadler is considered.
Author

Review: This brief mathematical paper is concerned with prediction intervals for certain functions of the total sample which can be obtained from a preliminary subsample. For example, one function which is often of interest is the total time necessary to test the full sample. The prediction of this on the basis of a part of the full sample can provide helpful information to statisticians who are planning life testing experiments. When it is possible to predict on the basis of the first k observations the total number of trials that it will be possible to perform, or the total cost of the experiment, the experimenter has information on which to base a decision regarding the possible redesign of the whole experiment. Such information available early in the course of the experiment can result in considerable savings of time and money. The cases considered in the paper are (1) sampling plan with uncensored observations, (2) inverse sampling with censoring, and (3) sampling with simultaneous testing. The paper includes a brief treatment of the general theory, which is then applied to the three cases mentioned. The discussion is keyed to 8 references, thus being placed in perspective relative to other published work on the subject. Because of the statistical sophistication needed to understand the results, the paper will be of interest to the statistician planning life testing experiments rather than to the reliability engineer.

R69-14374 ASQC 824; 413; 822
SOME TESTS OF HYPOTHESES CONCERNING THE THREE-PARAMETER WEIBULL DISTRIBUTION.
Lee J. Bain and Darrel R. Thoman (University of Missouri, Rolla).
Journal of the American Statistical Association, vol. 63, Sep. 1968, p. 853–860. 7 refs.

Tests are developed concerning the mean of the three-parameter Weibull distribution with the variance known and with the variance unknown, and concerning the variance with the mean unknown. The shape parameter is considered known. These tests are compared with tests developed by Harter and Dubey based on the usual statistics for the normal case. A two-sample test for difference in means and for difference in reliability is also discussed. For the most part the tests are simple yet provide improvements over existing methods. Author

Review: This paper makes a contribution to the theory of tests of hypotheses for the mean of the three-parameter Weibull distribution with variance known and with variance unknown and for the variance with the mean unknown. The tests are compared with those developed by Harter and Dubey in the report covered by R68-14100. They are more powerful than the Harter and Dubey tests and may be used with smaller tables than those in the Harter and Dubey report. A two-sample problem is also considered in this paper. The material is clearly and concisely presented and adequately referenced. This paper will be of value to applied statisticians concerned with the analysis of Weibull data, which occur quite commonly in reliability and life testing.

R69-14376 ASQC 821
EXPECTATIONS IN CERTAIN RELIABILITY PROBLEMS.
D. J. Newman (Yeshiva University, Dept. of Mathematics, New York, N. Y.). and W. E. Weissblum (Avco Manufacturing Corp., Wilmington, Mass.).
Siam Review, vol. 9, Oct. 1967, p. 744–747. 1 ref.

Based on a knowledge of the failure rate of its parts, the expected lifetime of a machine made up of several components is discussed. Each component is further composed of several parts. The machine continues to function until any one of its components breaks down, and a component breaks down when all its parts do. An analogy is made with the classical problem of balls in urns. Computation is given for two situations: one when replacements are allowed, the other when they are not. The machine lifetime is established as the random variable minimum. L.B.H.

Review: This is a mathematical paper concerned with the investigation of the expected lifetime of a machine made up of several components, each of which is further composed of several parts. The machine continues to function until any one of its components breaks down, and a component breaks down when all of its parts do. The problem is solved by considering it to be analogous to a problem involving balls and urns, which is a model commonly used in discussions of probability theory. While the mathematics in the paper appears competent, the verbal description is too sketchy for those who might wish to use the results to analyze the corresponding reliability problem. It is not clear that sampling of balls from the urn by replacing each ball selected before the next selection is made is pertinent to the reliability situation which the authors are attempting to analyze. If in fact the sampling with replacement is considered to be pertinent to the physical situation under consideration, then apparently some device for identifying the balls of a given color, such as numbering, would appear to be necessary in order to let the investigator know when all of the balls of a given color have been selected. This information would be available automatically, of course, in the case of sampling without replacement. The question is, however, if one attaches numbers or other identifying marks to the balls of a given color, does this change the probabilistic aspects of the problem? Anyone wishing to use the results in this paper for the analysis of the expected lifetime problem which is cited as its motivation will need to clarify these questions before proceeding. One solution would, of course, be to use the results for sampling without replacement and ignore those for sampling with replacement (the result for this is standard).

83 DESIGN

R69-14332 ASQC 831; 844
EARTH ORBITAL SPACE STATION EFFECTIVENESS: RELIABILITY, SAFETY, AND MAINTAINABILITY.
F. E. Senator, S. S. Calderon, and R. L. Buchanan (McDonnell Douglas Corp., Douglas Aircraft Co., Missile and Space Systems Div., Huntington Beach, Calif.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 11–28. 5 refs.
(A68-37598)

Description of approach for the prediction of the overall reliability of an earth-orbital space-station design and for establishment of the safety and maintainability requirements. Criteria required the utilization of current or near-term subsystem which, as designed and packaged, would not meet the long-life requirements. Repackaging, with accessibility, spares, and redundancy, became mandatory. Design philosophies and methodology were developed for a design approach that improves system reliability and provides a capability to restore the space station during flight. The design philosophy embodies the concept of utilizing man's potential and onboard resources to increase the reliability life of a space station during a 1- to 5-year mission. Design criteria, data, and existing design options were evaluated to increase system reliability. Also, the resources were identified that are necessary to perform in-flight restoration. Author (IAA)

Review: This is a long paper and is of use primarily to those who are already familiar with the various topics mentioned. The novice to manned spaceflight will have to study the paper carefully and long in order to get appreciable value from it. There is of necessity a considerable amount of jargon. (Most of it is explained the first time it occurs; nevertheless, the novice is still at a disadvantage.) The paper does show how difficult it will be to have high reliability and crew safety for a one-year manned mission; the authors' analysis of what needs to be done is generally good. Some details are not clear. The following are examples. (1) In the summary it is stated that a high order of statistical confidence was not possible and as a consequence a high level of engineering confidence would be necessary. In general, the reason why statistical confidence will be less than engineering confidence, in calculations such as these, is that there is engineering knowledge which cannot be translated easily into statistical terms. It is not at all clear from the discussion what this would be. There is further the problem that engineering confidence is often less than statistical confidence when the approximate nature of the mathematical models is taken into account. In a private communication the authors have pointed out that engineering confidence was gained from accelerated tests, subsystem tests, performance variation tests, etc. (presumably in lieu of testing entire systems at nominal conditions). (2) In the discussion on solar cell redundancy, the important approximation is glossed over (viz., assuming that a mean degradation is caused by parts having either zero degradation or complete degradation). This turns out to be a conservative calculation. (The relatively exact method involves using the approximation that the mean of a large sample has a Normal distribution with mean equal to the population mean and variance equal to the population variance divided by sample size.) The authors' assumption is equivalent to assuming the worst possible distribution of degradation for a given mean. Either way the calculations are made, it is obvious that the extra number of cells that must be added to account for the sampling uncertainty is small (about 100 to 600 degraded cells depending on the method used to estimate the variance). Unfortunately, even through the arithmetic is in fact correct and the model is solved correctly, it would appear that there is an engineering uncertainty not accounted for, viz., the actual value of the mean degradation. The tacit assumption has been made that the true mean will require several thousand surplus of degraded cells to be on the safe side which is obviously much more than the few hundred required for statistical sampling confidence. In a private communication the authors have added that the uncertainty in mean degradation is accounted for by various conservative assumptions and design margins. This kind of approach has resulted in needed improvements in hardware at modest cost during planning stages. (3) In the section on spares for constant rate, the terminology is neither consistent nor clear and the algebraic notation is not always clear. It would have been better for this paper if the details of the computational approximations had been omitted.

R69-14333 ASQC 830
LONG LIFE DESIGN FEATURES OF THE NIMBUS 2 METEOROLOGICAL OBSERVATORY.
S. Charp (General Electric Co., Aerospace Group, Missile and Space Div., Re-entry Systems Dept. Philadelphia, Pa.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968 Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 29–49.
(A68-37599)

Review of the long-life aspects of the basic design of the Nimbus 2 satellite which was launched Feb. 15, 1968. The spacecraft includes a three-axis active stabilization and attitude control system which is described. The mechanical design of the spacecraft provided for two independent structural containers separated by a truss structure, the upper unit being the stabilization and attitude controls, the lower unit the sensor ring for payloads. This two-container separation made the center of gravity of the entire spacecraft accessible. The command system allowed 128 encoded and 4 unencoded (emergency) commands. Any 16 of the coded commands could be transmitted from the ground to be stored in a memory, to be actuated at specified times during a given orbit. Significant failures/anomalies which occurred during ground system testing and in orbit are discussed. IAA

Review: This is a documentary type of paper for the significant reliability events concerned with Nimbus I and II spacecraft. This type of paper has appeal to those in the same business who wish to find out what the experience of others has been. It also serves a useful reference purpose for those who have just gotten into the business to see what the state-of-the-art was 3–5 years ago. The paper appears to be reasonably factual and will be useful for the purposes indicated above.

R69-14334 ASQC 838
DESIGN TOOLS FOR THE OPTIMIZATION OF REDUNDANCY FOR A PLANETARY VEHICLE.
H. P. Nicely, Jr. and C. B. Mayer (General Electric Co., Valley Forge, Pa.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 50–60. 7 refs.

An approach is developed to determine mission expected worth (MEW), defined as the sum of probabilities of achieving each useful mission outcome, multiplied by a value associated with that outcome. The major steps of the method are: (1) mission definition, (2) system definition, (3) mission model definition, (4) reliability model definition, (5) reliability predictions, (6) MEW optimization, and (7) results analysis. Emphasis is placed on definition of system functions to be performed during a mission and the criticality of these functions. A detailed functional flow and failure mode effects analysis are the foundation of the approach. Analysis is carried out on independent functional groups and their alternatives, which represent various design approaches and varying degrees of redundancy with differing resource requirements. Reliability models are constructed, predictions are calculated for each alternative, and the optimization is performed by a large-memory computer to determine the set of alternatives which yields the highest probabilistic mission value. L.B.H.

Review: This is a difficult paper to read unless one is familiar with the jargon being used and the methods being described. The methods are good and worthwhile although, as the authors state, many of the principles involved are not new. Thus this paper documents the state-of-the-art at the time this work was being done. For one who has been involved in similar analyses, there is value in comparing the stated procedure with one's own; but the paper is too detailed for the novice. Some of the figures are difficult to read.

R69-14336 ASQC 830; 844
HAZARD ANALYSIS AND IDENTIFICATION IN SYSTEM SAFETY ENGINEERING.
C. O. Miller (Southern California University, Institute of Aerospace Safety and Management, Los Angeles, Calif.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 336–343. 23 refs.
(A68-37620)

Examination of the hazard analysis methodology spectrum, followed by review of hazard identification concepts. The result is an attempt to further delineate the principal system safety contribution during the design process. Viewing the system safety life cycle in toto (a precept that should continually be observed by safety specialists), five basic types of hazard analyses are proposed and discussed: Preliminary Hazard Analysis (PHA), Hazard Mode and Effects Analyses (HMEA); Hazard Integration Analysis (HIA), Job Hazard Analysis (JHA), and Accident/Incident Analysis (AIA). IAA

Review: This paper is as much an exhortation to perform safety analyses in a logical manner throughout a system's life cycle as it is a general description of the classes into which such analyses fall. The discussion can easily be divided into four parts according to when and with what the analyses are performed. The first one is that performed when only the ideas and concepts of the system are available. The second is performed when drawings are available; the third is performed with mockups and actual systems, together with people working in them. The last category is the analysis of accidents and feeding that information back into system design production. As with reliability, safety is "infinite attention to detail," and one of the real needs for engineers who are charged with actually incorporating safety into a system is an indoctrination into the kinds of details to which one must pay attention. The more explicitly these details can be spelled out, the better; although, as mentioned by the author, checklists are no substitute for brains. The paper itself does not contain checklists. All in all, the paper will have most value for those who are trying to plan a safety effort at the managerial level.

R69-14347 ASQC 830; 821

DESIGNING FOR RELIABILITY BASED ON PROBABILISTIC MODELING USING REMOTE ACCESS COMPUTER SYSTEMS.

G. E. Ingram, E. L. Welker, and C. R. Herrmann (General Electric Co., Santa Barbara, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 492–500. 8 refs. (A68-37631)

Discussion of the rationale and some techniques for considering reliability during the process of designing a system or the elements which constitute the system. Emphasis is placed on the fact that the approach to the design process in a probabilistic sense does not present an intractable problem. It is pointed out that "time sharing" computer systems, used from remote access terminals, allow engineers of either the small or large companies to solve complex probabilistic problems efficiently and economically. Author (IAA)

Review: This paper deals largely with explaining the authors' method of numerical combination of random variables and the computer-programs by which it may be put on a time-sharing computer. The discussion is reasonably straightforward; this particular description of a numerical combination method has appeared in the literature before. The three purposes of the paper are accomplished reasonably well. The reader should not be overwhelmed by the authors' combining several techniques into one tutorial paper (presumably, the authors did not so intend). One need not, of course, use a time-sharing computer; one could use any kind of computer. One need not use the specific method of numerical combination given here; one could use another method. It is in the following sense that one can mislead himself in reading the paper. It is easy to get the feeling that the contents of the paper are a package arrangement and that one must use it all or none of it (although the authors probably did not intend that one should get that impression). For those not familiar with probabilistic description during design, or with numerical combination of random variables where necessary, or with the use of a computer, this paper can be helpful.

R69-14349 ASQC 830; 844

DESIGNING FOR EXPECTED FATIGUE LIFE.

E. R. Forrester and V. H. Thevenov (General Motors Corp., Allison Div., Indianapolis, Ind.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 511–519. 21 refs.

Discussion of some of the processing and operational factors which reduce fatigue strength. Emphasis is placed on the finite fatigue life region, often called low-cycle fatigue, because in many lightweight, high-performance systems, hardware cannot be designed for infinite life. An approach for estimating the probability of fatigue failure on the basis of the scatter inherent in material properties and fatigue life is described. IAA

Review: This is generally a good practical paper for design engineers. It will have its greatest use for those who are not entirely familiar with fatigue but must consider it in their designs right away. As these designers become more familiar with the field of fatigue (so that they can handle the language and jargon) they should learn more about it from more complete sources. A considerable number of references are included in this paper for that purpose. There is little if any discussion of random fatigue which is being pushed hard now in some quarters. There are a few editorial problems, for example: (1) The abstract states, "Hardware failures frequently occur at stress levels far below the intrinsic strength of a material." Since the word *intrinsic* is not defined well here, perhaps the authors meant *tensile strength.* (2) On page 516, the statement appears "... the scatter is less in the low-life region near the endurance limit." It should probably read something like "... low-life region *than* near the endurance limit." (3) A value of 6.7% of the mean fatigue strength is suggested as the standard deviation at long life in the absence of test data. It is not clear where this number comes from (especially to two significant figures) when only very rough numbers have been mentioned previously to this and all of them are smaller. (4) On page 514, it is said that parts are rarely given surface treatment to alter fatigue resistance. This may be true in the low-cycle fatigue range but many automotive parts are shot peened, for example, to improve their fatigue resistance. In general, the authors have stuck to very simple, practical advice rather than getting tied up in complicated theory. Often in engineering these are called quick and dirty methods; they are the ones engineers often use but rarely brag about.

R69-14350 ASQC 837

A UNIFIED LOOK AT DESIGN SAFETY FACTORS, SAFETY MARGINS, AND MEASURES OF RELIABILITY.

Dimitri Kececioglu and Edward B. Haugen (Arizona University, Engineering Dept., Tucson, Ariz.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July 14–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 520–530. 23 refs. (A68-37634)

The various definitions of safety factors and safety margins are analyzed and related to the failure governing stress and strength distributions and their parameters. The fundamental definition of reliability is presented and formulated variously. Methods of incorporating the safety factor, or the safety margin, into the formulation of reliability are expounded upon, and unification of the various concepts of safety factor, safety margin, and reliability is achieved. The various unifications are graphically illustrated, to enable the engineer to determine the reliability, the safety factor, and the safety margin he is designing into a component, knowing the parameters of the failure governing stress and strength distributions involved. Author (IAA)

Review: This paper contains some good material, especially for the novice to the field of reliability; the contributions can be thought-provoking for them. The experienced reliability practitioner may find that parts of the paper are irritating to read, present routine applications of well-known theory as advances in the state of the art, belabor the obvious, and/or are misleading; little if anything is outright wrong. For these reasons, the beginner will want to be very careful about what he takes for gospel. Some of the curves in the latter part of the paper which show relationships between various factors of safety and reliability are interesting although they are all virtually limited to the Normal or log-Normal distribution. Unfortunately, this restriction was omitted from Figures 6 and 8. The more knowledgeable person will have to try not to be distracted from the important points. Some examples of the deficiencies are listed below: (1) In Figure 1, the shaded area is a poor way to show the point which is being made. It is not clear what the abscissa is; it is not even clear what the ordinate is. It would have been better to show the shaded area on a separate diagram with strength-minus-stress as the abscissa, and probability density of that variable as the ordinate. Tucked as it is between the two curves, it is misleading. (2) The authors' point Number 4 on page 521 needs to be modified. The criterion for highest probability of failure is not correct since it implicitly presumes that the strength is uniform throughout, and it may very well not be. About all one can really say is that the location with the highest probability of failure will in fact have the highest probability of failure (not a very illuminating tautology). (3) The whole paper applies only where the simple stress-strength theory of failure can be used. For example, it is not valid in fatigue without careful generalizations of the concepts; even then there can be difficulties. On page 522, where the authors mention endurance strength, it is obvious that instantaneous loads above the endurance strength will not produce failure. (4) The factor-of-safety approach does need overhauling. But the discussion in the text ignores some of the historical bases for a factor of safety and the usefulness to which it has been put. In some of those uses it largely and satisfactorily accounted for three things: (a) the failure mode of the test-specimens (usually tensile failure of a simple specimen) was not the mode of failure of the device (often this was fatigue); (b) the actual loads under use conditions were quite different from the nominal loads as calculated (for example, loads due to the inertia of a moving body); (c) the static loads to be applied were not known in any great detail and a factor had to be allowed for user safety. Therefore the scatter in tensile strengths and in some of the nominal stresses was small compared to the size of the safety factor. (5) One of the better definitions for safety margins was not given, viz., safety margin is mean of strength-minus-stress divided by standard deviation of strength-minus-stress. This can be as good an indicator of reliability as a probability which is calculated from unrealistic assumptions about behavior in the appropriate tail regions. (6) The authors point out correctly that "...exact reliability determinations are quite sensitive to the overlapping tails of these distributions." Unfortunately, in much of the discussion in the paper where one is supposed to be calculating a distribution, virtually nothing is known about the behavior in the tail regions, unless it is presumed to be given by one of the conventionally tractable functions. For example, in Figures 7, 8, and 11, the graph extends down to unreliabilities of 10^{-6}. It is ridiculous to presume that anyone knows a failure distribution that far out in the tails away from the data, for any real physical situation. Obviously, as the figures show, it is extremely easy to calculate for a mathematical model.

R69-14352 ASQC 833; 770; 844

AN INSULATION MATERIALS DESIGN TO ACHIEVE A HIGH RELIABILITY, MEDIUM WEIGHT WIRE.

William W. Dunn (Raychem Corp., Menlo Park, Calif.)

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July–17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 537–546. 3 refs. (A68-37636)

Data on 600-volt medium-weight wire insulation are presented and discussed. Comparisons are made with other commonly used insulations. These comparisons include size, weight, flammability, current overload, and mechanical toughness. The examination of these properties combined with numerous quality control checks gives an indication of the reliability of the finished product. The construction described in the paper consists of a 0.010-in. core insulation of radiation cross-linked modified polyalkene over which is extruded a 0.005-in. wall of modified polyvinylidene fluoride, which subsequently is radiation cross-linked. The polyalkene core possesses excellent electrical properties while the polyvinylidene fluoride, being a very tough polymer with a high modulus of elasticity, offers a high degree of resistance to physical damage. Author (IAA)

Review: This paper shows the kinds of detail to which one must pay attention in order to develop a reliable hook-up wire. The paper will most probably be of interest only to wire specialists, whether users or manufacturers. The ordinary designer should have at least a rough idea of the kinds of failure modes expressed in this paper, so that he can design around them. There are many tradeoffs on the actual selection of a wire; for example, one may wish to standardize on one type that will be suitable for all needs; therefore sometimes a better wire will be used than is absolutely necessary. In this case, the great benefits of standardization (economic as well as reliability) overcome the extra cost of the wire.

R69-14359 ASQC 831; 882

FIGURES OF MERIT FOR THE DIAGNOSTICS OF A DIGITAL SYSTEM.

Herbert Y. Chang (Bell Telephone Laboratories, Inc., Naperville, Ill.).

IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 147–153. 7 refs.

The concepts of accuracy and resolution of a diagnostic procedure are introduced. Both measures are computed using diagnostic data obtained from the fault simulation process and used as figures of merit for the diagnostics applied to the system. With these measures the designer is able to evaluate his diagnostic program design and dictionary or catalog techniques prior to the actual field implementation. The results obtained by applying these measures to an electronic switching system are also discussed. Author

Review: This is a good paper which introduces some concepts not ordinarily encountered in the reliability literature. They are nevertheless useful for techniques of measuring which are designed to assure high system availability. The paper is well written with a minimum amount of jargon, so that most reliability engineers can understand it. The assumptions and approximations are clearly stated, so that it is easy to understand exactly what problem the author is talking about. While the paper itself is nominally confined to the diagnostics for a digital system, the principles are applicable to other systems as well. Thus the paper has broader application than might at first appear; it can be of value to both designers and reliability engineers.

R69-14364 ASQC 838

A STANDBY REDUNDANT MODEL WITH NONINSTANTANEOUS SWITCHOVER.

V. S. Srinivasan (Ministry of Defence, Research and Development Organization, Directorate of Scientific Evaluation, New Delhi, India).

IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 175–178. 4 refs.

The case of a standby redundant system is considered where the switchover is not instantaneous. The duration of time between the instant at which action is initiated on the standby subsystem in order to bring it to the active state and the instant at which it becomes operating standby is called switchover time, and is considered to be a random variable. A policy specifying the instant at which action is initiated on the standby subsystem in order to bring it to the operating standby state is proposed and under this proposed policy, the Laplace transform of the probability density function of time to system failure and the expression for expected time to system failure are derived. Author

Review: This paper presents some interesting results in an area which may be important in particular circumstances. The mathematical derivations are somewhat heuristic, but it is fairly clear that they could be "cleaned up" without too much difficulty.

R69-14367 ASQC 838

OPTIMUM REDUNDANCY USING LOSS FUNCTIONS.

Jon A. Jenny (Stanford University, Stanford, Calif.).

IEEE Transactions on Reliability, vol. R-17, Sept. 1968, p. 181, 182. 3 refs.

A technique for synthesizing reliable systems using parallel redundancy at the subsystem level is described. The specification of a loss function allows the calculation of the average expected loss which can be used to determine the optimum amount of redundancy for a given application. This optimum is statistical and therefore applicable only when the mission is performed many times. Author

Review: This paper contains an algorithm similar in form (but differing in its details) to some others for calculating optimum redundancy. In general, one calculates the increase in some figure-of-merit (usually reliability) for adding one redundant unit to each series element in the system. The one providing the greatest increase in figure-of-merit is then used and the entire operation repeated until some bound is reached (usually some constraint is violated or the increase in figure-of-merit is negligible). In the case of this paper, the figure-of-merit is the average expected loss (the loss function is a monotonically decreasing function of time); the process is terminated when the change in average expected loss is less than the cost to achieve that improvement. It is a method with which reliability engineers should be familiar. In Fig. 3, the parameter C_T is not defined but is apparently the cost of the redundant system whereas C_1 is the loss if the system is never available (i.e., the initial value of the loss function). It is not clear how sensitive conclusions (1) and (2) are to the particular data chosen for illustration. For example, in papers written by authors at Bell Laboratories, Inc., it is shown that even higher reliability than available today would be economically feasible in the telephone systems. One also has to be careful in this kind of analysis that the loss function *in fact* appropriately weights all of the factors involved including some of the ones which are difficult to make tangible. It is also very possible that after doing an analysis like this and finding that its logical consequence is that very poor reliability is acceptable, a good reaction would be to change the model, rather than to accept the decision.

84 METHODS OF RELIABILITY ANALYSIS

R69-14331 ASQC 844

AN ENGINEERING APPROACH TO LONG-LIFE COMPLEX SPACE SYSTEMS.

B. H. Caldwell (General Electric Co., Aerospace Group, Missile and Space Div., Philadelphia, Pa.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July – 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 2 – 10. 2 refs.

(A68-37597)

A number of significant failures or malfunctions occurring in flights of complex spacecraft during the past few years have been analyzed to search for systematic or generic failure sources and causes. Although failures occurring in both ground test and in actual flight operations were studied, only the flight failure data are included in this paper. The failure data are presented in a variety of ways, and from these presentations certain general conclusions pertinent to program managers, spacecraft designers, and test managers can be drawn. The data show that about half of the flight failures are due to design deficiencies and about a fourth are such that the failure effects can be prevented only by use of redundancy or alternate modes of operation. Author (IAA)

Review: Even though this paper is directed toward the hardware aspects of space systems, it has a good message for those who are doing theoretical work. It clearly shows what kinds of problems actually exist in the final hardware and where theoretical effort could be put with good effect. Unfortunately, these areas are extremely intractable for theorists and are not particularly interesting to them. The "infinite attention to detail" we hear so much about in Reliability is shown to be very important. Just how a designer goes about paying more attention to detail may be difficult for both him and his manager to decide, but obviously it needs to be done. Even though the paper can have its greatest impact on hardware engineers, it should be required reading for all desk jockeys who do not often brave the world of hardware. The author is to be commended for publishing these data and his analyses of it. (Unfortunately, some of the graphs are not clear, due apparently to poor markings on the vertical scale.)

R69-14351 ASQC 844; 716

AGING EFFECTS IN AU-AL AND AL–AL BONDS USED IN MICROELECTRONICS.

J. H. Anderson, Jr. and W. P. Cox (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Research Laboratories, Palo Alto, Calif.).

In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July – 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 533–536. 8 refs.

(A68-37635)

One-mil-diameter gold and aluminum wires were bonded to thin films of a aluminum by thermocompression and ultrasonic techniques, respectively. Both kinds of bonds were aged at temperatures up to 400°C for times as long as 2000 hr, and the tensile strength and electrical resistance of the bonds were measured as a function of the aging conditions. The electrical resistance of the Au–Al bonds increased with high-temperature aging, whereas the Al–Al bonds did not degrade electrically. However, the strength of the Al–Al bonds declined as they were annealed under high-temperature aging, whereas the strength of the Au–Al bonds remained essentially unchanged. Author (IAA)

Review: This paper is a straightforward, informative comparison of gold–aluminum and aluminum–aluminum bonds as used with contemporary silicon integrated circuits. The emphasis is on the demonstrated reliability and the consequent practical implications rather than the physics of bond failure. Figure 4 which shows the allowable time at various temperatures before increases in Au–Al contact resistance occur should be of particular interest. The paper is short but nevertheless sufficiently thorough to interest both the novice and the expert. It is well-organized and well-written—almost a model of technical-paper preparation.

R69-14353 ASQC 844
EXPERIENCE DERIVED GUIDELINES FOR EFFECTIVE FAILURE ANALYSIS.
James R. Koch (Honeywell Inc., Aerospace Div., St. Petersburg, Fla.).
In: Annals of Assurance Sciences; Proceedings of the 7th Reliability and Maintainability Conference, San Francisco, July – 17, 1968. Conference sponsored by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Aeronautics and Astronautics. New York, American Society of Mechanical Engineers, 1968, p. 547–553. 2 refs.
(A68-37637)

Actual case histories of failure analyses are drawn from experience on the Dyna Soar/X-15, Centaur, Gemini and PRIME programs to illustrate the controls, disciplines, and analytical capabilities essential to the effectiveness of failure analysis activities. Selected examples cover a wide range of part failures involving electrical and electromechanical devices. Each failure analysis is examined to identify the factors which contributed to its success or failure. The examples reviewed illustrate the two basic requirements for effective failure analysis: (1) control and documentation of design manufacture, assembly, and test activities; and (2) laboratory analysis capability to determine the specific failure mechanism of the smallest failed part. Author (IAA)

Review: This is a good paper for at least the following two reasons: (1) It is realistically written. Many people can identify themselves with the examples. (2) The recommendations are valid and necessary ones where very high reliability is essential. The beginner should be aware that there are many situations in industry where the economic vs. reliability factors will be such that one prefers to take his beating on reliability occasionally in order to avoid the expense of maintaining all of the records and a failure analysis laboratory. He should also be aware that not every failure requires an extensive investigation in order to determine why it happened and what could be done to prevent its recurrence. This paper may be helpful to those who are having difficulty convincing their managements that money invested in good reliability techniques can pay off.

R69-14356 ASQC 844
SYSTEM PATHOLOGY.
Peter H. Fowler (TRW Systems Group, Effectiveness Analysis Div., Redondo Beach, Calif.).
IEEE Transactions on Reliability, vol. R-17 Sept. 1968, p. 122–126. 7 refs.
(A68-44393)

A system of classifying failures is proposed as a starting point for increasing the amount of science in the art of reliability engineering. Failures are classified as: (1) lack of qualification, (2) human error and (3) wear out. Subsets are proposed covering the majority of failures observed in practice. Usefulness of the classification is illustrated by relating specific methods of failure control to each type of failure. Validity of current reliability prediction techniques is discussed. The suggestion is made that validity and accuracy would be improved if new predictive methods were used which are more directly related to the distinct type of failure being examined. Author (IAA)

Review: It is gratifying to read an article on reliability engineering in which the author indicates that the function of reliability engineers is something less than complete management of the company. The tasks suggested here are reasonable, even if somewhat controversial as to their exact nature and degree. This article is another one of those attempting to clarify the qualitative nature of eliminating failures and is a worthwhile addition to this literature. As in any classification scheme, it is necessary to refine extensively the descriptions of the categories until they are reasonably clear to everyone and are reasonably non-overlapping. Examples where improvements in these descriptions are desirable are the following: (1) In type II the phrase "just like the drawing" is used. All drawings, like other specifications, are incomplete in some respects. Further, the distinction is not clear between this and type I errors when the tolerances are too wide on the drawings, because some parts made to the drawing will work and other parts made to the drawing will not. (2) In type IIa the phrase "faulty piece part" is used. Since the specifications for the part will be incomplete, just as the drawings are incomplete, it is sometimes difficult to tell whether a part is faulty or not. It may be difficult, for example, to find a nondestructive test method to measure the ability of the part. An example of this might be the breakdown voltage in a capacitor. Further, being faulty is often a matter of degree. (3) The distinctions between type IIIa and type IIIb parts are not as clear as the author intended. Apparently, environmental damage is to include such things as that due to operating voltages rather than just to the environment external to the equipment. In type IIIa some phrase other than "thermodynamic equilibrium" would be helpful, since it is not clear what is in the closed system and what is not. For example, a capacitor with voltage on it obviously is accumulating damage such that the part is approaching thermodynamic equilibrium—if the voltage on the capacitor is included in the thermodynamic system. (4) The idea that a production lot can be divided into two groups, those which are defective and those which are not, is very difficult to elucidate in a meaningful, unambiguous manner. For example, if the endurances of the various parts have a distribution extending to that equivalent to an extremely long time of operation, one will never completely eliminate all of the parts with less than the maximum endurance. One needs to try making more exact statements about the nature of the endurance distribution of parts. For example, the endurance would be suggested as falling into two quite distinct groups, one rather low and one quite high, the latter being over and beyond anything the part will be called upon to produce. (5) In the suggestions for controlling type IIIa failures, the first one is not sufficiently exact. It is the failure mechanisms which should have high activation energy and, even there, all one is really after is that the rate of occurrence under operating conditions be sufficiently small. (6) In the next item, where derating is suggested, one has to be very careful to distinguish between a nominal derating and actually reducing the severity level. Relays are an excellent example of this. All in all, this paper is a worthwhile contribution toward making the reliability engineering function more scientific.

R69-14368 ASQC 844; 555; 838
RELIABILITY CALCULATIONS.
EDN, vol. 13, Nov. 25, 1968, p. 26, 27.

Methods for calculating equipment reliability are given with sample problems and solutions. One equation and nomograph are presented to determine the probability of success, which is related to a given mission time and mean time between failures. A second equation and nomograph are described for situations in which the reliability specified is such that two or more identical systems are paralleled. The required redundancy is thus calculated. L.B.H.

Review: This is part of a special issue on instrumentation and measurement in which a page or two is given to each of many types of calculations that must be made. In general, nomographs and articles of this kind are intended for the convenience of experienced designers rather than the edification of the neophyte. This holds especially true for the present paper. Items that should be carefully considered and which are not mentioned in the paper are the following. 1. The titles on the two nomographs are reversed. 2. The exponential assumption is the only one considered for the calculation of reliability in terms of time. Many others are possible. 3. The equation for redundancy presumes statistical independence among the failure events (the exponential assumption is not required). This is a critical assumption and is often not true in systems where, for example, (a) the damage is likely to be mechanical and the redundant elements are close together or (b) the exact environmental profile is uncertain. The nomographs themselves are spot checked and appear to solve the equations correctly. On Nomograph 2, the time need not be in hours but merely must be the same for both mission-time and MTBF. This paper when originally published was covered by R65-11883.

R69-14375 ASQC 844; 775
THE DEVELOPMENT OF NONDESTRUCTIVE TESTING.
Leslie Mullins (Kodak Ltd., Harrow, Great Britain).
(National Fall Conference of the American Society for Nondestructive Testing. 27th, Cleveland, Oct. 16, 1967.) Materials Evaluation, vol. 26, Jun. 1968, p. 93–105. 13 refs.

The current definitions of nondestructive testing are critically reviewed. Some aspects of the history and current status of the technology are discussed to provide a background for guidelines for the development and expansion of the art under the headings training, research and expansion of nondestructive testing with areas not currently using the techniques. Planned development is recommended. Author

Review: This paper is typical of many survey papers on nondestructive testing (NDT); it reviews the definitions, traces some aspects of the history, and indicates the current status of NDT. The need for coordinated training centers for NDT personnel and a need for more research to develop new methods are discussed. Brief reference is made to cost factors and economics of NDT. This paper is essentially a highlighting of some of the important problems in the field of NDT, many of the techniques of which have an important role to play in ensuring the reliability of equipment. However, the paper presents no detailed information on any of these techniques. Thus it will be of general interest to those who are concerned with the development of the NDT industry, but not of practical value to test engineers who are utilizing NDT techniques, or are seeking new uses for them.

R69-14379 ASQC 844;775
MUST ALL WELDS BE DEFECTFREE?
Neale E. Orrok, ed.
Metal Progress, no. 5, Nov. 1968, p. 107, 108, 110, 112, 114, 116. 1 ref.

The test program for evaluating the effects of a variety of weld defects and joint conditions on the performance of butt-welded pipe joints is reviewed. The fatigue behavior of defective and pilot welds made to high standards as compared. The objective of the program was to establish a level of merit for pilot welds and then determine the severity of a given defect which would reduce fatigue behavior. Results led to the conclusions that some types of defects do not seriously affect fatigue life of butt-welded pipe; other types of defects or joint conditions permitted by the specification, NAVSHIPS 250-692-2, do seriously reduce fatigue strength; the natural notch at the root of a weld overrides the effect of all but the most gross defects, and the fatigue properties of backing-ring joints are generally inferior to those of consumable-insert joints in mild steel. The defects studied were slag inclusions; porosity, repaired burn-through, spaced-ring condition, root undercut, root concavity, crater pits, incomplete insert melting, root oxidation, counterbore, and excess weld-face reinforcement. S.P.G.

Review: The subject of this paper is becoming more well-known in the industry. It is not limited to welding along, but is applicable to all nondestructive test methods wherein the sensitivity has become so high that it can detect discrepancies in the material which do not damage any of the material's essential properties. In each one of these fields and for each kind of situation, the techniques used in this paper must be applied; that is, discrepancies are introduced into the material either during processing or afterwards and the properties of the part are tested (in this case, it was fatigue strength). Then those discrepancies which actually cause harm can be measured and new standards of acceptability (in terms of the test radiographic inspection here) can be promulgated. As the use of nondestructive testing grows, both in the kinds available and the amount to which it is used, this problem will become greater. In some cases, it may be most convenient to disallow certain discrepancies, not because they do harm but because they are too hard to distinguish from discrepancies which are severe defects. This paper is a good one and a valuable contribution to the state-of-the-art. Those who are active in this field would be well advised to be acquainted with its contants.

R69-14381 ASQC 844
FATIGUE FAILURE OF A REDUNDANT STRUCTURE.
R. A. Heller (Columbia University, Institute for the Study of Fatigue and Reliability, New York, N. Y.). and R. C. Donat (Columbia University, Dept. of Civil Engineering, New York, N. Y.).
In: Structural Fatigue in Aircraft: American Society for Testing and Materials, Pacific Area National Meeting, 5th, Symposium, Seattle, Oct. 31–Nov. 5, 1965, Papers. Symposium sponsored by Committee E-9 on Fatigue of the American Society for Testing and Materials. Philadelphia, American Society for Testing and Materials, 1966, p. 55–66. 8 refs. Research sponsored by Columbia University.
(Contract Nonr-266(91))
(ASTM-STP-404; A67-23432)

Multiple-load-path redundant structures have been utilized in "fail-safe" design applications for a long time without a thorough investigation into the statistical nature of their failure. Experiments conducted on a model ten-member redundant structure subjected to constant-amplitude loads have been analyzed, and the statistical distribution of consecutive failures was determined. The experimental results are compared with various theoretical computations which were found to be conservative. Author (IAA)

Review: The development of the model for failure in this paper is not clear and contains either logical inconsistencies (mathematical errors) or a definition which is too elastic and subject to the whim of the authors. For these reasons it is difficult to find the exact spot at which the paper's troubles occur. It is even more difficult to write a lucid review which will explain the source and cure of the troubles. (Some private correspondence over an extended period from one of the authors has helped, however.) Reference 4 of the paper contains a similar development and this review applied to it as well. The authors' model for damage accumulation can be written as follows: $dA/dN = -A^*K$ (1a) where: A is a parameter that can be visualized as a simple cross-sectional area of an axial specimen, A^* is the value of A at the beginning of the "step" and is a "constant" insofar as N is concerned, K is a constant which depends *only* on the present load, not on any history of the specimen, and N is the number of cycles of load (considered to be a continuous variable). (A_o will be used later to denote the initial value of A before any loads are applied.) The "step" referred to in the definition of A* is not yet defined, and, indeed, is too elastic. Three cases can be extracted from the paper: (a) constant amplitude load—the "step" begins when the load is first applied, (b) redundant structure—a "step" begins each time one of the elements fails, and (c) in a sequence of random loads, the "step" begins at the start of the sequence. Since the paper's troubles appear to be localized in this concept of step, the concept will be explored further. As the title states, the paper is concerned with a redundant structure. The total load is appropriately divided among the supporting elements and the structure is fatigued. As each supporting element fails, the load it once supported is likewise appropriately divided among the survivors. When all have failed, the structure fails. Thus, if a constant amplitude *load* is applied to the structure during its life, the *stress* on an unfailed element will increase in a "step" at each element failure. Presumably the authors are willing to consider a random (stationary statistics?) load applied to the structure. The stress amplitudes in nonfailed elements likewise have the same random character as the load, except for the "step" increases in amplitude at each element failure. An individual element does not *know* what is going on in the rest of the structure. All that it *knows* is the magnitude of the uniaxial cyclic stress being applied to itself. Thus, for all it *knows*, it is on a fatigue machine with a programmed load. Once we are this far, a *reductio ad absurdum* can be set up. Suppose the programmed load has very small increases in stress occasionally. Each one of these increases is a "step," so that A* must be reckoned anew at the beginning of each one. Let the size of those increases go toward zero; A* is still reckoned anew at the beginning of each one. But if there were no "step" at all, A* would stay constant at the original value A_O before the test. A model which gives different answers for a "step" of zero size and for no "step" at all is in trouble. A different *reductio ad absurdum* can be considered by assuming that each "step" length is only one cycle long; since N is being considered as a continuous variable, formally $N \rightarrow 0$. Then Eq. 1a becomes $dA/dN = -AK$ (1b) which gives a quite different law of cumulative damage from 1a or 1c. A reasonable way out of the dilemma is to put $dA/dN = -A_OK$. (1c) Then the model development would proceed in the following way from Eq. 1c. The criterion for failure is defined by the relationships $P = A_OS_O = A_fS_u$ (2) where: P is the load, A_f is the value of A at failure, S_O is the initial stress, S_u is the ultimate strength (In the paper, this is a random variable; the demonstration of trouble is simplified by calling it a constant.) The balance of the demonstration is more easily carried through with normalized variables. Define $s \equiv S_O/S_u$, $a \equiv A/A_O$. Then $da/dN = -K$, (3a) $a_f = s$. (3b) Eq 3a is easily integrated to $\Delta a_s = -K_s \Delta N_s$, (3c) i.e., the change in a for a given loading is proportional to the number of cycles of that loading and to a constant which depends *only* on that load. The subscript s has been added to emphasize this point. If the load is programmed, with θ_i cycles during the i^{th} step at load s_i (and if failure does not occur), then $a_j = I - \sum_i K_i \theta_i - K_jn_j$ (from I to j-1) where: a_j is the value of a after n_j cycles of the j^{th} step. (This much of the development is consistent with the authors' expression for an equivalent K for a random sequence.) Define $a_j^* \equiv 1 - \sum_i K_i\theta_i$ (from I to j) as the value of a immediately before the j^{th} step. Then $a_j = a_j^* - K_jn_j$. (4) The authors' "corresponding" equation is equivalent to (in this notation, much of which is copied from the authors): $a_j = a_j^*(I - K_jn_j) = a_j^* - a_j^*K_jn_j$. (5) Equations 4 and 5 are the same except for the factor a_j^* in front of the K_jn_j. (This is the possible mathematical error mentioned in the first sentence of this review.) It would appear that the authors have the alternative of using Eq. 1b or 1c. One might be preferred over the other on physical grounds, but you cannot change failure laws in the middle of a derivation. Equation 1c unfortunately is very similar (in its non-probabilistic formulation) to the Palmgren – Miner (PM) model of cumulative damage (the PM model can be extended to give itself a probabilistic basis). Equation 1b would require considerable modification of the authors' paper, but probably would give a radically different model for cumulative damage. There are other less important poor places in the paper; examples are the following: (1) Eq. 1 of the paper can be written more exactly as $\lambda dN = pr\{r(N) \leq s \leq r(N + dN)\}$. If N is a continuous variable, and otherwise one could not integrate with it, the hazard rate is *not* a probability. Eqs. 3 and 5 could be similarly modified. (2) It would have been helpful if Eq. 5 had not been written in such shorthand notation; not even a general integration region is indicated. (3) $\bar{s}_u$ should not appear in Eqs. 10 and 11; it is confusing. Furthermore, the authors do not show the way in which they are comparing theory to experiment — that is, there is no indication of how they are evaluating the various parameters that appear in their equations. The authors state that some of the data imply a fatigue life below which the probability of failure is negligible. It is not at all clear how the data imply this since many of the curves which are not drawn that way could easily have been drawn to show such a minimum life. It is not at all clear why curved lines appear on some data sets and straight lines on the others. It should further be noted that some of these straight lines, if extrapolated, will cross at a fairly high number of cycles. This, of course, cannot happen. Therefore, it is easy to conclude that the drawing of these curves is more a personal art than a science. This difficulty also goes back to the fact that the authors did not clearly indicate how they were estimating the parameters in the equations from the data points. Since the authors' s_u is a random variable whose distribution does not depend on the stress level, there is implied (as shown by the authors in their Reference 4) a particular relationship between the probability distribution function for life and the one for s_u. It would be interesting to explore this relationship (both experimentally and theoretically) to see if it is true. In summary, the paper presents an ambiguous theory of cumulative damage and some very valuable experimental work. The methods by which the theory is compared with experiment are not clear.

R69-14382 ASQC 844

STUDY FRACTURE SURFACES TO PREDICT METAL FAILURES.

John A. Mock.

Materials Engineering, vol. 66, Oct. 1967, p. 90–91. 5 refs.

Fractography is discussed as a means of predicting metal failure by determining the mode of fracture (intergranular, cleavage, or shear), the origin of fracture, and the location and nature of flaws that may have initiated the failure. Characteristics of fractures are noted, along with recent achievements in fractography. Microscopes for both solid and nonsolid surface observation and study are discussed as important tools in metal failure research. L.B.H.

Review: This paper is designed to introduce the non-specialist into the field of fracture observation. The actual fractured surface of a material (usually a metal) can give much information about the local properties of the material and how it had been used. The paper shows what kinds of things can be observed and some results obtained with fractography. It does not tell what those techniques are nor give any of the details of fractographic analysis per se. There are four general references (largely ASTM and ASM publications) where one can get further information. The analysis of failures and determination of their causes is certainly one of the important parts of reliability engineering and this paper can introduce reliability engineers to yet another tool with which they may not be fully familiar. It uses a minimum of jargon and thus should be quite understandable to the intended audience.

85 DEMONSTRATION/MEASUREMENT

R69-14369 ASQC 851; 771; 824; 844

RELIABILITY OF ENGINEERED SAFETY FEATURES AS A FUNCTION OF TESTING FREQUENCY.

I. M. Jacobs (General Electric Co., San Jose, Calif.).

Nuclear Safety, vol. 9, Jul./Aug. 1968, p. 303–312 1 ref.

The reliability of an engineered safety system is highly dependent on the frequency of tests performed to demonstrate its operability. Thus the frequency of tests becomes a design consideration of utmost importance. When the system is new, the operator must rely primarily on the designer's recommended test frequency. With actual in-service experience, the operator is able to regulate the test frequencies to attain an overall reliability goal. Under certain limiting conditions, there is clearly an optimum test frequency; more frequent or less frequent testing will degrade reliability. Techniques of modeling have been developed to solve safety-system reliability problems. The models serve as the means to bridge the gap between the uncertainty of design decisions and the stark reality of actual application. Author

Review: This is a well-written paper on the subject of check-out testing of safety systems. It is concerned with the time interval between tests as a design consideration, optimizing the availability by proper selection of the time interval between tests, and adjusting the time interval between tests on the basis of field failure-rate information to assure conformance to a reliability goal. While the author is concerned specifically with reactor safety systems, the ideas have much wider applicability. The underlying assumptions are clearly stated and the mathematical treatment is readily comprehensible to those with a knowledge of elementary probability. Appropriate illustrative figures are used throughout the paper. Points which the author emphasizes are that the designer should consider the testing program for his system from the outset of the design, and that the reliability analyst should strive for testing programs which are optimum in a well-integrated system design. This is a worthwhile message for reliability engineers and designers of aerospace systems, as well as those concerned with reactor safety systems.

R69-14370 ASQC 851; 844

THE PROGRESSIVE-STRESS VOLTAGE ENDURANCE TEST METHOD FOR EVALUATION OF HIGH VOLTAGE, TURBINE-GENERATOR INSULATION SYSTEMS.

Harold N. Galpern (General Electric Co., Medium Steam Turbine, Generator, and Gear Dept., West Lynn, Mass.).

Reprinted from *Proceedings of the 7th Electrical Insulation Conference, Oct. 15–19, 1967.* 3 p. 5 refs.

The progressive-stress and the conventional fixed-stress voltage endurance test procedures used on two high-voltage insulation systems are compared. Fixed-stress voltage endurance testing was carried out at five different voltage stress levels, and the progressive-stress voltage endurance testing was carried out at six different rates of voltage stress increase. Six test specimens were used at each voltage stress test level for both tests. It was concluded that the progressive-stress test method affords insulation system voltage endurance curves equivalent to that obtained by the conventional fixed-stress test method, and that a time savings of approximately 50% in actual testing time is achieved by the use of the progressive-stress test method. S.P.G.

Review: This paper is a comparison of constant-stress versus progressive-stress tests and shows that in the cases considered, the two kinds of testing give consistent and closely agreeing results. Since the progressive-stress method gives results in a much shorter time, especially for preliminary results, it is of great value. The author states that they are now using it exclusively in his department. The subject of accelerated testing is an important and controversial one; publishing of this kind of data is especially valuable since it helps to reduce the areas of controversy. The 95% confidence lines in most cases appeared to be parallel to the center straight line, whereas they should diverge. It should be noted that this confidence band gives the uncertainty in the average value, not the range in which 95% of the population would lie (the latter is called a tolerance interval). The confusion in distinguishing between these 2 statistics is yet another reason why the complete equation for life vs. voltage should be given. For example (using the author's notation) one could write $\log T_F = \log T_R - m \log V_R/V_F + \sigma\epsilon$ where T_F and V_F are the failure time and voltage, V_R and T_R are a reference voltage and failure time, σ is a constant, and ϵ is a random variable with a standard Normal distribution, T_R, m, and σ are to be estimated from the data. For large extrapolations, the uncertainty in m is often the major cause of the uncertainty in T_F. Even so, the uncertainty is over a factor of 10 and approaches a factor of 100 in time. In some situations, although apparently not here, there is a maximum value of stress which cannot be exceeded without drastically changing the nature of the failure.

R69-14377 ASQC 851; 770; 844

HOW TO USE IC RELIABILITY SCREENING TECHNIQUES.

Richard E. Howard (Transitron Electronic Corp., Wakefield, Mass.).

Evaluation Engineering, Nov./Dec. 1968, and Jan./Feb. 1969, p. 22–26 and 8, 10.

The relative merits of screening tests designed to assure integrated circuits (IC) reliability are compared. The screening tests evaluated were pre-cap visual examination, high temperature bake, temperature cycling, constant acceleration, X-ray, hermeticity, burn-in, and electrical testing. The purpose of any screening is defined as the detection and removal of devices which could cause failure in the user's system; the selection of tests should be compatible with the user's equipment requirements and should not add to the probability of failure. Tabular data on IC failure mechanisms and screens is provided. S.P.G.

Review: The photographs in this paper of defective integrated circuits are reproduced very well and are a substantial part of the usefulness of the paper. The information will be of value to anyone involved with IC reliability. There is worthwhile mention of (1) defects which are caused by test equipment (the test equipment produced voltage spikes under certain conditions and ruined the transistors) and (2) the fact that screens should be based both on the individual part and on the particular manufacturer who is making it (so as to catch as many as possible of the vagaries which can be introduced by his particular production line). It is easy to tell that this paper was written by a manufacturer rather than a consumer, especially from the emphasis on all the cooperation the customer will get from the manufacturer. For a comparison with a consumer-oriented article in IC reliability, see [1]. The chart of "failure mode" vs. "screening technique to avoid it" (in Part II of the paper) will be very useful. The article does not actually compare the techniques (contrary to the editor's statement), but it will be an extremely good starting point for anyone who wishes to institute screens.

Reference: [1] "Sure, integrated circuits are improving, but it's no time for complacency," by John H. Simm, *Quality Assurance*, vol. 7, Nov. 68, p. 48–51.

R69-14378 ASQC 851; 770; 844

SURE, INTEGRATED CIRCUITS ARE IMPROVING, BUT IT'S NO TIME FOR COMPLACENCY!

John H. Simm (Beckman Instruments, Inc., Electronics Instruments Div., Richmond, Calif).

Quality Assurance, no. 11, Nov. 1968, p. 48 – 51.

Integrated circuit (IC) reliability was investigated and major causes of failure were analyzed. Principal defects which escape assessment in the manufacturing process were found in wiring, bonding, metalization, surfaces, die-header, and bulk. The IC packaging was also noted to be a significant reliability factor. Test procedures are discussed, including computerized test facilities, infrared scanners, go/no-go electrical testers, and screening and preconditioning methods of detection. L.B.H.

Review: It is not difficult to tell that this article is written by user rather than a maker of integrated circuits. Somehow no matter how objective each kind tries to be, the articles come out sounding very different. For a manufacturer's approach see [1]. This paper is written from the point of view of the commercial user rather than the exotic military or NASA user. It nevertheless offers extremely good advice in addition to sound criticism of manufacturers and their propaganda. The author points out that it is not wise to accept the idea that incoming quality will be good. The figure he uses in some examples is 10% defectives. By some very simple screens, he has reduced the percent defective to about 0.5% (the last line of the article should read "... dropped to less than 0.5%", rather than "... dropped to less than 5%"). Presumably, these are digital rather than analog ICs. Unfortunately, the author does not say what kind of incoming inspection he uses to save over $5000/mo. in scrap and rework costs. (In a private communication he has indicated that the tests are thermal shock and functional tests at 50°C.)

Reference: [1] "How to use IC reliability screening techniques", by Richard E. Howard, Evaluation Engineering, vol. 7, Nov/Dec 68, p. 22–26.

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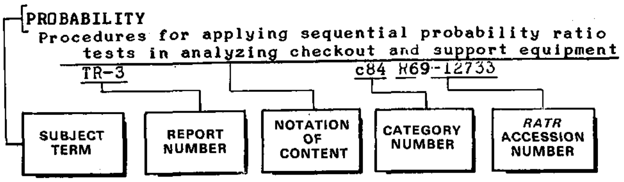

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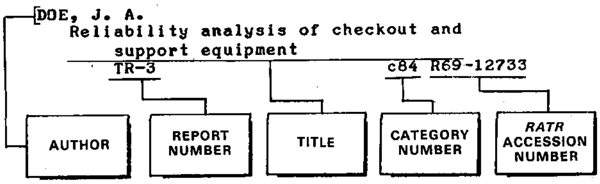

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Reliability Abstracts and Technical Reviews

The first section of *RATR* contains bibliographic citations, abstracts, and reviews. The items (each identified by an *RATR* accession number) are arranged in subject categories based on the first two digits of the codes developed by the American Society for Quality Control. The complete listing of these ASQC codes appears on the inside back cover. Examples of citations of reports, journal articles, and conference papers are shown below. The principal subject field of the item (and therefore the category in which the item appears in the journal) is indicated by the first ASQC code number; related subject fields are indicated by additional code numbers. The appearance of a *TAB, STAR,* or *IAA* accession number indicates that the item has been announced in, respectively, *Technical Abstract Bulletin, Scientific and Technical Aerospace Reports,* or *International Aerospace Abstracts.*

The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

***RATR* ACCESSION NUMBER**	R69-12733 ASQC 844; 413	**ASQC CODES**
	General Equipment Company, Banville, Calif.	**CORPORATE SOURCE**
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	**PUBLICATION DATE**
CONTRACT OR GRANT	(Contract NAS15-13411)	
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	***TAB* AND *STAR* ACCESSION NUMBERS** / **AVAILABILITY SOURCE**

***RATR* ACCESSION NUMBER**	R69-12739 ASQC 814	**ASQC CODE**
TITLE	**SEMICONDUCTOR RELIABILITY.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	**AUTHOR AND AFFILIATION**
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER**	R69-12765 ASQC 773; 221; 823	**ASQC CODES**
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).	**AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*	
	Available from Assoc. of Reliability Eng., New York: $1.00	**AVAILABILITY AND PRICE**
***IAA* ACCESSION NUMBER**	(A69-12407)	

VOLUME 9 NUMBER 5

Reliability Abstracts and Technical Reviews

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May 1969

80 RELIABILITY

R69-14412 ASQC 802
RELIABILITY THEORY AND PRACTICE.
Igor Bazovsky (Genge Industries, Inc., Scientific and Consulting Div., Sherman Oaks, Calif.). Englewood Cliffs, N.J., Prentice-Hall, Inc., 1961, 292 p. 35 refs.

The subject of reliability is quantitatively treated, and reliability concepts and methods are developed logically from simple components to complex systems. The objective is to show the engineer how to solve reliability problems by analysis, design, and testing. Reliability formulas are presented as an aid in predicting system reliability, establishing reliability goals, and determining the procedures necessary to achieve them. It is pointed out that reliability is closely connected with the concepts of system maintainability, availability, and safety. A quantitative treatment of these concepts is included, and the methods to be followed are outlined. Author

Review: This was one of the very first reliability books and is still referenced in the current literature. It is appropriate at this time to review the book in the present-day context to see how useful it still is. In general, it is not now a very good book, better ones have since been published. The dustjacket propaganda is overly optimistic, as is to be expected, and the statement "This book encompasses the entire field of reliability engineering" should be taken as a definition by the publisher that reliability engineering consists of what is covered by the book. The emphasis is largely on those techniques applicable to electronics systems. Claims for newness, while possibly true when the book was published, are no longer true, perhaps due in large part to its presence. The book is concerned largely with the mathematics of reliability (which is considered as a probability of success); there is little mention of management techniques, government documents, and the like. The qualitative aspects of the book tend to be very good. On the other hand, often throughout the book the mathematical theory is inadequately (and sometimes incorrectly) presented, and more recent books on the subject should be consulted, especially those which consider probability theory as a mathematical theory in its own right and then apply it to the reliability problem. Virtually all of the probability formulas for more than one event (in Chapter 6 et seq.) are true only if the events are statistically independent; yet this limitation is rarely if ever mentioned. It is wise to use the modifier "statistically" when writing for engineers, so they do not confuse statistical independence with physical independence wherein one is concerned with cause and effect. Since reliabilities are probabilities, all the formulas for reliability of several events are subject to the same difficulty. Probability is defined in terms of relative frequency, rather than being introduced as a mathematical concept which has application to certain phases of engineering. The author's approach leads to some difficulties, especially when comparing probabilities in the model to probabilities in practice. He does not adequately distinguish between the probabilities derived for a simple-minded model and the behavior of the real world. Further, much of the text seems to be a collection of examples as opposed to a development of the subject. Since the mathematical theory of probability was not developed in this book as a self-contained, self-consistent discipline, but rather introduced piecemeal as required, a reader relying on this book for his knowledge of the subject should not feel confident to apply the theory in cases not explicitly treated in the text, for the simple reason that he does not know what the general principles are. Thus the engineer is presented with an accumulated miscellaneous assortment of facts, rather than a coherent body of theory based on a very few assumptions which he can readily verify. Detailed comments on each chapter are given below (the general ones above apply to all chapters). They are largely negative, since the reader presumes that the technical book he is reading is accurate unless he is otherwise advised. Not all nomenclature and concepts in reliability are standardized, so that some of the comments can be considered more opinion than categorical fact, and the reader will have to decide for himself what he prefers. *Chapter 1.* The breakdown of failures into early, wearout, and chance is done here. Unfortunately the last term implies that failures in the early and wearout regions are not random events, whereas they are. A better term than "chance" or "pure chance" would be the "constant hazard rate" region. There is little in this chapter to make it out of date. Many of the engineering problems which are mentioned are still with us. *Chapter 2.* (a) The author tries to eliminate anything but success/failure in reliability determinations. Work has been done with many different possible states and a different value attached to each of those states. (b) In the discussion of drift failures, the author becomes somewhat involved in semantics. Where any apparent paradoxes are involved (such as saying the equipment malfunctions but none of its parts malfunction) the sources of paradox are inadequate definitions of what one is talking about. *Chapter 3.* (a) The author states that if there are no early failures or wearout failures, the device must follow a constant hazard rate formula (the author's terminology is "chance failure rate"). This of course is not necessarily so or perhaps should be taken as a definition of "properly debugged". (b) No distinction is made between mean time between failures and mean time to failure. *Chapter 4.* The author's derivation of hazard rate (failure rate) is not illuminating since one can start with the final result by definition. Some of the descriptive properties of various reliability functions, such as the probability density function, are true in general for all kinds of probability functions, whether related to reliability or not. *Chapter 5*. One needs to be very careful about implying the causes for a bathtub curve and in giving rigid reasons why the hazard rate in the central portion must be constant and why it behaves as it does elsewhere. This chapter gives some useful information as long as the statements are interpreted qualitatively. *Chapters 6–7*. (a) When the author states that "the Normal distribution depends upon age, whereas the exponential does not!" he is really discussing just the hazard rate, not all properties of the distribution itself. Just why the author uses the term *a priori* probability of failure is not clear, since the *a priori* seems to serve no useful purpose. The author's use of a priori and a posteriori probabilities is not in accordance with useful statistical custom, especially in a text wherein Bayesian probabilities are used. Apparently the implied event in the author's use of the two terms is whether or not the equipment has been observed to see if it is still operating. (b) The author states that one cannot use the Normal distribution if it would have appreciable area below the zero value of time. While this is strictly true, this is not the only alternative. One can, of course, use a truncated Normal distribution. (c) In interpreting some of the calculations the author performs and the resulting conclusions about what should or should not be done, it is important to keep in mind his figure-of-merit. Other figures-of-merit are possible, especially with respect to replacing elements which may enter a wearout phase. One example is minimum cost. (d) The author uses extensive algebra in discussing the conditional failure probabilities. It could have been appreciably shortened by using the hazard rate as follows: The probability of survival during the time interval t_1 to t_2 (given operation at time t_1) is $\exp(-\int_{t_1}^{t_2} \lambda\, dt)$. If λ is a constant the probability is obviously a function of the time difference only. If λ is not a constant, this probability is much less in periods of high hazard rate than in periods of low hazard rate. (e) One must be careful about the way in which one combines probability of failure due to both "chance" and "wearout". When some of the probabilities are small, approximate methods may be all right, but when these probabilities are high, exact formulas must be used. It is often desirable in the latter case to use hazard rates, since normalization factors are not required for them. (f) One need not be overly concerned about distinguishing between "chance" and "wearout" failures. Usually one cannot tell by looking at a failed component whether the population was in a period of very high and increasing hazard rate, or in a period of low and constant hazard rate. *Chapter 8*. (a) The failure models implied by the author's discussion are not too clear. Sometimes a simple stress–strength model appears to be implied, and other times it is some kind of cumulative damage model. One should be careful about blithely utilizing concepts from mechanical failure of metallic specimens under simple uniaxial stress. For example, a component is said to have failed when it no longer performs its function. How one wants to interpret this in terms of stress relative to strength, a degraded strength, or cumulative damage, depends on other considerations. For example, a pipe may fail because the cross section is reduced by corrosion (like the steel water pipes in your house). Stress and strength are inadequate for describing this situation. (b) It is an extremely hazardous process to ascribe specific, definite, immutable reasons and descriptions to what is happening in the infant mortality, constant hazard, and wearout regions of the bathtub curve. Therefore the discussions of early failures should be interpreted qualitatively. (c) The statement that early failures are distributed exponentially is not in accord with the earlier graphs. In that event the graph would have two horizontal lines for hazard rate, one initially high and the other following it at a low value. (d) The author has still another model for the decreasing hazard rate in the infant mortality period and goes through some complex mathematics with it. These manipulations tend to be irrelevant in practical engineering situations since the numbers are derivable only from experience and usually after the fact. *Chapter 9*. (a) The emphasis on chance failures which continues throughout the text is controversial. It is considered in engineering that every failure has a cause. We are not operating near the quantum mechanical or statistical mechanical limits of our hardware. We may wish for our personal convenience or because of our ignorance of some of the factors of manufacture to describe the life behavior by probability distributions. (b) The proof of the formula that mean life equals $\int_0^\infty R(t)dt$ is exact, not approximate as suggested by the author, and there is not the implied limitation on the hazard rate, it may even decrease steadily. The only requirement is that the mean exist in the first place. (c) The discussion of the Poisson distribution is heuristic at best. The derivation is not a derivation at all, but merely a good device for remembering what the formula is. *Chapter 10*. (a) Equation 10.1 (or a logical equivalent) is the definition of two events' being statistically independent, not something that follows when the two events are otherwise known to be independent. (b) In equation 10.3 if the events are mutually exclusive, obviously, they cannot be statistically independent. The equation is true, however. (c) *On page 87 the author gets into still further trouble* when he implies that independence is physical independence rather than statistical independence. A good example of the situation when this is not so occurs when there are two possible environments which differ appreciably in their severity. Given a particular environment, the failure events might be statistically and physically independent. But if the environment is not given, then unconditional failure events can no longer be statistically independent. (d) The author states that all complex systems are series systems. This statement is not true unless it is used as a definition of complex. (e) On page 90 the hazard rates should have units associated with them. Apparently the author means to imply that each one is "per hour". At the bottom of the page the author is incorrect when he says, "this does not mean that the circuit could be expected to operate without failure for 10,000 hours," since that is exactly what we do mean (assuming the technical meaning of *expected*). What we do not mean of course is that a substantial fraction of a population of such circuits would operate for that length of time without failure. (f) On page 2 there is a stricture to use as few components as possible for high reliability. This is valid where only catastrophic failures are concerned. Where drift failures are important, the use of extra components in such configurations as negative feedback often tremendously improves the overall reliability. *Chapter 11*. (a) On pages 101–102 the calculations with triple redundancy can be misleading because *both* sets of calculations are for no repair, whereas the author implies that only the second set is for no repair. The reason that the two calculations give such different answers is that the two figures-of-merit are different (one is probability of failure, the other is an MTTF). Inadvertently the author shows why *the mean time to* failure is often not a good figure-of-merit for redundant systems. (b) The author is too categorical in his denunciation of "parallel" redundancy for resistors and capacitors (he says that it cannot improve the reliability). In a private communication he has stated that there was an implicit restriction to analog circuits. *Chapter 12*. On page 114 reliabilities of 0.905 and 0.9953 are asserted to be only slightly different. The failure probabilities, however, differ by a factor of 20, which is a significant difference. Chapters 13 and 14 are adequate. *Chapter 15*. (a) The author repeats the by-now familiar fallacy that, "...exponential components do not deteriorate with time and are subject to chance failures only." Exponential components can deteriorate with time just as much as any component. The only requirement is that the initial values and rates be such that the final distribution is in fact exponential. (b) The author makes the incorrect comment "When components can fail only because of chance, the system will fail only because of chance" ("chance" in this text implies the exponential distribution or Poisson behavior). Exponential components can be combined to give a nonexponential system. (c) The author states the Arrhenius law poorly; a better way is to give the law itself. In this chapter as in others, it is the qualitative expression of problems and difficulties that are good. The author's explicit solutions are not necessarily the only ones or the best ones. *Chapter 16.* Unfortunately the author states early that the human factors of operating and maintenance personnel should not enter into system reliability design. It should most definitely come into it (but there is little mathematics involved). Some of his latter explanation agrees that it should be considered. *Chapter 17* on maintainability is good as far as it goes; it considers only averages. Chapters 18 and 19 are adequate. *Chapter 20.* The specific courses of action recommended by the author are governed by figures-of-merit which are usually implicit rather than explicit. Choices of different figures-of-merit will result in different actions being recommended. *Chapter 21.* (a) On page 209 the author makes the mistake of assuming that the log-Normal distribution is a wearout distribution; it is not. Since the log-Normal has a *decreasing* hazard rate as time becomes large, it cannot be a wearout distribution, by definition. This again shows that the author's emphatic distinction between the two kinds of failures (wearout and "chance") leaves much to be desired. (b) On p. 212 the author implies that the best estimate is always the maximum likelihood estimate; whereas this of course is not necessarily so, there being no universal criteria for "best". This is further illustrated by the first footnote on p. 221 where a non-maximum likelihood estimate is called "optimum." (c) The footnote for Eq. 21.11 discusses the unbiased estimate of the variance, not of the standard deviation. *Chapter 22.* (a) The formula on page 228 does not give an unbiased estimate of the population standard deviation, but it is the statistic that is required for many calculations. (b) The author does not mention the student's t distribution which would have gotten him out of some of his difficulties with requiring large samples from a Normal distribution. (c) In the discussion on arranging a test, it is important to consider the differences between a single sample and a sequential test. While the equations 22.25 and 22.26 might look as if they are of a sequential nature, they are not, since they are an endeavor to keep the total test time the same as originally stated, but the ensuing discussion talks about other situations wherein the test becomes a sequential one. Since the literature (especially that written for engineers) tends to be very misleading, if not erroneous, on this score, it is wise to consult a statistician who is familiar with this kind of testing before going ahead with an important program. (d) In the example on page 239 the statement is ambiguous because the proper statistical formula to use classically depends on original intention, not on coincidences which may occur. Thus one needs to know whether it was intended to stop the test on the twentieth failure or at 2000 test hours. The fact that they occurred virtually simultaneously is not valid basis for proceeding with a classical analysis. In general, however, the discussion on confidence limits is good. *Chapter 23.* The continual distinction between "wearout" and "chance" failures is not always useful. In fact, unless "wearout" is of the kind showing actual physical wear, the difference between the two is difficult if not impossible to detect when looking at a particular failed part. *Chapter 24* on sequential reliability tests is good. Subsequently to this book, Aroian has published extensively on truncation of this kind of test and his work should be consulted. One must be careful in discussing confidence levels associated with sequential tests because using the results for single sample distributions can result in errors. Again a statistician qualified in this subject should be consulted, if it is important to have correct answers. In a private communication the author has mentioned that he is working on a new, completely revised edition with five more chapters added.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14392 ASQC 813; 830

EXPLORER 33 AND 35-RELIABILITY ACHIEVEMENT BY DESIGN.

Ronald H. Broadhurst (Bird Engineering-Research Associates, Inc.). in : *EASCON'68; Institute of Electrical and Electronics Engineers, Electronics and Aerospace Systems Convention, Washington, D. C., September 9–11, 1968, Record.* p. 422–430 New York, Institute of Electrical and Electronics Engineers, Inc., 1968, p. 422–430. 7 refs.

(A69-13232)

Description of the reliability performance of Explorer 33 and 35, which were placed in selenocentric orbits by the Anchored Interplanetary Monitoring Platform (AIMP) Program. The two spacecraft, launched by a Delta booster, measure properties of interplanetary plasma and magnetic field. The spacecraft design achieved or surpassed the reliability goals by: (1) employing extensive parallel redundancy for the retromotor control circuitry; (2) minimizing the number and complexity of essential series-reliability blocks; (3) using digital circuitry almost exclusively; and (4) incorporating a large safety factor in solar array output. In six experiments, considerable data redundancy was provided by overlapping measurements of plasma and magnetic field. Additionally, all experiments have sensor arrays or one sensor for several independent measurements. Both missions were officially classed as successful. IAA

Review: This is a typical paper written about a spacecraft after a reasonably successful mission showing why the spacecraft was a success. The actual mean-time-between-failures was over ten times that predicted on the basis of MIL-HDBK-217. The author attributes this to the great care taken for a reliable design. The philosophy expounded here is good and those who are involved in spacecraft design should be aware of it. Two minor comments on the text are: (1) The author's reference 3, used for a source of exact probability theorems, should be used for those theorems only by experienced personnel. The novice may be led astray by some of the wording. (2) The concept of inherent failure rate is ambiguous at best. In practice, inherent failures tend to be only those that the designer cannot blame on someone else. In this situation, since MIL-HDBK-217 presumably gives an *inherent* failure rate and the spacecraft did not experience that rate, obviously not all of the failures were *inherent*. Often a better term to use is *reference failure rate*.

R69-14395 ASQC 810; 612; 844

RELIABILITY IN COMPUTER PROGRAMS.

J. L. Sauter (International Business Machines Corp., San Jose, Calif.).

Mechanical Engineering, vol. 91, Feb. 1969, p. 24–27.

The failure of the $18.5 million Mariner 1, due to a missing bar over a letter in a computer equation, is discussed in relation to the need for stimulating interest in programming reliability. The three elements comprising a computing system are discussed: the hardware, the operating system usually written by the manufacturer, and the application programs written by the user for his own specific application. Consideration is also given to a typical hardware system, and hardware and programming similarities are compared. A programming development process for each and every phase of the program is depicted, along with the data bank feedback cycle. Recommendations made to deal with the problem include: (1) As human error is a prime cause of program failure, psychologists should begin to examine the causes through the use of controlled experiments. (2) Specific maintainability solutions should be proposed to existing problems. (3) Better methods should be developed for specifying and controlling program requirements, reliability, and testing through the operational phase. (4) The ability to tie hardware and program together in a total systems reliability management plan should be developed. M.G.J.

Review: Although the title is different, this paper is essentially the same as the one covered by R69-14309.

R69-14403 ASQC 817; 825; 831

SUBSYSTEM OPTIMIZATION EFFECTIVENESS IMPROVEMENT BY THE OPTION TRADEOFF ANALYSIS PROCESS.

Stanley Laut (Aerojet-General Corp., Azusa, Calif.).

IEEE Transactions on Systems Science and Cybernetics, vol. SSC-4, July 1968, p. 33–37. 8 refs.

An approach for optimum effectiveness improvement of subsystem equipment by the option tradeoff analysis process is discussed. The objective is to generate more effectiveness ideas in furthering tradeoff procedures for subsystem design improvement. Two hypothetical spacecraft subsystems are used to illustrate the results. A sequence of block diagrams, tabulations, and graphs is presented to reflect these results. Although only two subsystems are shown, it is apparent that this method could be applied to others. Author

Review: This paper identifies and illustrates some of the attributes which are appropriate for cost effectiveness analyses, and cites some pertinent references. It does little more than that, and readers interested in tradeoff and cost effectiveness analyses should not consider it as representative of the state-of-the-art of this type of analysis. Readers who are seeking an introduction to the topic addressed by this paper should look elsewhere in the literature. Reference 1 of this paper would be a good starting place. Effectiveness tradeoff analyses typically are seeking some measure for effectiveness, for cost, and for bringing these two together. There are usually many indirect considerations (some of which are mentioned in this paper) which cannot be reflected in these measures, and these are carried along in some appropriate manner so that the decision maker is aware of them. The attributes of equipment performance capability, operational reliability, and tactical availability as noted in this paper are typically thought of as determining the effectiveness. The author obtains a numerical value for each of these for the entire system and then multiplies them together. He acknowledges that he is doing something out of the ordinary. Models for obtaining this type of effectiveness should take into account system state dependence. This involves using matrix algebra and is not overly complicated, considering the scope of the problems being addressed. The simplified type of model proposed in this paper is inconsistent with the numerical reliability measures which are cited to five decimal places. The cost aspect of what this paper is proposing is particularly difficult to understand. The nomenclature is unusual and is not well defined. Part of it has little precedent. The term "functional worth" is particularly elusive. User's costs are apparently considered as being something separate from recurring costs, and just how these and other cost categories relate to the important consideration of total lifetime costs and other principles of engineering economy is not at all clear. This paper uses an unusual method for bringing together effectiveness and cost in that it converts cost to some measure having no unit, and simply includes this in the simple product noted above for effectiveness. The author does not justify his use of this cost effectiveness model. The paper is rather short and oversimplifies the problem to which it is addressed. Terms need to be defined much better and more support needs to be presented for some of the approaches taken. Strange terminology is used, such as that on Page 135 regarding conventional and elementary reliability block diagrams and their associated equations. Figures 7 through 9 are each a family of curves and at first glance appear to contribute something substantive; but it turns out that they are only a family of curves of products and quotients which are used simply to show the location on the graph of some of the effectiveness and cost attributes of the examples.

R69-14404 ASQC 810; 830

Boeing Co., Renton, Wash. Supersonic Transport Branch.

RELIABILITY MAINTAINABILITY: CONCEPTS AND TECHNIQUES IN DESIGN OF AIRCRAFT SYSTEMS AND COMPONENTS

[1967] 22 p

(AD-664370; N68-18722) Avail: CFSTI

The paper discusses the subsonic service experience, the application of this experience to the design of the Mach 2.7 SST, and the establishment of definitive reliability and maintainability goals for each SST subsystem. These goals were established, based on Boeings analysis of the airline experience, with appropriate factors applied to account for the differences in supersonic and subsonic flight profiles, flight and ground environments, and subsystem configurations. The SST landing gear and hydraulic subsystems were selected to illustrate the manner in which reliability and maintainability requirements, compatible with the continuing changes in airline maintenance concepts, have been incorporated into the SST design. In addition, the manner by which these design improvements were analyzed with respect to their effect on dispatch and block-to-block reliability and maintenance man-hours and task times is reviewed. The paper also briefly discusses how the reliability, maintainability, safety, and human engineering programs are integrated with the current SST design effort to provide Boeing, the FAA, and airline management with visibility and assurance that the program goals will be met. Author (TAB)

Review: The first part of this report deals with a very general assessment of reliability requirements for the supersonic transport (SST). The second part gives some reliability figures for subsystems on several in-service aircraft and compares them with the reliability goals for the SST. The method of making the analysis and allocations is briefly explained. The authors show how the loop is completed by making modifications in design when the reliability figures of merit predicted for a subsystem fall short of the requirements. The loop is also completed by modifying the designs in accordance with field experience of in-service aircraft. The paper uses general, easy-to-understand terms with negligible jargon. It is suitable for managers and newcomers to the field.

R69-14405 ASQC 810;871

Douglas Aircraft Co., Inc., Long Beach, Calif. Aircraft Div.

PREDICTIVE MAINTENANCE, FORLORN HOPE OF FORESEEABLE REALITY?

R. V. MacGregor [1967] 31 p

(AD-664371; N68-18697) Avail: CFSTI

Consideration is given to predicting the maintenance of functional subsystems and components of aircraft based on the theory that it is better to detect and correct deteriorating functional conditions than to isolate and correct active malfunctions or failures. The prerequisites of predictive maintenance are delineated, and the problems of identifying and specifying probable modes of malfunction or failure are illustrated. A distinction is drawn between functional perfection and malfunction, and an assessment is made of three characteristic modes of malfunction and the time factor which is involved. The provisions which make it possible to determine and measure deterioration in the hydraulic subsystems, mechanical/electrical subsystems, and components of the DC-9 are discussed. The future applications of predictive maintenance are briefly mentioned in relation to an onboard computer that can provide instantaneous malfunction detection and fault isolation capabilities. B.S.D.

Review: This is a good paper. The ideas are sound and well presented, and a sense of realism pervades the discussion. Most of the activities are those which many reliability engineers would include in their own discipline but there is no need to start a war over names. As the author seems to imply, predicting the time of occurrence of severe degradation is going to be very difficult because of the tremendous uncertainties involved. It is and probably will continue to be much simpler to monitor the degradation or performance itself either continuously or intermittently and use the results as a basis for preventive maintenance. The author unfortunately uses the poor current jargon which equates random failures to the Poisson distribution whereas, of course, all that *occurring at random* means is that the exact time of occurrence is uncertain. The times themselves are not constrained to have any particular one of the probability distributions. The author does wisely point out that where the hazard rate is reasonably constant or decreasing, preventive maintenance often makes little sense (except where the condition can be monitored and more information about the individual members of the population can be obtained). The article is short and easy to read; the examples are from a commercial jet aircraft.

R69-14406 ASQC 810; 871

Trans World Airlines, Inc., Kansas City, Mo.

CONTROL OF PERIODIC MAINTENANCE THROUGH RELIABILITY ANALYSIS SYSTEMS

B. M. Meador [1967] 6 p Presented at the FAA Maintenance Symp., Oklahoma City, 7 Nov. 1967

(AD-664374; N68-19713)

A general discussion is presented on methods of improving reliability of commercial aircraft. TAB

Review: This is a rather general discussion of the reliability/maintenance area and will be a good introduction for managers and others who have no time for details. The author makes some very good points; for example, some parts are best left alone until they fail, disturbing and testing them is apt to decrease their life rather than to increase it and does not help in finding soon-to-happen malfunctions. The paper is valuable for reliability engineers since it shows that the development of newer techniques in the field of reliability does not mean that the old ones are completely thrown out. For example, periodic maintenance is still a useful thing. Apparently quasi-periodic maintenance is also used wherein some subsystems which have degraded, but not sufficiently to require repair, are removed to ease the scheduling of service work. The idea is to maximize safety and service and to minimize overall airline expense at the same time.

R69-14409 ASQC 810; 871

Atlantic Aviation Corp., Wilmington, Del.

MAINTAINABILITY AND RELIABILITY OF AIRCRAFT SYSTEMS

John G. Hite 9 Nov. 1967 10 p Presented at FAA Maintenance Symp., Oklahoma City, 7–9 Nov. 1967

(AD-664380; N68-18701) Avail: CFSTI

Topics include: Why do we need maintainability: How does a manufacturer obtain maintainability: Who can detect the need for something lacking in systems maintainability: Some prime examples of poor maintainability: Systems maintainability in the future. TAB

Review: Reliability and maintainability are discussed by giving a series of illustrations of poor design and then at least one case of a redesign so that an item no longer needed regular maintenance. The perspective is that of a professional maintenance shop man whose concern is with the frequency, difficulty, and expense of performing required maintenance operations. Perhaps the important question to ask is, "Are retrofits and living with bad problems cheaper than the effort it would take to analyze in more detail the actual design and construction of the aircraft?" In some cases it may be cheaper to live with the problems, but it is very likely that that time is receding into the past. Designers and reliability engineers should expose themselves reasonably often to *horrible hardware* stories of this kind. Perhaps a man cannot be a good designer until he has scraped many a knuckle in servicing the kinds of hardware he is to design. That kind of experience gives a man a different outlook on life than does approaching it from the perspective of a nice clean desk.

R69-14410 ASQC 810; 871

Eastern Air Lines, Inc., Miami, Fla. Power Plant Engineering.

EASTERN AIR LINES' REAP: RELIABILITY ENGINEERING ANALYSIS AND PLANNING PROGRAM

Max Dow 7 Nov. 1967 47 p refs Presented at FAA Ann. Maintenance Symp., Oklahoma City, 7 Nov. 1967

(AD-664377; N68-18814)

REAP embraces the essential principles set out in the FAA Handbook for Maintenance Control by Reliability Methods. These principles include: (1) Measure and audit. (2) Check and balance in decision making. (3) Maximum decentralization for flexibility and responsibility plus communication to a central FAA. TAB

Review: At the close of this paper, the author might have written, "Knowledge is necessary, but when the chips are down, wisdom is what counts." The maze of going into detail in order to get more information, so that optimum decisions can be made is a difficult one to solve, but this paper takes a good crack at it. It contains more technical jargon and engineering sophistication than many of the other reliability papers at this symposium. The problems the airlines face are very real ones. Airlines are at the point where they are operating a public utility in terms of the analytic depths into which they can go for their economic and reliability optimization. The spirit of cooperation that exists among the operating lines in exchanging engineering information would make the public feel happier if they knew about it. The kind of research described in the paper is not as romantic as some that gets done for space vehicles, but it is nevertheless an extremely important part of our engineering aerospace effort. This will be a good paper for reading by those who have the background to follow it well.

R69-14411 ASQC 810; 871

Allegheny Airlines, Inc., Pittsburgh, Pa.

FUTURE APPLICATIONS OF MAINTENANCE RELIABILITY SYSTEMS FOR THE SMALL FLEET OPERATOR

R. J. Masiello Nov. 1967 10 p Presented at FAA Maintenance Symp., Oklahoma City, 7–9 Nov. 1967

(AD-664375; N68-19611) Avail: CFSTI

The report discusses application of reliability systems by expanding data base of small fleet operators, i.e., Concorde, Airbus and DC-9 by pooling experience across corporate lines. Positive fall out of reliability systems is the necessity to manage. Reliability systems systemize the measure, analyze, and repair loop. Decreased dependence upon diagnostic and correction capability of individuals or single operators is noted. Wider use of reliability systems in the future will reduce cockpit workload associated with operational status of equipment. Author (TAB)

Review: This paper deals largely with ways by which the small operator can increase the reliability of his small fleet of aircraft. The major way is to pool knowledge on similar equipment. It is suggested that in the future much of the avionics gear can be made self-checking, redundant, etc., to reduce the chance of failure in flight and to make servicing easier. The idea of pooling information by fleet operators and by manufacturers of a specific type of gear is a good one for the reasons the author suggests. Trying to cross the lines of avionics manufacturers and thus allow Company A to get excessive information about Company B's faults may meet with resistance among some of the electronics companies. Some of the prognostications for the future of computerized data handling can easily be interpreted as providing more benefits sooner than is likely to be the case. The time scale is at least five to ten years before practical economical computers will do what many people envision for them.

R69-14419 ASQC 810; 870

United Air Lines, Inc., San Francisco, Calif.

UNITED AIR LINES TEST AND REPLACE AS NECESSARY (TARAN) PROGRAM

N. K. Davis Nov. 1967 12 p Presented at the FAA Maintenance Symp., Oklahoma City, 7–9 Nov. 1967

(AD-664376; N69-71925)

Test And Replace As Necessary (TARAN), the hydraulic system overhaul plan, is discussed as a mature program which has become a routine part of each turbine airplane's maintenance. Its implementation is based on the following primary qualifications which a system or component must meet: (1) adequate visual inspections; (2) normal performance of functions when last needed by the flight crew; and (3) internal leakage measurement to determine the condition of critical internal parts. TARAN's operation is described as a methodical procedure of measuring system fluid flow, scoring the results to allow for orderly, preplanned replacement during the airframe overhaul, and flow checking again. A removed component receives its own TARAN check in the shop, where the philosophy of minimum disturbance is again followed. At three month intervals TARAN officials meet with FAA representatives to review the program status. Benefits of the program are discussed, and consideration is given to applying TARAN to other systems. L.B.H.

Review: With the increasing complexity of both mechanical and electronic systems over the past two decades, it has become apparent that tearing into many things just to see if they are working right will cause more troubles than it will fix. This paper describes an example of the application of this kind of philosophy to the hydraulic systems of various aircraft. Of course the details of the procedure that must be gone through are much more complicated than appears from the brief statement of the principle, and this paper shows the time and effort that are required to apply it. The results so far have been worthwhile and the company is looking around for other places to apply the principle and for ways in which their particular procedures can be modified to increase reliability and decrease costs. In the present circumstances, they were apparently able to get both at once. Often one is limited to increasing the reliability at no cost or to decreasing the cost for the same reliability, but either of these lesser goals is still a worthwhile achievement. The paper is suitable for people at a management level who are interested in (a) finding out how others have proceeded, (b) knowing the general kinds of caution that are necessary, and (c) getting an idea of the benefits that will be obtained.

R69-14421 ASQC 810; 871

Applied Science Associates, Inc., Valencia, Pa.

DEVELOPMENT OF FULLY PROCEDURALIZED TROUBLESHOOTING ROUTINES Final Report, Apr.–Nov. 1966

Thomas K. Elliott Wright-Patterson AFB, Ohio AMRL Nov. 1967 64 p refs.

(Contract AF 33(615)-3966)

(AD-664076; AMRL-TR-67-152; N68-18299)

Several studies over the past decade have shown that proceduralized troubleshooting can produce acceptable or better performance of this complex maintenance task while permitting substantial reduction in the costly training typically associated with its accomplishment. The term proceduralized troubleshooting is usually applied when the decision about where the system the technician is to check next, based on the results of previous checks, is made by a performance aid which directs his actions. This same performance aid, however, can also display expected normal readings and tolerance, test point locations, test equipment and test selection parts identification, and much other necessary and/or useful quidance. The method described follows from experiences with and subsequent to development of a fully proceduralized within stage troubleshooting performance system for purposes of experimental evaluation. It is based upon the rationale of maximizing information gain per unit test or operation cost. Examples of troubleshooting procedures developed for use in the evaluation are presented and described. Author (TAB)

Review: This is a good paper on the topic. It is not a definitive one but does discuss well and realistically many of the important points. The real-world outlook on what technicians do or do not do is especially helpful; some papers tend to dwell on what could be accomplished if repair technicians were different (much more capable on the average). The discussion limits itself to the routine wherein a complete choice is made with only one test; that is, one is not allowed to have a complicated truth table. The discussion is apparently also limited to electronic systems. Many prognosticators hope to have self-checking hardware available so that locating the source of the trouble can be done more automatically. The preliminary experiment showed that differences in aptitude between the two groups (high and low aptitudes) were not related to differences in performance with the proceduralized trouble shooting routines. It did not test the difference between this kind of routine and other kinds nor any one of several other things that could have been done. (This is not to condemn the experiment but merely to emphasize the limitations of it.) A later report by the author and an associate [1] describes experiments which show that the proceduralized routines with relatively unskilled technicians (the two groups above) were appreciably more effective than conventional methods executed by the usual technicians. The methods certainly seem worth exploring further. They do put a greater load on the equipment cost, although this extra cost would presumably be more than offset by reduced maintenance costs. These techniques are important to reliability and design engineers since they involve tradeoffs that need be made on the equipment.

Reference: [1] Thomas K. Elliott and Reid P. Joyce, "An experimental comparison of procedural and conventional electronic troubleshooting," Technical Report AFHRL-TR-68-1, Air Force Human Resources Laboratory, AFSC, W–P AFB, Ohio, Nov. 68.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14389 ASQC 824; 822

Purdue Univ., Lafayette, Ind. School of Electrical Engineering.

ESTIMATION OF PROBABILITY DENSITY AND DISTRIBUTION FUNCTIONS

R. L. Kashyap and C. C. Blaydon Aug. 1967 18 p refs IEEE Transactions on Information Theory, vol. IT-14, Jul. 1968 p 449–556

(Contract N00014-67-A-0226-0004; Grant NSF GK-1970)

(AD-660690; TR-EE67-14; N68-12110)

First and second order stochastic gradient algorithms are developed for suitably approximating the unknown density and distribution functions of a random vector, from a sequence of independent samples. Mean square error criterion and the integral square error criterion are used in the approximations. The rates of convergence and the approximation error are also evaluated. Author (TAB)

Review: This report presents an interesting application of the stochastic approximation method to the problem of estimating distribution functions and density functions. The estimates are obtained from a sequence of samples, and are required when determining the conditional rate of failure (hazard rate) in reliability theory. However, the procedure given involves estimating a certain approximation of F (or f) instead of estimating F (or f) directly. The authors establish various results, one of which is that the estimates converge with probability one to the approximate F (or f) as the sample size tends to infinity. However, it would seem to be more important to have the approximate F (or f) depend on the sample size and indeed converge to the true F (or f) (in an appropriate sense). In an example, the authors show how their estimates compare with an approximation to F but say nothing about how close this approximation is to the true distribution function. Finally, the authors' use of the same notation for random vectors and the arguments of their distribution functions is a bit confusing. The authors' definition of mean-square error is quite different from that used by Parzen in [1] for a similar problem.

Reference: [1] E. Parzen, "On estimation of a probability density function and mode," *Ann. Math. Statist.*, vol. 33 (1962), pp. 1065–1076.

R69-14390 ASQC 824

Lockheed Missiles and Space Co. Sunnyvale, Calif.

ON THE ANALYSIS OF THE EXCURSIONS OF RANDOM FUNCTIONS

A. S. Gusev 1967 5 p refs Transl. into ENGLISH from Izv. Vyssh. Ucher. Zaved., Mashinostro. (Moscow), no. 3, 1967 p 27–31.

(N67-36498)

The problem of determining the number of excursions of a random function beyond a certain level possessing statistical properties is considered herein. This problem is of interest in connection with the question of cumulative damage and the estimation of the reliability of a structure under random loadings. The case investigated herein is when the "danger" level can be represented as the series with stochastic coefficients distributed normally, and according to Rayleigh. Author

Review: This paper presents some heuristic derivations on the mean number of excursions of a random function $\sigma(t)$ above a random level A(t) during a fixed time interval. Equation 5 implies the stochastic independence at time t of the following two functions: (1) $\sigma(t)-A(t)$ and (2) the derivative process $\dot{\sigma}(t)-\dot{A}(t)$. However, for several of the special cases considered this assumption does not hold, thus involving a logical contradiction. In the other examples, it should be pointed out that a stationary form is implicitly assumed.

R69-14391 ASQC 824; 614

California Univ., Berkeley. Operations Research Center.

AN APPLICATION OF THE BRANCH-AND-BOUND METHOD TO THE CATALOGUE ORDERING PROBLEM

Leonard J. Jacobson Jul. 1968 22 p ref

(Contract Nonr-3656(18))

(AD-675035; ORC-68-20; N69-12566) Avail: CFSTI

A parallel (or series) system of components is considered. Each component of the system is assumed to be chosen from a set of available components each with a specified reliability and a specified cost. The problem, that of minimizing the cost of the system while guaranteeing a specified system reliability, can be written as a zero-one integer program. A branch-and-bound algorithm is the suggested solution method. Author (TAB)

Review: A very thorough discussion of the special linear programming techniques needed to minimize the cost of a system while guaranteeing a specified reliability is given in this report. The techniques are "special" in the sense of being a subcategory of something more general. The branch-and-bound technique is a part of the larger body of general linear programming techniques. It is not new, having been first reported in the literature in 1960, but this may be an original application. For complete comprehension, the reader must already have a basic knowledge of linear programming. The exposition is quite clear; however, neither numerical examples nor computer programs are given.

R69-14394 ASQC 823; 831

Academy of Sciences (USSR), Moscow.

ANALOG PROBABILITY SIMULATION OF SYSTEMS WITH UNRELIABLE ELEMENTS

V. M. Boychenko, V. S. Gladkiy, and Ye. M. Chernyy

Engineering Cybernetics no. 1, 1967 p 164–176. 5 refs.

(N69-71928)

The problem of transforming stochastic systems of different physical nature by probability graphs of the class of systems of unreliable binary elements is stated, and the method for analog probability simulation of such systems is proposed. Expressions which relate the accuracy of the reproduction of the given reliability of the analog models with their high speed are derived. The problem of synthesis of optimal models is solved. An experimental analog probability machine is described together with examples of the probability analysis of the stochastic networks in such a machine. Author

Review: The abstract mathematical approach of this article will make it unsuitable for the general reader. However, the paper is nicely written. The authors are presenting here the theory of their analog probability computer, and they present it very well, with a good example (a probability binary element). The paper is thorough and accurate. The bibliography includes three articles by the present authors in its five entries, a bad ratio. More reference should be made to other work which forms a foundation for this. On the whole, this is an excellent and worthwhile paper.

R69-14396 ASQC 821; 872

AUTOMATIC MAINTENANCE IMPROVES SYSTEMS RELIABILITY.

James L. Maskasky (General Dynamics, Electric Boat Div., Groton, Conn.) and Robert G. Field (Sylvania Electric Products, Inc. Needham, Mass.).

The Electronic Engineer, July 1968, p. 49–52.

Two practical approaches for automatic maintenance are presented along with the analytical tools needed to compute their effect upon system reliability. Mean time between failures is determined, and the system probability of survival is calculated by assuming a probability density function for the failure times of each of the components which comprise the subsystems. The two self-maintenance techniques are (1) to replace a specific segment of the system with an identical one which has been standing by to replace it, and (2) to replace a failed unit with a functionally equivalent one out of a group of "universal" replacements, any of which can replace any one of the original or replacement units. Multiple standbys can be used for complex systems. The first technique is based on the assumption that the replacement unit has the same failure rate as the original; the second applies when a predetermined amount of system degradation is allowed. System reliability improvement is charted for examples of each technique. L.B.H.

Review: The novice should be careful of using this paper for tutorial purposes. Unless he understands enough about the subject to recognize the misleading comments, he will be confused or led astray. Examples of some of the difficulties are the following: (1) "We find the system probability of survival curve...by direct multiplication. The median time...is a conservative estimate of the MTBF..." These statements are not clear; one does not know what one should directly multiply nor what is meant by a conservative estimate (conservative is an ambiguous word and its meaning usually depends on whether you are buying or selling). In the exponential case, the median is less than the mean; in the Gaussian distribution, they are the same and in some distributions the median will be greater than the mean. (2) The equation for probability of survival as a product of the subsystem survival probabilities is true only for statistically independent subsystems. (3) In the section on standby replacements, the exact operating situation is not always clear; for example, it appears that only one unit is essential for correct operation and all the rest are spares, but this is not explicitly stated. Two additional assumptions are necessary in this section: (a) the hazard rate on standby must be negligible so that it can be treated as zero in the appropriate reliability equation; (b) the failure events of the subsystems are statistically independent. This is not always so in practice especially when the subsystems are close together or when the exact environmental profile is uncertain. (4) "...but what is really important is the median time to failure as standbys are added." The reason for this importance is not clear. For example, many are concerned with the hazard rate of the system at times small compared to a characteristic time to failure. In a private communication the authors indicate that they are emphasizing the median in this paper. (5) In the discussion of universal replacements, it is important to realize that the standby hazard rate is equal to the operating hazard rate in direct contrast to the previous section on standby replacements. This is not clear from the title, although it is mentioned in the text. (6) The Normal density function is not clearly given (apparently n is a misprint and should be η). The error function is defined in one of the less common ways. It is used inconsistently with the definition. (7) The problem discussed in the section on universal replacement is a double binomial one, each binomial being replaced by the Normal approximation and then the two Normal variables being combined by the usual rules. Even though some of the notation is poor in this section, the curves in Figure 4 appear to be accurate. It is worthwhile noting that maintenance can be considered a form of redundancy wherein the switching is done by hand in some cases or, in the case of this article, may be done automatically. Thus, formulas which apply for redundancy will also apply to maintained systems. While it is not common in the American literature to solve the problem in general, some Russian articles have solved the problem wherein the spares have a hazard rate different from that of the items in use.

R69-14401 ASQC 824; 552

DETERMINATION OF EQUATIONS AND CONSTANTS FOR LIFE EXPECTANCY STUDIES FOR TRANSFORMERS AND SIMILAR APPARATUS.

M. F. Beavers (General Electric Co., Pittsfield, Mass.).

(IEEE Winter Power Meeting, New York, Jan. 30–Feb. 4, 1966.) IEEE Transactions on Power Apparatus and Systems, vol. PAS-86, Oct. 1967, p. 1192–1197. 12 refs.

(IEEE Paper 31-TP-66-88)

When preparing a computer program involving the use of insulation life expectancy data, it is necessary to know the equation for the life expectancy, or loss-of-life vs. temperature relationship. This information is often presented in chart form for which, in many cases, the equation is not given. To those who work closely with the accepted chemical reaction rate theory (Arrhenius relationship) for thermal aging, there is little problem in determining the constant A and B in life (L) vs. temperature (T) charts based on the equation $\ln L = B/T + A$. For those who may use such charts for insulation aging studies, but are less familiar with the subject than the authors, the procedure for the determination of the values and signs of the constant A and the slope B may not be readily apparent, particularly when some charts show the temperature scale with increasing values toward the left and some toward the right. In some life expectancy is shown in hours, etc., while in others it is shown as relative life or loss-of-life in percent, per units, etc., or as an aging factor. Several variations of the basic Arrhenius equation are presented and a simple procedure for obtaining the equation of any insulation aging chart based on this chemical reaction rate theory is outlined. Author

Review: This paper is generally written for those older engineers whose algebra has become too rusty through the passage of time and the erosion of non-use. Not all of the equations were checked, but apart from an occasional obvious misprint, they appear to be correct. All of the equations presume Arrhenius behavior (its applicability is not under discussion). Newcomers to the electrical power field may find this paper of value in that it also discusses the various ways that power engineers plot such insulation data (although there is a lot of arithmetic to wade through if that is all that is desired).

R69-14407 ASQC 822

Boeing Scientific Research Labs., Seattle, Wash. Mathematics Research Lab.

A NEW FAMILY OF LIFE DISTRIBUTIONS

Z. W. Birnbaum and Sam C. Saunders Oct. 1968 19 p refs

Its Math. Note 576

(AD-677586; D1-82-0762; N69-14648) Avail: Issuing Activity

A new two parameter family of life length distributions is presented which is derived from a model for fatigue. This derivation follows from considerations of renewal theory for the number of cycles needed to force a fatigue crack extension to exceed a critical value. Some closure properties of this family are given and some comparisons made with other families such as the lognormal which have been previously used in fatigue studies. Author (TAB)

Review: This is a later, somewhat revised, version of the report covered by R68-14149. Much of it is copied verbatim, but other parts are added and deleted.

R69-14414 ASQC 824; 414

THE FOUNDATIONS OF DECISION ANALYSIS.

Ronald A. Howard (Stanford University, Dept. of Engineering-Economic Systems, Stanford, Calif.)

IEEE Transactions on Systems Science and Cybernetics, vol. SSC-4, Sept. 1968, p. 211–219. 5 refs.

(Contracts N00014-67-A-0112-0008; N00014-67-A-0112-0010; Grant NSF-GK-1683)

Decision analysis has emerged from theory to practice to form a discipline for balancing the many factors that bear upon a decision. Unusual features of the discipline are the treatment of uncertainty through subjective probability and of attitude toward risk through utility theory. Capturing the structure of problem relationships occupies a central position; the process can be visualized in a graphical problem space. These features are combined with other preference measures to produce a useful conceptual model for analyzing decisions, the decision analysis cycle. In its three phases (deterministic, probabilistic, and informational) the cycle progressively determines the importance of variables in deterministic, probabilistic, and economic environments. The ability to assign an economic value to the complete or partial elimination of uncertainty through experimentation is a particularly important characteristic. Recent applications in business and government indicate that the increased logical scope afforded by decision analysis offers new opportunities for rationality to those who wish it. Author

Review: This paper is an excellent lucid presentation of a difficult subject. It uses a minimum of jargon and conveys the essential ideas clearly to a beginner, which, in accordance with the title, is what one would hope it would do. It is a model of how such a paper should be written, because nothing in the author's style gets in the way of learning the concepts he is presenting. While various experts might quibble over certain phases of the presentation and while there is certainly a long way to go between understanding the basic concepts of decision analysis and actually using it in a complicated problem, this paper can serve reliability engineers well. Reliability engineers are rarely interested in the various things they find out per se. They are eventually interested in making a decision to accept or not, to test more or not, etc. Rarely do they make use of all the existing knowledge they have in arriving at any such decision. Therefore the subject of decision analysis is one with which reliability engineers should become more familiar. This article is an excellent starting point.

R69-14415 ASQC 821; 414

PRIOR PROBABILITIES.

Edwin T. Jaynes (Washington University, Dept. of Physics, St. Louis, Mo.).

IEEE Transactions on Systems Science and Cybernetics, vol.SSC-4, Sept. 1968, p. 227–241. 27 refs.

(Grant NSF-GP-6210)

In decision theory, mathematical analysis shows that once the sampling distribution, loss function, and sample are specified, the only remaining basis for a choice among different admissible decisions lies in the prior probabilities. Therefore the logical foundations of decision theory cannot be put in fully satisfactory form until the old problem of arbitrariness (sometimes called "subjectiveness") in assigning prior probabilities is resolved. The principle of maximum entropy represents one step in this direction. Its use is illustrated, and a correspondence property between maximum-entropy probabilities and frequencies is demonstrated. However, an ambiguity remains in setting up a prior on a continuous parameter space because the results lack invariance under a change of parameters; thus a further principle is needed. It is shown that in many problems, this ambiguity can be removed by applying methods of group theoretical reasoning which have long been used in theoretical physics. By finding the group of transformations on the parameter space which convert the problem into an equivalent one, a basic desideratum of consistency can be stated in the form of functional equations. In realistic problems, both the transformation group analysis and the principle of maximum entropy are needed to determine the prior. Author

Review: This is a good paper, not because it gives an extremely clear deductive exposition of a model or theory, but because it discusses very important concepts in the use of probability theory and makes important contributions to the theory. Probability theory is an important part of reliability engineering, even though there are other essential facets. The use of prior information in a reasonable agreeable way will do much to lift probability theory in reliability engineering from its present, somewhat disreputable, state. Perhaps the most important contribution of this paper is the suggesting of a way to determine the appropriate parameter to use in the maximum entropy formulation. This virtually removes the complete arbitrariness which earlier applications of maximum entropy theory possessed. It is probably best to consider this as a working paper wherein the author is continually improving and enlarging his principle of maximum entropy, so as to widen its range of applicability. Regarding it so removes the need to quibble about small points. Perhaps in a future article the author can discuss the reasons for always using mean values as constraints since much of our prior knowledge is not in the form of mean values, but is more extensive. This paper is recommended for research-minded reliability engineers because of its nature as mentioned above. For them, it is virtually required reading and they will presumably have enough ability to read the paper critically rather than taking it all as gospel.

R69-14416 ASQC 821; 414

THE WIDGET PROBLEM REVISITED.

Myron Tribus and Gary Fitts (Dartmouth College, Thayer School of Engineering, Hanover, N. H.).

IEEE Transactions on Systems Science and Cybernetics, vol. SSC-4, Sept. 1968, p. 241–248. 4 refs. Research sponsored by NSF.

The Jaynes "widget problem" is reviewed as an example of an application of the principle of maximum entropy in the making of decisions. The exact solution yields an unusual probability distribution. The problem illustrates why some kinds of decisions can be made intuitively and accurately, but would be difficult to rationalize without the principle of maximum entropy. Author

Review: In reliability engineering, one is virtually always making decisions on the basis of insufficient information; thus the reason for probability theory. One assigns the form of probability distributions on some such basis; often there are insufficient data to distinguish one distribution from another on the basis of goodness of fit. The Jaynes' principle of maximum entropy has been used to "show" that when only a mean value of time is given, the exponential distribution is the least prejudiced one to use. (See earlier works by the first author.) While the paper by Jaynes in the same issue of this journal extends and clarifies his maximum entropy principle, the present paper uses it for a specific example. Further, it is an example originally presented by Jaynes but only approximately solved then. This exact solution is interesting and instructive and can help give the reader more confidence in the maximum entropy principle. Two difficulties so far with the principle are that some people are not sure how to apply it (in what circumstances it is appropriate) and that a few others have had too much confidence (their extra assumptions were grossly oversimplified). Such is not the case with the present paper since the problem is expressly formulated to avoid those problems, among other things.

R69-14420 ASQC 821; 882

New York Univ., N. Y. Dept. of Industrial Engineering and Operations Research.

MINIMAX SURVEILLANCE SCHEDULES FOR REPLACEABLE UNITS

Robert Roeloffs (Ph.D. Thesis—Columbia Univ.) Washington Office of Naval Res. Dec. 1967 12 p refs Repr. from Naval Res. Logistics Quarterly, v. 14, no. 4

(AD-663142; NAVSO-P-1278; N69-71926)

An analysis is made of the problem of finding optimal schedules for checking an operating unit subject to random failure detectable only by inspection of the unit. It is assumed that only partial information, in the form of a single percentile of the otherwise unknown life distribution of the unit, is available. In a previous paper some results were given for the case with a finite time horizon. In this work it is assumed that the unit is replaceable at will with a new, statistically identical unit, and the horizon is infinite. Author (TAB)

Review: One of the views of reliability is that a piece of gear should work when you want it to; this paper treats a special case for maximizing that probability. As the author points out, this is one of many such repair–inspection schedules that can be run. In the course of the derivation, the worst failure case is presumed, viz., after the guarantee period all units will fail rapidly; therefore there are no inspections after that guarantee period. This is a theoretical paper in the sense that no real life situations are described which might fit the assumptions. It would be interesting to know how much of this kind of theoretical work actually is used in practice for determining repair schedules, or whether much simpler rules of thumb are used. Not all of the mathematics was checked but it appears to be competent; that is, the results are a logical consequence of the assumptions.

R69-14422 ASQC 824; 433

BAYESIAN METHODS IN RELIABILITY AND LIFE TESTING.

H. Balaban (ARINC Research Corp.; Annapolis, Md.).

Electronics Division Newsletter, no. 2, American Society for Quality Control, Oct. 1968, p. 3–8. 4 refs.

A numerical reliability requirement is noted as an important controlling factor in the design, development, and production phases of a system's life cycle; yet conformance problems encountered cannot be solved by the classical statistical methods of testing. The Bayes theory is reviewed and its applications to reliability and life tests are discussed in terms of reducing the amount of equipment, money, and time necessary to demonstrate conformance to numerical reliability requirements. An application to the design of life tests for constant-failure-rate items is considered for the exponential case; tests for reliability are approached in the same manner for the binomial case. Requirements are stated for (1) acceptance of satisfactory quality (producer's viewpoint), and (2) outgoing quality (consumer's viewpoint). The Bayesian approach considered is suitable for a lot-by-lot sampling process. It can be applied to other types of failure distributions and forms of tests, and can also be further extended to incorporate cost factors into the test-design criteria within a decision-theory framework. L.B.H.

Review: This is a technically competent paper on a most important topic. (Not all of the algebra was checked but it appears to be accurate.) Being able to understand this paper will require some statistical sophistication in classical methods even though the Bayesian modifications are explained well. Only conjugate prior distributions are illustrated. There is concern by some, however, about how accurately such conjugate distributions express prior knowledge, i.e., accuracy and suitability may be sacrificed in return for a very modest increase in computational ease. The topic of Bayesian statistics in testing needs a thorough discussion in the technical literature, since it is one of the big hopes for more realistic acceptance testing. There is really no reason to continue using the older classical statistical methods wherein it is assumed that one knows absolutely nothing about the product except the information from the immediate test results.

R69-14424 ASQC 824; 432; 831; 838; 882

A RELIABILITY PROBLEM WITH SPARES AND MULTIPLE REPAIR FACILITIES.

R. Natarajan (Directorate of Scientific Evaluation, New Delhi, India).

Operations Research, vol. 16, Sept./Oct. 1968, p. 1041–1057. 17 refs.

(A68-45032)

A single unit system with (N-1) spares and c repair facilities is considered. It is assumed that the failure time distribution of each unit is negative exponential with parameter λ and repair time distribution of each repair facility is again a negative exponential with parameter μ. The time-to-system failure period (TSFP) process has been investigated solving the difference-differential equation through the compensating function technique. The general process probabilities are obtained through renewal arguments from TSFP process and system down time process, and their ergodic properties are discussed. Author (IAA)

Review: Some availability and related formulas for standby redundancy (without automatic switching) are derived in this paper. An appealing feature is that some of the resulting equations are simple functions of the well-tabulated terms of the Poisson distribution. Some of the material is also presented elsewhere, and this paper provides a useful bibliography on this topic. (Most of the items listed deal with active rather than standby redundancy.) In contrast to many literature items concerned with queueing, this paper uses the terminology of the reliability discipline and therefore is more readily followed by the "practical" engineer. It will be of interest to those concerned with the details of the theoretical treatment as well as to those who wish to apply the resulting equations without too much difficulty. Readers concerned with availability for standby redundancy may also wish to see the item covered by R64-11479.

R69-14429 ASQC 823; 844; 851

COMPONENT DEGRADATION ESTIMATION BASED ON DAMAGE ACCUMULATION PRINCIPLE.

Hiroshi Shiomi (Electrotechnical Lab., MITI, Tokyo, Japan).

Electronics and Communications in Japan, no. 12, 1967, p. 26–32. 19 refs.

In order to estimate component degradation and the cumulative percent failure for various stresses, graphical or mathematical methods are used which also permit determination of the excess degradation accompanying variations in stress. If the relationship $f_K(x) = Kt$ holds for the reaction theory model, where x is the characteristic value, K is the reaction rate constant, and t is time, the lifetime L for a given stress can easily be predicted. By introducing the principle of cumulative degradation, the degradation for various stresses can be obtained. The expected lifetime can be obtained. As examples, the step-stress testing of a composition resistor degradation during on-off cycling, and the testing of a mylar capacitor are considered. Some precautions for using this method are also discussed in this paper. Author

Review: The author has published papers on this topic elsewhere; two of them were covered by R67-13385 and R68-13926 and those reviews are applicable to this paper (where the subject matter overlaps). Cumulative damage is apparently used to mean linear-cumulative-damage which is one of the more common hypotheses in the literature, especially in the field of fatigue. The author does illustrate that not all components accumulate damage in this way. This paper, like the other two, will be of little value to practicing design and reliability engineers; it will be of more value to theorists both because of the subject matter and because of the necessity to sift the relevant from the irrelevant.

R69-14432 ASQC 824; 414
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
METHODS FOR THE DETERMINATION OF THE APPROXIMATE VALUES OF THE AGING TIME AND SUBSTITUTION TIME OF ELEMENTS
L. P. Leont'yev 9 Nov. 1967 10 p Transl. into ENGLISH from Avtomat. Vychisl. Tekh. (Riga), no. 11, 1965 p 193–198
(AD-675229; FTD-HT-23-901-67; N69-11071) Avail: CFSTI

A method is described for the determination of approximate aging times and substitution times of electronic elements. It is based on the minimization of the loss function. For certain simple types of distribution (e.g., gamma distribution) the theory yields reasonably simple equations for the determination of substitution times and aging times which can be used during reliability determination of electronic equipment. TAB

Review: The translation is crude and somewhat difficult to read. Apparently the author is trying to minimize some expected loss function by aging the equipment and thus getting rid of infant failures before they have a chance to do any real damage. As a second problem, he wants to minimize expected losses by replacing components when they have deteriorated a certain amount. He writes down general expressions which really say very little except the kinds of costs he is considering. Then he substitutes some very simple cost models for these general quantities and solves the equation. In principle, it appears to be an application of decision theory; the actual models chosen are crude and tractable. Reliability engineers will want to stick, in this case, to the fairly standard treatments in the American literature.

83 DESIGN

R69-14393 ASQC 831; 838
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
SELF-MONITORING, SELF-CORRECTION AND SELF-REPAIR AS MEANS TO IMPROVED RELIABILITY OF COMPLEX DIGITAL SYSTEMS
A. D. Radchenko 25 Jan. 1967 23 p refs Transl. into ENGLISH from the Russian
(AD-650804; FTD-HT-66-597; N67-28630) Avail: CFSTI

Correcting codes are used widely for increasing the reliability of communications equipment and digital computers. If the errors do not exceed a certain magnitude, the system does the correcting; however, the reliability emphasis is shifted to the correcting filter, and a defect in the filter may introduce additional perturbations. The present article proposes a method for increasing the reliability of the correcting filters and other devices by means of secondary (internal) coding. The required design redundancy is moderate compared with complete duplication. During the wearing-out process spare components are introduced only for those components which actually went out of operation. The article also discusses the self-diagnosis of possible failures and their self-repair. Mechanical repairs can be avoided by introducing learning matrices and the learning process leads to the establishment of contacts between appropriate bushbars. Author (TAB)

Review: This article is intended for a reader who is well-versed in coding theory. Either the original or the translation suffers from severe lack of clarity. Ideas which are fairly obvious cannot be understood on the first reading. One would think from the title that this paper was a survey of this whole field, or covered at least several topics in some depth. Such is not the case. The basic idea, however, is interesting and valuable, although not profound or unique to this report. Implementations of the self-correcting code concept are presented both in hardware and, nonmechanically, by means of a learning matrix. The bibliography is inbred, but this is a common failing. Any reader who can follow this paper will have access to other references.

R69-14398 ASQC 831; 844
A COMPARISON OF SOLAR-CELL AND BATTERY-TYPE POWER SYSTEMS FOR SPACECRAFT.
Leo Pessin and Douglas Rusta (Radio Corporation of America, Defense Electronic Products, Astro-Electronics Div., Hightstown, N. J.).
(Institute of Electrical and Electronics Engineers, Aerospace Systems Conference, Seattle, July 11–15, 1966, Paper.) IEEE Transactions on Aerospace and Electronics Systems, vol. AES-3, Nov. 1967, p. 889–897.
(A68-15536)

Comparison of three spacecraft electrical power systems, each containing a solar-cell energy converter and using different voltage regulation schemes, for a common mission specification. Each system is made to meet a given reliability goal by a method which adds redundant components in a manner minimizing a system design characteristic such as weight. The reliability design goal is kept constant as mission length is increased, permitting system comparison in terms of weight and cost as a function of time. IAA

Review: This is an example of the kinds of calculations which engineers must make in the course of a design effort. The authors show that if different systems are designed to the same reliability, each for a minimum cost or weight, that the system desirability appears different than if reliability is ignored. The usual constant hazard rate assumption is made; no information is given as to the source of the failure rates used. It is also interesting that the following maximum failure rates have been effectively assumed: solar cells: 10^{-9}/hr., battery cells: 3×10^{-7}/hr. (this presumes that the hazard rate due to the batteries or solar cells would be less than about 20% of the total system hazard rate, not allowing for any redundancy effects in these two units). The failure rate calculations are given to five significant figures, which is far too many for the available accuracy (ordinarily two significant figures are more than enough to imply the available accuracy). Even though the calculation is performed for weight and cost, presumably no combined figure of merit was necessary since cost and reliability treated individually gave the same redundant configuration. All in all, the paper is an adequate demonstration of the kind of calculations engineers must perform for design purposes.

R69-14431 ASQC 830
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
PROGRAM LOGICAL METHODS OF INCREASING THE RELIABILITY OF DIGITAL CONTROL SYSTEM [PROGRAMMO-LOGICHESKIYE METODY POVYSCHENIYA NADEZHNOSTI TSIFROVYKH UPRAVLYAYUSHCHIKI SISTEM]
Yu. B. Arkhangel'skiy, V. V. Zhdanovich, and G. P. Chuguyev 26 Sep. 1967 10 refs Transl. into ENGLISH from Akad. Nauk SSSR. Inst. Elektromekhaniki. Avtomatizirovannyy Elektroprivod (Moscow), 1965 p 167–173
(AD-675232; FTD-HT-23-517-67; N69-11052) Avail: CFSTI

Computer errors are essentially random in character, and the authors discuss them from the point of view of the theory of random processes. For the control of information processed by

computers, they propose program logic control based on the redundancy of the original and intermediate information. This differs from other cases encountered in various branches of technology where the computer control may be based on comparisons with appropriate standards. The redundancy leads to various control relationships connecting the calculated quantities which may then be verified at the end of each computational cycle. The computer self-control is applied to the specific case of telescope control. A complete block diagram is given of the program logic and test control appropriate for this type of azimuthal rotation control.
TAB

Review: This is a typical machine translation of a Russian document. The general context can be reasonably deciphered; but some of the details are difficult both because of lack of optical resolution in the reproduction and because of the necessarily awkward language from the machine translator. Apparently what is happening is the following: The digital control system is involved in a telescope-orienting device; the computer is to calculate the proper new position every so often. Obviously, this application is typical of many positioning situations in aerospace applications. The checking algorithm (a) calculates a linear extrapolation on what the values should be of the functions and their first derivatives and (b) compares this result with the values from the original formula. The maximum allowed error between the two is specified in the program; if that error is exceeded, the calculation is redone. The probability of an incorrect command is said to be reduced to a factor of 100 by this process. The system uses redundancy in the time domain as opposed to the equipment domain. It is not clear what internal faults are being protected against or whether this is supplemented by redundant coding. This technique is interesting as being one possible method of accomplishing the objective. Designers of servo-equipment with digital computers in the loop might wish to include this as one of the options for improving performance; it can then be evaluated with regard to criteria for optimality.

84 METHODS OF RELIABILITY ANALYSIS

R69-14383 ASQC 844; 711; 712; 713

National Lucht-En Ruimtevaartlaboratorium, Amsterdam (Netherlands). National Aerospace Lab.

FATIGUE TESTS WITH RANDOM AND PROGRAMMED LOAD SEQUENCES, WITH AND WITHOUT GROUND-TO-AIR CYCLES. A COMPARATIVE STUDY ON FULL-SCALE WING CENTER SECTIONS

J. Schijve, D. Broek, P. De Rijk, A. Wederveen, and P. J. Sevenhuysen *In its* Rept. and Trans., vol. 32 1967 52 p refs

Prepared for AFFOAB and Neth. Aircraft Develop. Board

(NLR-TR-S.613; N67-36128)

Fatigue tests were carried out on full-scale tension skins of a wing center section of 7075-T6 material. Variable amplitude tests were carried out with the following load sequences: random load, program load, random load with GTAC (ground-to-air cycles), and program load with GTAC. Constant-amplitude tests were carried out with GTAC and gust amplitudes. The main objectives were to investigate (1) the equivalence of random and program loading, (2) the damping effect of GTAC, and (3) recommendations for full-scale testing. Results obtained are related to the indication of fatigue-critical components, fatigue lives, crack propagation, residual strength, $\Sigma n/N$-values, scatter, and inspection methods. Relevant information of the literature is summarized. Recommendations for full-scale testing are concerned with the indication of the loads to be incorporated into the test, the assessment of load spectra, and highest loads to be applied, the smallest load fluctuations to be included, the load sequence to be adopted, the duration of the test, and experimental conditions.
Author

Review: This paper presents a lengthy but comprehensive documentary on some interesting fatigue tests that were conducted in full-scale tension skins of wing center section made from 7075-T6 aluminum. The objectives of the program were three-fold and consisted of an investigation into: (1) the equivalence between random and program loading, (2) the fatigue damage effects of GTAC (ground to air cycles), and (3) the "why" and "how" of full scale testing. The test results indicate that fatigue life under this particular program-load simulation was 10% to 30% higher than those obtained for random load tests. The addition of GTAC reduced the overall fatigue life 40% to 50%. Some interesting secondary observations concerning crack propagation, crack types, $\Sigma n/N$-values, sequence of loading, residual strength, stress concentration, healing effects, and test environments are made. These observations, although pertinent, are somewhat overdone and tend to interrupt the continuity of the paper. The test results related to the original objectives point out that a good correlation between random and programmed loading is difficult to obtain. This is further substantiated by the numerous literature references that are cited. The paper's greatest value may be the recommendations pertaining to full scale testing and the assessment of the damage effects due to GTAC. The paper will be useful to those involved in fatigue evaluation of aircraft structures, especially those concerned with full-scale testing.

R69-14384 ASQC 844

Advisory Group for Aerospace Research and Development, Paris (France).

THE INFLUENCE OF FRETTING ON FATIGUE

W. J. Harris 1967 36 p refs Presented at the 24th Meeting of AGARD, Unione Industriale, Turin, Italy, 16–26 Apr. 1967

(AGARD-AR-8; N68-13553) Avail: CFSTI

Evidence to support the claim that fretting must be ranked in importance with geometric stress concentration and the like, when considering the fatigue behavior of structures, is presented. Mean structures curves, crack propagation and non-propagating cracks, and some fundamental fretting fatigue researches are described and interpreted with the elucidation of the fretting fatigue mechanism in mind. A survey of certain anti-fret techniques has been included not only to emphasize the gains to be made in terms of structural efficiency but to justify the main thesis that primarily, the fretting fatigue mechanism is controlled by the stress fields generated by the contact of two surface topographies. Author

Review: This is a well-written, easy-to-read paper which reviews the problem of fretting corrosion and its effects on fatigue. The different aspects of fretting which are covered are: fretting phenomenon, incidence of fretting fatigue, mechanism of fretting fatigue, research into fretting fatigue, anti-fretting (techniques, treatments and processes) and future research recommendations. Specifically, the author considers fretting damage to be as significant as a geometric stress concentration. The quality of the photomicrographs which are included in the Clearinghouse copy of the paper is poor, but this is most probably due to the reproduction technique and not the original photography. Editorially, however, the paper is well done. Design and reliability engineers will find it a useful reference.

R69-14385 ASQC 844
Lockheed Missiles and Space Co., Palo Alto, Calif.
ON METAL FATIGUE
T. B. Larina 4 Jan. 1967 4 p Transl. into ENGLISH from Dokl. Akad. Nauk SSSR. (Moscow), v. 177, no. 1, 1967 p 59–60
(PB-17794T; N68-22396) Avail: CFSTI

Equations of state are derived which describe the thermodynamic parameters of one dimensional problems, and, by means of a holomomic model of a continuum, to describe materials with complex properties. It is shown that heating of the sample plays a decisive role in fatigue rupture of metals. E.J.S.

Review: This translation from the Russian literature is best classified as a technical communication rather than a technical paper. It is only four pages long, but is complicated and difficult to understand. The exact purpose of the paper is somewhat vague and there do not appear to be any conclusions, suggestions, or recommendations that support the title. The document presents a complicated mathematical treatment which was not checked in detail. Theorists rather than design or reliability engineers will derive whatever benefits there are from the document.

R69-14386 ASQC 844
DEVELOPMENT OF MATERIAL FATIGUE TESTING.
S. V. Serensen.
(Zavodskaia Laboratoriia, Vol. 33, Oct. 1967, p. 1305–1316.) *Industrial Laboratory*, vol. 33, Oct. 1967, p. 1493–1502 157 refs. Translation.
(A68-28340)

Survey of the development of fatigue-testing methods for materials—methods of measuring the mechanical properties that characterize the resistance to deformations and to failure under the action of varying loads. Their development is closely associated on the one hand with the extension of concepts concerning fatigue failure mechanisms, and on the other with those service characteristics that are determined by the advancement of mechanical and thermal operating design parameters and their use for the preparation of new materials and technological processes. IAA

Review: This paper reviews the development of fatigue testing in Russia during the last 54 years. It begins with the first work which was performed in pre-revolutionary Russia in 1914 and cites 156 subsequent papers on fatigue, the majority of which were written during the 50 years following the revolution. The fatigue aspects covered by these papers are numerous and range from fundamental fatigue phenomena to the establishment of state standards for specimen size, surface quality, methods and modes of loading, treatment of results, and test machine requirements. The paper is well written and easy to read. Test engineers and, perhaps, design engineers and reliability engineers will find the paper interesting reading but of limited value as a permanent reference. The paper is a translation from the Russian.

R69-14387 ASQC 844; 090
Battelle Memorial Inst., Columbus, Ohio. Defense Metals Information Center.
STRESS-CORROSION CRACKING OF ALUMINUM ALLOYS—REVIEW OF THE GERMAN LITERATURE
F. R. Mertens Aug. 1967 61 p refs
(Contract F33615-68-C-1325)
(AD-666083; DMIC-MEMO-23; N68-21509)

The phenomenon known as stress corrosion has been defined in several ways. For example, the definition which has been accepted in England is restricted to static stress: The term stress corrosion implies a greater deterioration in the mechanical properties of the material through the simultaneous action of the static stress and exposure to corrosive environment than would occur by the separate, but additive action of these surroundings. This definition includes stress-accelerated corrosion, but excludes corrosion fatigue. Author (TAB)

Review: This document is a review of the German literature on stress–corrosion cracking in aluminum alloys. It was written by a German author from the Battelle-Institute e.V., Frankfurt, Germany and edited by the Battelle Memorial Institute of Columbus, Ohio. A few English, French, Italian, and U. S. references are included. Stress corrosion is an important insidious failure mechanism in aerospace structures. Some of the data appear to be speculative, but in general the memorandum is well written and covers the many aspects of the stress–corrosion problem. Considerable stress–corrosion data, which the design engineer and the reliability engineer will find most useful, are presented in graphical and tabular format. The reproduction quality of the photographs and the photomicrographs in the Clearinghouse copy is unsatisfactory.

R69-14388 ASQC 844; 531
Royal Aircraft Establishment, Farnborough (England).
CORRELATION OF FATIGUE CRACK PROPAGATION RATES WITH THE STRESS INTENSITY FACTOR IN AN ALUMINUM ALLOY (DTD 5070A)
D. P. Rooke Sep. 1967 15 p refs
(RAE-TR-67238; N68-22192) Avail: CFSTI

The results of fatigue crack propagation tests made on the aluminum alloy which were given in a previous report are further analyzed and correlated using improved calculations of the stress intensity factor. Koiter's correction for the plastic flow at the tip of the crack are used. The tests were done on 3 inch panels at three stress levels: 4400 ± 3600 psi, 8800 ± 7200 psi, and 13200 ± 10800 psi; and on 10 inch panels at 4400 ± 3600 psi. The correlation of the results from the 3 inch panels is improved at all stress levels, using the improved stress intensity factor. The correlation between results from 3 inch and 10 inch panels tested at the same stress level was not as good as previously but the differences are not thought to be significant. Author (ESRO)

Review: This brief paper presents a second look at the author's earlier and moderately successful attempt to correlate fatigue crack propagation rate to the stress intensity factor. This earlier correlation was inadequate because it appeared to be strongly dependent on the stress level at which the tests were conducted. In this recent work, the author applies an improved correction factor (for finite plate width and plastic flow at the crack tip) to the previous calculation for the stress intensity factor. The newly calculated stress intensity factor is less dependent on the applied stress level. The mathematical relationships and the results are clearly presented and can be of value to engineers who are involved with fatigue phenomena. Access to the author's earlier paper, "Crack Propagation in Fatigue—Some Experiments with DTD 507A Aluminum Alloy Sheet," R.A.E. Technical Report 64025 (1964), would be helpful when reading this one.

R69-14397 ASQC 844; 775
International Business Machines Corp., East Fishkill, N. Y. Components Div.
INFRARED MICRORADIOMETRY—PRECISION AND ACCURACY CONSIDERATIONS APPLICABLE TO MICROCIRCUIT TEMPERATURE MEASUREMENTS
D. D. Griffin 24 Oct. 1967 14 p refs Presented at the 1967 Fall Mtg. of the Soc. for Non-Destructive Testing, Cleveland, 16–20 Oct. 1967
(TR-22.438)

The problems of IRMR precision and accuracy are divided into two groups. First, there exists those factors such as signal stability and specimen ambients which are largely dependent upon hardware integrity. A second realm of consideration begins where the hardware ceases to be a significant factor. In this second category one would necessarily include physical and chemical properties of the targets under investigation. Also included in the second are problems originating in the mathematics of calibration functions. In summation it is suggested that the experimenter strengthen the capability of his hardware short of major reinstrumentation, and having done so, concentrate largely on measurement technique, using systematic statistical checks as a precision indicator. Author

Review: Articles on the uses of microradiometry have been appearing regularly in the physics-of-failure literature. The use of this technique is expected especially to improve appreciably the reliability of microelectronic devices. This paper goes into some of the finer points on how to make such microradiometry meaningful. The information, while known to some of the workers in this field, should be in the storehouse of knowledge of all who are using infrared microradiometry. Some of the more popular articles on the subject seem to imply that this technique is one that is easily used, whereas its application is fraught with many pitfalls for the unwary.

R69-14399 ASQC 844
General Precision, Inc., Glendale, Calif. Librascope Group.
STUDY OF FAILURE AND RELIABILITY IN MICROELECTRONIC DEVICES
H. M. Muncheryan 16 Oct. 1967 52 p
(Contract NAS12-72)
(NASA-CR-90425; TR-2-0459; N68-11587) Avail: CFSTI

Four groups of integrated microcircuits produced by various manufacturers were subjected to thermal cycling, step-stress tests, and operating life tests in excess of 10,000 hours. The failure modes were verified metallographically by direct observation from the uncapped devices and by indirect failure derivations. Major failure mechanisms identified were inhomogeneous aluminum metallization, faulty contact deposition, bubbles and pinholes in the pyrolytic passivation film, and randomly occurring cracks or surface pits in the silicon pellet. Other discrepancies were attributed to surface reactions, such as inversion layer formation, ionic migration at the silicon dioxide surface, ionic entrapment at oxide defects, and metallization changes. All failure modes encountered could be reduced to three fundamental failure indicators, namely, leakage current, breakdown voltage, and output saturation voltage, all other failure indicators being derivations of these types. Author

Review: This report appears to be a good summary of a well-conceived and well-executed testing project. (At least, no negative remarks are included in the report.) The report will be of value to those who are engaged in similar kinds of testing on integrated circuits; there is considerable detail about the test methods, the devices themselves, and the failures. Articles such as this, written by a user, tend to present a different story on the reliability of integrated circuits than do those written by producers. Apparently, no statistical analyses were performed during this project. For example, the assertion that the several lots differed in hazard rate was not accompanied by a statistical test of any sort which might have assisted in arriving at the conclusion. (One may have wished to test the null-hypothesis that the lots did not differ in hazard rate.) In general, the report is easy to read (in places, the editorial polish is poor but one can usually figure out what was meant). It is interesting to compare this report (concerned presumably with very high reliability devices) with [1].

Reference: [1] "Sure, integrated circuits are improving, but it's no time for complacency," by John H. Simm, *Quality Assurance*, vol. 7, Nov 68, p. 48–51.

R69-14400 ASQC 844
ANALYSIS OF TAPERED ROLLER BEARING DAMAGE.
R. L. Widner and J. O. Wolfe (Timken Roller Bearing Co., Canton, Ohio). *1967 National Metal Congress, Cleveland, Oct. 16–19, 1967, Paper.* Metals Park, Ohio, American Society for Metals, [1967], 32 p. 21 refs.
(ASM-TR-C7-11.1)

Tapered roller bearings, damaged in field applications or laboratory tests by fatigue or by other mechanisms, were subjected to a systematic analysis of such damage to prevent its recurrence in the field or to gain knowledge of its control in the laboratory. A method of analysis is described which has been developed for examining such bearing damage. Examples of various types of bearing damage are given, and the essential steps of the analysis are described with emphasis on the visual classification and metallographic examination of the damage. Author

Review: This paper can be useful to design and reliability engineers by showing them the kinds of details that are important in a bearing application. While there is occasional jargon that is peculiar to metallurgy, the designers and reliability engineers will be able to understand most of the paper. The illustrative photographs are generally good and provide an important aid in understanding. Those newer metallurgists who are just becoming acquainted with this kind of laboratory work can also find the article helpful. One caution not included in the text is important with regard to application information, i.e., the bearing user may dissemble appreciably in order to imply that he was not as foolish as it turns out he was. It is important that the bearing field engineer be reasonably well versed in this aspect of human behavior.

R69-14402 ASQC 844
Autonetics, Anaheim, Calif.
ADVANCED COMPUTER DORMANT RELIABILITY STUDY Final Report
L. K. Davis, T. G. Schairer, and G. A. Watson 14 Oct. 1967 69 p refs
(Contract NAS12-536)
(NASA-CR-86025; C7-2318/301; N68-15481) Avail: CFSTI

Effect of applied power was studied on the reliability of integrated circuits and discrete components and the relationship between bipolar and MOS integrated circuit reliability, with emphasis on the electronics of the computer and a dormant module for Minuteman II. Minuteman component failure modes were analyzed under "full power" and "no power" input power modes, and theoretical effects on MOS devices subjected to these power inputs were determined. Predicted failure rates were determined for MOS devices for present technology and for the late 1970's on the basis of a reliability transfer model. Future MOS reliability extrapolations and power condition of spare modules in space flight were also considered. M.W.R.

Review: The first part of this paper which deals with estimating the dormant/active hazard rate ratio for some of the electronic components in Minuteman II appears reasonable enough. Not all of the data are given in the report, nor is a reference given to the particular theory of combination of confidence intervals which was used; so it is not feasible to make exact checks on the numbers. In any event, the statistical methods are probably good enough (even if not exact) in view of the use to which the results will be put. The prediction of MOS reliability seems somewhat optimistic in view of all the grandiose predictions that had been made for some years about the great benefits of MOS technology; yet these benefits were very slow in coming because of manufacturing problems. These very manufacturing problems will be ones that affect reliability. The radiation environment is not considered for either the bipolar or MOS transistors. It was originally thought that MOS transistors would be much more resistant to radiation than bipolars, but such was found not to be the case; the MOS were actually more sensitive. The reliability extrapolations that were made in this paper are about as good as can be done with the limited knowledge available. Other groups performing the same kind of analysis would probably have arrived at different answers, some of them radically different; but this merely shows the uncertain state of the art, not any necessary deficiency in the engineering judgment made in this report.

R69-14408 ASQC 844; 824

Ford Motor Co., Dearborn, Mich. Advanced Test Engineering Dept.

FATIGUE LIFE OF A LOW CARBON STEEL NOTCHED SPECIMEN UNDER STOCHASTIC CONDITIONS

Stephen L. Bussa (M.S. Thesis—Wayne State Univ., Detroit, Mich.). 1967 85 p refs Prepared in cooperation with MTS Systems Corp., Minneapolis

(REPT-900.21-1; N69-71927)

A test program was designed to determine which stress probability distribution function can be described either as the peak probability distribution function or the range probability distribution function. The peak probability distribution function depends on the irregularity factor (R), which is the ratio of the average mean crossings per second to the average peaks per second (N_o+/N_p). For band-limited random vibration, the range distribution function depends on the frequency (F), which is the ratio of the lower cutoff frequency to the upper cutoff frequency. The objective was to clearly separate the effect of R and F, and to determine which parameter better characterized fatigue and the relationship between the value of the controlling parameter and fatigue life for a common automotive steel. Random load fatigue test data are tabulated and assessed. Consideration was also given to the response of a cumulative damage strain gage to random strains; figures are included depicting the resistance change vs. time. M.G.J.

Review: This master's degree thesis appears to have been well handled. The major emphasis was on the engineering aspects of the problem rather than the theoretical side. In the past few years, random fatigue has become prominent and it is encouraging to see industry and universities cooperating in this way of looking at fatigue. Insofar as one can tell from reading the report, the overall approach is adequate, and reasonable engineering judgments were made in the course of the investigation and in the methods of analysis. A few questions of a theoretical nature arise, of which the following are examples: (1) The formula used to compute the mean number of crossings uses the geometric mean of times-to-failure rather than the arithmetic mean. If they are very close together, the two means are very similar. The product of the rate of zero crossings and the geometric mean does not give the desired answer. One should use the arithmetic mean. (2) S^2 is an unbiased estimate of the variance. S is not an unbiased estimate of the standard deviation. (3) On page 21, it is not clear how both F and R were simultaneously considered in deducing their effects on fatigue life. It appears from the text that all of the effect is ascribed alternately to the one and then the other variable. In a private communication the author has stated that F and R are alternate ways of describing the situation. Therefore the test is correct, but not clear. (4) Equation 4-1 is misprinted. It should be (according to the author): $\beta = 1 + 1/q \log_{10} N_A/N_A + N_a$.

R69-14413 ASQC 844

Naval Ship Research and Development Center, Annapolis, Md. Marine Engineering Lab.

LOW-CYCLE FATIGUE BEHAVIOR OF A DOUBLE-BOX STRUCTURE

M. R. Gross Dec. 1967 16 p refs

(AD-662677; NSRDC-2568; N68-15497)

A double-box test was devised to compare the effects of internal and external cyclic pressurization on the low-cycle fatigue behavior of HY-80 steel. The outer box was fabricated from 2-inch-thick plate and the inner box from 1-inch-thick plate. Major conclusions reached from this and previous tests were (1) the fatigue life of an externally pressurized box is appreciably greater than that of an internally pressurized box and (2) the fatigue crack propagation rate of an internally pressurized box having a 1-inch wall thickness is more than five times higher than that of one having a 1-inch wall thickness. Author (TAB)

Review: Our knowledge about fatigue failures is gradually increased by this kind of report. Every once in a while, someone needs to take all of the small reports and combine that information into a survey article which will extend the applied fatigue theory. The conclusions of this paper are interesting in themselves. The questions raised show that we have yet a long way to go in understanding fatigue. Fatigue failures are one of the major causes of unreliability in mechanical structures, and understanding of this phenomenon is essential for high reliability.

R69-14417 ASQC 844

RESULTS OF RELIABILITY TESTS ON PLANAR TRANSISTORS.

E. Schlegel (Hanburg-Lokstedt, Germany).

Microelectronics and Reliability, vol. 7, Nov. 1968, p. 291–300.

(A69-13006)

Life tests of two types of planar transistors show that failure rates of the order of magnitude of 10^{-7}/hr must be accepted when the transistors are operated at the limiting conditions. With circuits and loads used in actual practice, the reliability characteristics may be expected to be one to two orders of magnitude better. The stability of planar transistors in the current gain and leakage current is already superior to that of germanium transistors when operated at limiting conditions. Under practical conditions, this superiority is even better because of the great distance between the practical load and that applied during the tests (higher loading capacity of the planar transistors with equal size envelopes). Temperature is the most important factor which affects the reliability of planar transistors. Author (IAA)

Review: The numerical results of some life tests on silicon planar transistors, without any attempt at a physics-of-failure explanation, are the major portion of this paper. Even though the three-parameter Weibull distribution is introduced at the beginning, the one-parameter exponential is used to analyze the data, largely because there were insufficient failures to justify any more-complex distributions. The tests were all run at the rated temperature of 200°C so that aging was only modestly accelerated. The first part of Section 2 says that (a) semiconductors have no wear-out modes and (b) transistors either do not have manufacturing defects or they are operated in regions where those defects do not hurt. All that discussion is most naive. The distribution curves obtained from the tests can be usefully plotted to see if they fit any of the reasonably tractable distributions, but the author did not do so. There is little indication that the results would be of value for any but these particular transistors.

R69-14418 ASQC 844
Naval Ammunition Depot, Crane, Ind. Quality Evaluation Lab.
ANALYSIS AND EVALUATION OF SPACECRAFT BATTERY LIFE TEST DATA
J. R. Kent Nov. 1967 75 p
(NASA Order S-23404-G)
(NASA-CR-92883; GE/C-67-592; N68-16705) Avail: CFSTI

This report presents the findings from the statistical and reliability analysis of large volumes of data on NASA spacecraft batteries. This data was generated from a life cycling test of 660 nickel-cadmium battery cells. A promising method is proposed where, after 1000 test cycles, the ultimate cycle lives of cells are predicted and the probability that an inferior cell would be rejected was estimated to be 90.5%. The probability that a good cell would be accepted was estimated to be 84.5%. The test results indicate that the number of test cycles necessary for reliable prediction may be further reduced to a few hundred cycles. Author

Review: Data analysis in a real engineering situation is more of an art than a science, especially where there are very few guideposts. This paper shows what was tried for these tests of nickel cadmium battery cells. Trying to find the life distributions was an unrewarding task partly because of the small sample sizes. Finding a screening technique was more successful but still not up to the author's hopes. The technique was quite good, however, and a substantial improvement over the previous inability to screen dependably at all. The authors seem to have tried about everything of a physical or statistical nature that they could think of to pin things down but Mother Nature's cooperation was limited. In the tests of significance being performed, it is important to distinguish between engineering significance and statistical significance since the two are in no wise the same thing.

R69-14425 ASQC 844
Advisory Group for Aerospace Research and Development, Paris (France).
STRESS CORROSION CRACKING IN AIRCRAFT STRUCTURAL MATERIALS
H. G. Cole, ed. 1967 251 p refs Presented at the AGARD Structures and Materials Panel Symp., Turin, 18–19 Apr. 1967
(AGARD-CP-18; N68-24397) Avail: CFSTI

A general theory of stress corrosion is presented with emphasis placed on aluminum alloys and steels as the major aircraft structural materials. Laboratory work on aluminum alloys and some engineering aspects of stress corrosion cracking in high strength aluminum alloys are discussed. Consideration is given to failure in martensitic steels, and cracking in high strength stainless steels and in very strong low-alloy and maraging steels. Stress corrosion of titanium alloys is also discussed, and national surveys of work done on stress corrosion cracking is presented. L.B.H.

Review: The fast pace at which materials technology is moving is causing a severe problem for reliability and design engineers. The trend toward the use of "higher strength" materials is especially insidious because the strength so referred to is largely a tensile strength measured in the laboratory on smooth specimens rather than any resistance to the numerous causes of field failures. The actual strength of a part is not a single number, but a set of numbers which encompasses all the different mechanisms and modes of failure that a part has. Among the more difficult failure mechanisms to prevent in new applications is stress-corrosion cracking, largely because it is so specific to each system. It is not uncommon for such cracking to show up in the field in a way that no one (research scientists and field engineers alike) would have predicted. Thus the printing of the proceedings of this conference is especially valuable in furthering the state of the art. Several of the papers are of direct value to design and reliability engineers, especially those which deal with the engineering aspects of stress-corrosion cracking. This field is still more of an art than a science as is shown by the controversy in the valuable discussions on the papers. The problem of stress-corrosion cracking is critical in aerospace structures because everyone is striving for extremely high strength/weight ratios without always being aware of the complexity of the concept of strength.

R69-14426 ASQC 844; 851
Army Natick Labs., Mass. Clothing and Organic Materials Lab.
THE APPLICATION OF THE CONCEPT OF RELIABILITY TO TEXTILE PRODUCTS
Stephen J. Kennedy and Louis I. Weiner Sep. 1967 30 p refs
Its TS-153
(AD-668907; TR-38-23-CM; N68-27045)

In common with many other natural products, the nature and use patterns of items of textile clothing and equipage are such that data for formulating exact models for predicting reliability in terms of mission times and mean-times-between failures are not easily obtainable. However, reliability analysis based upon the probability of determining whether or not a given characteristic falls within the use requirements for the material or material system has been found feasible in many cases. A considerable amount of such data is available and is presented in the report to suggest possible approaches for reliability analysis studies. Some of the inherent problems in applying reliability analysis to a broad range of textile end items are examined and discussed. Author (TAB)

Review: Aerospace engineers need to be reminded occasionally that they along with their defense counterparts do not have a monopoly on the reliability discipline. This paper provides an example of the reliability discipline's moving into yet another field, that of textiles. The paper is valuable to aerospace engineers because their kind of problem appears here but in a different language, e.g., (a) the problem of not everyone's treating a piece of hardware as severely as everyone else and (b) the fact that some demand more of the hardware than others do. There are aerospace applications of the textiles themselves, wherein the probability of their proper performance is essential to the mission success and wherein it may be difficult to assure that performance. It would appear from the paper that the authors have read too many introductory treatments and elementary texts on the subject and are presuming that reliability in electronic and mechanical hardware is as simple a subject as these sources seem to indicate. This is not so even without going to the field of consumer appliances, for example. Some specific comments on the paper are appropriate. (1) In discussing the body armor, it is apparently presumed that there is no deterioration in the strength or spread of strength as a function of use. In a private communication the first author has stated that such deterioration is insignificant. (2) The median strength per se is a poor indicator of the worthwhileness of the armor since one rarely wishes to have 50% failures (regardless of the standardness of the median in ballistic testing and the statistical difficulties in estimating the lower fractiles). One might choose, say, the 10% strength as is done in ball and roller bearings. This takes into account some of the spread and is not too difficult a number to estimate. (3) It would be useful to estimate the reliability of parachutes or conversely to estimate a maximum probability of their failure, to some value other than "very near zero." For example, by combining stress–strength estimates with the number of successful trials, one could put an upper bound on the failure probability of the textiles or of the parachute itself. Again, those involved with space hardware have very similar problems, especially where failures are likely to occur due to human frailty along the line, not due to the factors which were being considered in calculating the reliability. (4) Virtually everyone has problems of finding tests which adequately simulate service. One need not apologize too much for not knowing what to do in this area nor feel that reliability techniques cannot be used in that circumstance. He just goes ahead doing the best he can. The author's cautions to textile technologists are appropriate since many people, especially newcomers to the field of reliability, tend to be overly optimistic about the precision of reliability predictions.

85 DEMONSTRATION/MEASUREMENT

R69-14423 ASQC 851
HARDWARE-SOFTWARE TRADEOFFS WHEN APPLYING COMPUTERS TO TESTING.
James E. Stuehler (International Business Machines Corp., Systems Manufacturing Div., White Plains, N. Y.).
In: Computers, Communications and Display Devices; Western Electronic Show and Convention, Los Angeles, Aug. 20–23, 1968, Technical Papers. Volume 12. Part 3. Convention sponsored by the Institute of Electrical and Electronics Engineers and the Western Electronic Manufacturers Association. North Hollywood, Calif., Western Periodicals Co., 1968, p. 13/3–1 to 13/3–9.
(A68-43849)

Discussion of test system philosophy using computers and hardware-software tradeoff considerations relevant to each subsystem. The considerations include data requirements, control requirements, personnel requirements, time, and cost. An approach to systematically determine the hardware-software tradeoff is suggested. The suggestion is that the test engineer analyze the needs of each previously defined subsystem rather than trying to look at the test system as a whole. If this approach is taken, a list of factors favoring hardware or software may be generated for each subsystem to help base a hardware/software tradeoff decision. Important factors which the engineer should consider are defined. In assessing these factors, the engineer need not be intimately familiar with the operation of a digital computer. IAA

Review: This paper discusses an important topic for reliability engineers and contains some good ideas. Since virtually everything is presented in the form of points to consider rather than recommendations on the choices, it is a device to help engineers think smarter rather than telling them what to do. The questions are good ones but unless an engineer is very familiar with the jargon being used (it is reasonably common in the field), he will have a difficult time understanding the article. For example, the interface subsystem presumably can be made all of software but obviously there has to be hardware somewhere if it is nothing but a few cables for connections. So apparently the discussion is limited to some subset of operations that these subsystems will perform. About the only time all hardware can truly be dispensed with is in the case of a digital computer itself where test programs are built into the machine but even then, some hardware in the form of extra memory may be required. A specific example might have made things clearer.

R69-14427 ASQC 851; 844
STEP STRESS AGING OF PLATED WIRE MEMORIES.
I. Danylchuk, U. F. Gianola, and John T. Sibilia (Bell Telephone Laboratories, Inc., New York, N. Y.).
The Bell System Technical Journal, No. 8, Oct. 1968, p. 1539–1559. Oct. 1968, 9 refs.

A rate of 0.3 failures per billion hours or less is desirable for memory components in large integrated arrays. This unusually stringent requirement complicates the determination of lifetime from accelerated aging studies. The value and limitations of step stress aging techniques are discussed in terms of experimental results obtained using plated wire memory arrays designed to withstand the high ambient temperatures required for accelerated aging. Step stress aging measurements alone are insufficient for confident lifetime prediction. Therefore, longer term measurements at lower temperatures must also be made to establish the validity of the lifetime extrapolations. It is essential to protect the plated wires against corrosion. Given proper protection a shelf life in the hundreds of years is forecast. The importance of duty cycle on lifetime in exercising the memory is discussed and the results of aging under extreme pulsed magnetic field stress conditions are reported. Criteria for wire selection, with long term stability in mind, are discussed. Author

Review: This appears to have been a well-planned and well-carried-out series of experiments, disturbed only by the usual problems everybody has when the realities of Nature intrude themselves. It is a good case history for reliability engineers since it shows the kinds of detail one needs to consider about failure mechanisms and how one's ideas about the model must be adapted as the tests proceed. In future work, it would be a good idea if the mathematical model for the plated wires could be written down somewhere for the step-stress experiments, especially in view of the extrapolations that are performed. It was the average behavior of failure times that was presumed to follow the Arrhenius equation. There was no indication in any of the equations how the random variable was fitting in. In these step-stress tests, it is important to remember that the authors have considered the steps large enough so that the amount of equivalent time at the beginning of the new temperature on each of the unfailed specimens is negligible compared to the failure times at that temperature. This in turn is equivalent to saying that the specimens at each temperature are virgin ones and that all of the tests are independent; thus the step-stressing is used only to conserve specimens. The authors apparently use the word random to mean following a Gaussian distribution. This is not a good idea since a random variable is not limited in advance to any particular probability distribution. (It is worthy of note that other people have used the word random to imply the Poisson distribution or its corresponding negative exponential distribution.)

R69-14428 ASQC 851; 782; 844
National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
ENVIRONMENTAL TEST CONTRIBUTION TO SPACECRAFT RELIABILITY
Kenneth R. Mercy Washington NASA Nov. 1967 17 p
Presented at Inst. of Environ. Sci. Ann. Tech. Meeting, Washington, D. C., 11 Apr. 1967
(NASA-TN-D-4181; N68-10192) Avail: CFSTI

Typical problems that have a major impact on some space programs are discussed. These problems include those that involve the interdependence of equipment in a system complex. The experiences obtained in producing reliable spacecraft for several programs (Relay, Syncom, Tiros, etc.) are analyzed. The techniques used to control and appraise space programs differ and are influenced by the spacecraft design, target dates, and budget restrictions. The validity of these techniques is indicated by the results of the test programs. Problem occurrences are analyzed relative to program phase. The results of this study are discussed with regard to optimizing techniques of quality and reliability planning for space hardware. Author

Review: This paper is an expansion and updating of one the author gave about two years before at a similar conference (see R65-12231). The topic is important and the author's treatment, while necessarily qualitative, is a good introduction to the subject and fulfills his purpose well. It not only shows the advantages of environmental testing, but also some of the dilemmas involved. The paper is obviously intended for those who wish only a general view of the situation, e.g., managers and newcomers to the field.

R69-14430 ASQC 851; 844

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

ACCELERATED TESTS FOR RELIABILITY AND DURABILITY OF MACHINE BUILDING INDUSTRY PRODUCTS [USKORENNYE ISPYTANIYA NA NADEZHNOST I DOLGOVECHNOST IZDELII MASHINOSTROENIYA]

K. P. Chudakov and A. I. Kubarev 17 Aug. 1967 12 p Transl. into ENGLISH from Standartizatsiya (Moscow), no. 9, 1965 p 33–36

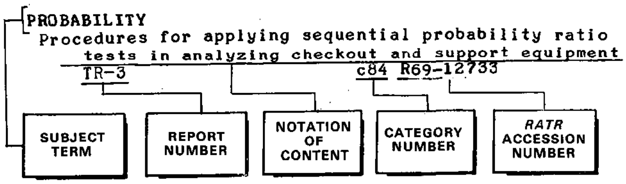
(AD-670095; FTD-HT-67-22; N68-30446)

Different methods for accelerated life and reliability testing are discussed qualitatively. Since it is not practical to wait 3 to 4 years to determine the reliability and wear characteristics of a given machine, accelerated tests must be performed which will give sufficient data in 3 to 6 weeks to predict the long-term behavior of machine elements. This can be achieved by either increasing the number of cycles per unit time, by intensifying the loads, or by both methods. It has been shown repeatedly that wear processes and fatigue processes can be extrapolated from limited test data with an accuracy of plus or minus 10%. Although under industrial conditions the scatter may be as much as plus or minus 150%, these extrapolation techniques give an excellent indication of average wear, life, and reliability. When fatigue is the life-limiting factor, the fatigue limit can be established by several increasing-load methods, such as a constant load increase to destruction, stepwise load increase to destruction, or cyclically increasing loads. Each of these methods has advantages for certain applications. Determining the fatigue limit by the critical stress method is of particular interest. This method depends on the energy hypothesis of fatigue, by which it has been established that the cyclic constant and the critical number of cycles are constant for a given type of metal. No specific recommendations are made, and the article represents a very general, qualitative discussion. Author (TAB)

Review: This is a very qualitative paper. It says that wear and fatigue should be accelerated in tests of machines by increasing both the frequency of load application and the severity of the load. In the discussion on fatigue, there is introduced a cyclic constant and a critical number of cycles which are presumed constants for a particular metal irrespective of its alloy composition, heat treatment, and geometry. The authors state that these constants are used in many countries and can reduce the time required to find a fatigue limit; it is not clear what these two concepts are. In regard to wear, the authors suggest that data be taken at several stresses and the results extrapolated by means of a least squares straight line to operating conditions. They are apparently also insisting that the statistical uncertainty in the answer be calculated. Their formulas are too difficult to check but, in any event, they are readily available in American texts. The important thing is to make these calculations since the statistical uncertainty in the answer will often be much greater than expected. A statistician should be consulted for advice on the appropriate formulas to use. It looks as if the ones in the text are a special case without this fact being mentioned. As is typical of many of the Russian translations, the topic itself is important, but the paper will be of value only to those who are trying to keep up with what the Russians are doing and saying. It is not useful for advancing the state of the art or for tutorial purposes.

SUBJECT INDEX

Typical Subject Index Listing



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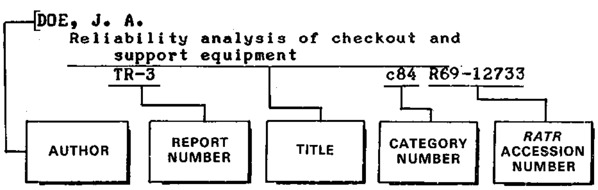
Typical Personal Author Index Listing



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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 5

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Reliability Abstracts and Technical Reviews

JUNE 1969

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EXAMPLES OF CITATIONS IN *RATR*

RATR ACCESSION NUMBER
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R69-12733 ASQC 844; 413
General Equipment Company, Banville, Calif.
RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT
John A. Doe 23 Sep. 1968 27 p refs
(Contract NAS15-13411)
(AD-629305; N69-15098; TR-3) Avail: CFSTI

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AVAILABILITY SOURCE

RATR ACCESSION NUMBER
TITLE
JOURNAL REFERENCE

R69-12739 ASQC 814
SEMICONDUCTOR RELIABILITY.
Joseph A. Smith (Eastern University, Arlington, Penn.).
Electric Journal, vol. 8, Apr. 1968, p 478–492.
(A69-12569)

ASQC CODE
AUTHOR AND AFFILIATION
***IAA* ACCESSION NUMBER**

RATR ACCESSION NUMBER
TITLE
CONFERENCE OR SYMPOSIUM REFERENCE
***IAA* ACCESSION NUMBER**

R69-12765 ASQC 773; 221; 823
TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.
Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).
Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.
Available from Assoc. of Reliability Eng., New York: $1.00
(A69-12407)

ASQC CODES
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VOLUME 9 NUMBER 6

Reliability Abstracts and Technical Reviews

A Monthly Publication
of the National Aeronautics and Space Administration

June 1969

80 RELIABILITY

No abstracts in this issue.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14433 ASQC 810
PRODUCTS LIABILITY AND RELIABILITY: SOME MANAGEMENT CONSIDERATIONS.
Washington, D. C. Machinery and Allied Products Institute 1967 186 p refs.
Members, $7.50; nonmembers, $15.00.

Products liability claims are discussed in terms of the total corporate response to the problem which will have to be made by every department of industrial and business organizations: engineering, manufacturing, packaging, advertising, sales, insurance, and law. In-depth consideration is given to the identification, prevention, or mitigation of products liability hazards in the design and manufacturing cycle and in relations with customers; warranties and hold-harmless clauses; internal corporate management for product safety; cooperation between a manufacturing company and its insurance carrier in the handling of products liability claims; and the availability of insurance coverage. It was generally concluded: (1) The overriding thrust of corporate engineering effort must be to produce better designs for manufactured products at reasonable cost from the standpoint of safety and reliability. (2) Products liability hazards in the manufacturing cycle can best be eliminated by total employee involvement in error-free performance and by rigorous quality control. M.G.J.

Review: This is a good and easily readable book for those who wish to learn more about product liability. It has limited value to reliability engineers who are interested in learning more about their own discipline. For convenience in reviewing, the main headings of the chapters (after the Introduction) have been numbered from I to IX. Many of the chapters discuss the law itself or the legal reasons for carrying out certain procedures. The book deals much more with product liability than it does with reliability but the two are interrelated since along with safety they deal with subsets of the failure events. The discipline of reliability engineering is equally applicable to product liability; thus there are the following two reasons why reliability engineers would be interested in the book. (1) They can learn more about their own discipline as it is shown in the different context; and (2) they themselves may become involved in product liability due to the close relationship of the two disciplines. In the Introduction and Chapter I, the viewpoint of the book is clearly presented; that is, it will represent the interests of manufacturers as opposed to those of consumers. The manufacturer is considered to be placed at a disadvantage by adverse law and needs to be shown how to get out from under. While there is not necessarily a dichotomy between the manufacturers' and consumers' interests, the problem is often expressed as such in the book; the bias of this book is neither unexpected nor hidden. The response to the challenge of product liability is generally a good one; that is, reliability and safety must be the job of each person in managing, engineering, production, sales, advertising, et al. Chapter III is a good discussion of the product cycle especially as seen from the reliability point of view. It describes some employee motivation programs and a quality audit; both are worthwhile. The last part of the chapter describes the kinds of detail to which one must pay attention if he is to avoid having his product do damage to the public, and the possible consequent legal action. These details are far-ranging; from foolproofing the equipment to reducing the amount of puffery in advertising claims. Chapter IV shows that the writing of a contract is important. Just as in reliability, too much specification is about as bad as too little specification. Field service is shown to help the customer get what he wants when he wants it (the essence of reliability). The chapter closes with a discussion of the ways in which a manufacturer can protect himself, and is made much more readable by the sense of humor. Chapter V deals with the internal management of the company. Employees are very adept at guessing the tradeoffs their boss would have made had he been required to make it. Employees will generally make their boss's real choice regardless of his nominal attitudes and formal pronouncements on the subject. Employees are adept at distinguishing between (a) lip service to reliability and product liability and (b) the real guts of manufacturing: meeting schedules and keeping costs down. Thus, when the products in the field are having reliability problems, it is management's own real attitudes that need overhauling first. The remainder of the book (including Chapter II) largely discusses the legal and insurance aspects. The closing statement of Chapter VI is interesting and is a good point on which to end this review: "Perhaps the public . . . is spoiled. It expects when it buys a product to have the product perform—to do what it is supposed to do—without personal injury or property damage. Give the public that product—everytime—and the manufacturer's liability will be zero. That is an impossible goal but strive for it."

R69-14440 ASQC 810

National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

FACTORS AFFECTING THE QUALITY AND RELIABILITY OF PRODUCTS

A. V. Glichev Redstone Arsenal, Ala. Redstone Sci. Inform. Center 4 Apr. 1968 13 p Transl. into ENGLISH from Standarty i Kachestvo (USSR), no. 6, 1966 p 69–71 Sponsored jointly by Army

(NASA-TM-X-61105; RSIC-775; N68-25364) Avail: CFSTI

A general discussion of factors affecting the quality and reliability of products classifies these factors according to technical, organizational, and price. Application of progressive technological processes and more know-how in the planning and design stages are considered among the more important factors. The three types of factors are then related to the planning, production, and operation of a product; and the role of the human operator is mentioned. M.W.R.

Review: This is a very qualitative paper which says essentially that the quality and reliability of a product are affected by technical expertise, organization, and economics. A brief breakdown of each of these three is given. Redundancy is briefly mentioned, both active and standby. The problem of labor incentives is given a few paragraphs and even profits are talked about. It is to be hoped that there are few if any in positions of responsibility in this country who are not yet familiar with the ideas in this paper. If they are not, there are many similar articles written originally in the English language, so that this paper will be of most interest to those who whish to use it as a gauge on Russian status and progress.

R69-14464 ASQC 813

RELIABILITY TASKS VS. PRODUCT RELIABILITY.

David I. Troxel (Radio Corp. of America, Defense Communication Systems Div., Camden, N. J.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 48–53.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

The objective is to analyze the various reliability tasks, often employed on hardware programs, with regard to their interrelationship and applicability to meeting requirements. A further objective is to provide an overall evaluation of the relative contribution of the various reliability tasks to actual reliability achievement in the hardware. Analysis of each task shows, for most tasks, that the potential contribution varies considerably depending upon the characteristics and requirements of the particular equipment. The analysis is summarized as an evaluation of relative average contribution of the reliability tasks to achievement of equipment reliability, and an indication of the variability relating to principal influencing factors. This variability necessitates customized selection of tasks and level of effort to accomplish the most effective reliability results on each hardware program. Author

Review: The first part of the paper is a reasonably conventional and brief but nevertheless good discussion of reliability tasks. One keeps waiting for the promised evaluation of the relative contribution of these tasks to the actual reliability achievement in the hardware. It is not till the end of the paper that the evaluation is provided. It is this evaluation that changes the paper from run-of-the-mill to a stimulating contribution. Of necessity, the evaluations are subjective. There was scatter in the initial data so that one should not be surprised if his own evaluation differs somewhat from the author's. Regardless of those differences, this attempt at semi-quantitative evaluation is helpful and managers can use it as an aid in their own evaluation of reliability programs. It is sobering to see some of the tasks given a rating of only 1 or 2 out of 5, especially after reading articles in the literature which suggest that without these particular tasks, any program effort is doomed to failure. The author does point out that these are average ratings and one should expect them to be different for different programs. Perhaps even more important than these specific ratings is the impetus they will give to evaluate the many different aspects of a reliability effort in terms of their relative contribution instead of expecting each task to be a full, all-out effort.

R69-14465 ASQC 814

COST OF RELIABILITY IMPROVEMENT.

Avery H. Hevesh (Avco Corp., Wilmington, Mass.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 54–61. 7 refs.

Available under IEEE Catalog No. 69 C 8-R; $ 8.00.

The contributions of individual, independent methods for reliability improvement are systematically examined and their efficiencies are computed using available, actual cost data from a number of reliability programs. It is pointed out that most military systems and many commercial systems are influenced by interactions including (1) the cost in development to go from a standard design to a more reliable one; (2) manufacturing costs resulting from the attained reliability of the design; and (3) the logistic cost to support produced equipments which is also sensitive to the degree of attained reliability. A cost modeling method is suggested which pertains to the starting and running costs of engineering services and materials from the inception of system design concepts through the engineering prototype phase to the release of manufacturing drawings. M.G.J.

Review: This is an interesting paper that treats the reliability improvement as a function of the engineering cost to achieve it. There were barely enough data to estimate the coefficients; so there is no idea of the uncertainty involved in the estimates. The limitation mentioned by the author should be emphasized, viz., this is just the engineering costs and does not include production costs. The assertion that the parts' costs are small compared to engineering costs is obviously not true for some programs. (There are high-production electronic equipments wherein parts' costs are most important.) Also, while it does not affect his arguments at all, the assertions that reliability testing is not a direct engineering effort for reliability improvement is in direct contrast to the statements in several of the papers given at the same symposium wherein good reliability testing is cited as one of the main avenues for reliability improvement (the difficulty may be semantic). This kind of paper is a worthwhile addition to knowledge on cost effectiveness.

R69-14466 ASQC 813

RELIABILITY: WHAT HAPPENS IF ... ?

Ervin F. Taylor (General Electric Co., Philadelphia, Pa.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 62–67. 1 ref.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

The quantitative and qualitative approaches to a reliability program are examined, based on experience with both aerospace and commercial products. To arrive at a reliability program melding both these approaches, a Failure Effect Management System is proposed. This is an iterative process starting with the conceptual design and continuing through use. Both the qualitative and quantitative reliability disciplines are utilized at each stage although the types of disciplines may vary. The following advantages of the system are cited: (1) The reliability impact is placed early in the project while there are sufficient resources to effect preventive action. (2) Early reliability effort is directed toward tangible failure effects. (3) Reliability numerics are employed for the critical trade-off process to answer the question, "How much?". (4) Reliability efforts result in three possible positive actions: eliminate the failure effect; reduce the failure effect; or accept the failure effect with known risk. (5) The reliability program is fully integrated with all other project technical and management disciplines. M.G.J.

Review: This is an enthusiastic presentation of the author's scheme to solve reliability management problems. Its uniqueness is undoubtedly considerably less than stated by the author although just as surely his exact system is not duplicated in the literature. The program is a reasonable one and those casting about for a mold for a reliability program would do well to consider this one. It is a rather general pattern and considerable management and engineering effort is necessary to fill in the important details. The author is over-enthusiastic about qualitative reliability improvements. Engineering changes which were intended to improve reliability have occasionally introduced more problems than they solved; so changes do not always improve the situation. Interestingly enough, in the text one has to know the cost of the particular failure mode or effect before he can do anything about it, i.e., a quantitative evaluation is necessary, yet this is the qualitative reliability stage where one is not sure how much reliability improvement will be achieved. In actual practice, one often makes a rough judgment in the matter; he does not know exactly what the outcome would be. All in all, if the paper is read with suitable discounting for the enthusiasm and very positive approach, it has many worthwhile points.

R69-14467 ASQC 810

RELIABILITY MANAGEMENT SIMULATION EXERCISE.

Virgil Rehg (Air Force Institute of Technology, Wright-Patterson AFB, Ohio).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York IEEE, Inc., 1969, p. 68–72.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

Details are given on a reliability simulation training technique which places the students in an atmosphere similar to what would be encountered in real life, and forces them to make decisions comparable to those that arise in the development, production, testing, and field usage of a system. The simulation emphasizes the problems that arise for both the vendor and the buyer in the acquisition of a system. The responsibilities of the two organizations are assumed by the students who are assigned key roles in these two organizations. They must make the pertinent decisions that arise during a three year time span that coincides with the various stages in the life cycle of a system. The problems given to the teams during the exercise are designed to bring out specific reliability problems. It is pointed out that this type of training can be used in conjunction with either a formal or informal training course, or it can be used by industry to determine the competency of their personnel. M.G.J.

Review: The only trouble with this paper is that it whets your appetite to learn more about the actual simulation exercise itself, then does not give any details nor show where they may be obtained. The general description of the reliability management simulation program sounds as if it is a most worthwhile exercise for the students, and one in which other groups would be interested. Presumably, the problems which the instructor injects and which the students themselves cause are realistic and create situations in which learning is the natural easy thing to do.

R69-14468 ASQC 813; 844

PHYSICS OF CONTROL OF ELECTRONIC DEVICES.

C. Y. Ang, P. H. Eisenberg, and H. C. Mattraw (North American Rockwell Corp., Autonetics Div., Anaheim, Calif.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 73–85. 5 refs.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

Based on data from physics of failure studies and continuing post-mortem analyses, it was found that a major source of reliability degradation of semiconductor devices is the lack of product homogeneity or quality consistency, and the incomplete solution of critical problems. An approach to the solution of this reliability problem is offered in the physics of control (POC) program for the electronic components of a weapon system: the integrated circuits and critical discrete devices. Designed for a priori reliability, the POC program attempts to (1) characterize in depth the good, qualified parts; (2) establish relationships between the chemical, physical, and electrical properties; (3) determine allowable ranges for the various parameters; and (4) recommend findings for specifications and corrective actions implementation. Selected data are presented to illustrate the applicability of the concept and how the multidisciplinary skills are utilized in the conduct of program tasks. Author

Review: Manufacturers, especially of electronic devices, like to insist that if the customer would only tell them exactly what he wants and then leave them alone, he would get it. Unfortunately, this idyllic state has yet to come to pass. This paper discusses work which is perhaps best described as an extended incoming inspection. Not only are specified parameters considered, but those characteristics of the device which are not specified but perhaps are important are also investigated. Furthermore, the program is not concerned just with some statistical risks of a mean or standard deviation but with the actual state of each device. In short, one is trying to describe the manufacturer's process for him. This is being done in advance of field failures as a precautionary measure. As testing and investigative methods have become more sensitive, the question has arisen: "When is a discrepancy a defect?" Obviously, if one has a fine enough detector, one can find inhomogeneities everywhere. Many of these inhomogeneities do not harm the device in its operation or shorten its life. That is, the system will fail for other reasons first. The name given to this task, "Physics of Control ..." again shows that when engineers must work smarter instead of harder and ask why, they tend to call it physics. All in all, this paper appears to be a reasonable discussion of a reasonable program.

(This paper is abstracted in *Electronics*, vol. 42, no. 5, 3 Mar. 69, pp. 227, 229, 231.)

R69-14470 ASQC 813; 844

MECHANICAL FAILURE TECHNOLOGY: A COORDINATED GOVERNMENT PROGRAM.

Marshall B. Peterson (Mechanical Technology, Inc., Latham, N. Y.) and Donald Flage (Office of Naval Research, Washington, D. C.)
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 127–132.
Available under IEEE Catalog No. 69 C 8-R; $8.00.

Mechanical failure technology is defined as the application of science to the understanding of mechanical failure processes. The objective is the study of failure processes in components to evolve better designs and criteria, or diagnostic instrumentation; thus, significant contributions can be made to reducing failures in practice. The establishment of a Mechanical Failure Working Group is discussed, and the work tasks under study are described briefly. M.G.J.

Review: This paper describes the program itself rather than any technical findings made under that program. As such, its value is current awareness rather than detailed facts which will help anyone prevent or avoid failure. It is extremely difficult to evaluate programs from a brief written description such as appears in this paper. There is certainly nothing in the description to make one think the program will not be a valuable contribution, but as is well known, many programs do not live up to the hopes expressed for them. Some of the areas have already been researched intensively, such as lubrication and microscopic behavior of balls and races in bearings. Other areas listed are difficult to decipher. For example, under the failure-indicating systems, somehow or other the bearing noise signature (presumably acoustic) is going to be combined with an optical laser spectrum. It is not clear what this laser spectrum will be of nor how it will be combined with the noise spectrum.

R69-14471 ASQC 810; 844; 871

STATE OF THE ART ASSESSMENT OF RELIABILITY AND MAINTAINABILITY AS APPLIED TO SHIP SYSTEMS.

B. L. Retterer (ARINC Research Corp., Washington, D. C.).
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 133–145. 1 ref.
Available under IEEE Catalog No. 69 C 8-R; $8.00.

The acquisition of a data base for machinery is discussed in relation to establishing an effectiveness assurance program for the comprehensive evaluation of the reliability, maintainability, and effectiveness of mechanical systems. The objectives are cited as (1) providing the means to establish realistic reliability requirements for mechanical systems; (2) developing specification methods to invoke these requirements in system procurement; (3) establishing analysis and design methods to assure that developed systems will meet requirements; (4) setting forth methods of contractually demonstrating that requirements have been met; and (5) providing training to cognizant personnel in the use of the developed technology to assure proper application. The technology requirements are divided into major elements: specification, assurance program standards, test techniques, modeling and analytic techniques, data base, life cycle costing methods, and integrated logistic support. Considered complementary to these are the management of technology development, and the training of management, engineering, and technical personnel. Author

Review: An overview of the quantitative analysis and program management aspects of reliability and maintainability of naval ship machinery is given in this paper. It is suited for readers who are seeking such background; however, the reader should beware of the author's conclusion which is essentially that the state-of-the-art of quantitative analysis and related program management techniques for reliability/maintainability is shallow. The basis of comparison is the analysis and program practices—mainly for electronics—which have evolved in recent years. However, in terms of the typical operational reliability and availability which have been realized, shipboard machinery has been significantly more successful than has electronics. Over-design and redundancy have been traditional approaches for shipboard machinery. The author may be correct in the implication that there is not a great deal of cost-effectiveness justification for shipboard machinery practices. This paper also implies that the state-of-the-art of reliability and maintainability quantitative analysis for machinery is rather barren. Actually, there is more in the literature for electronics than for mechanical machinery, but there is some non-electronic coverage. The reader should also guard against the impression that the analysis and program techniques for electronics are without room for improvement.

R69-14474 ASQC 815; 881

SPECIFICATIONS AND VERIFICATION OF AVAILABILITY IN TOTAL PACKAGE PROCUREMENT.

George F. Floyd (Bissett-Berman Corp., Santa Monica, Calif.).
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 168–172.
Available under IEEE Catalog No. 69 C 8-R; $8.00.

Availability is defined as the probability that a subsystem is operable at the start of a mission, with the mission start-time assumed to be a random variable. As a specific example, the formula used by the Navy to predict subsystem availability for new ship systems is given: Availability (A) = Mean Time Between Failure (MTBF)/MTBF+Mean Time to Repair (MTTR). This formula computes the true availability only if the equipment is used as much of the time as possible, consistent with its failure rate. When the equipment is only wanted a fraction (u) of the time, then the correct formula to compute the availability probability should incorporate the desired utilization factor as follows: A = 1−u MTTR/MTBF. The differences between the two formulas are discussed, with examples given for actual systems. In particular, the significant differences which would occur in subsystem design are shown. Specific problems of measuring achieved availabilities under the two formulations are treated, and recommendations are made for appropriate measurement methods. Author

Review: This paper does a good job of presenting some realistic problems in the specification and verification of availability in total package procurement. Both contractor and government personnel who are concerned with this topic should read it and pursue the topic further. The paper illustrates the possible financial impact resulting from two different simple availability equations. The problem is actually more involved than the paper illustrates. For instance, the two simple availability equations compared are not suitable for multi-state systems such as those containing some redundancy. Also, many availability models are based on the assumption of a Poisson distribution of equipment failures and an exponential distribution of time-to-repair. The validity of these for application to an array of subsystems, such as those for a naval vessel noted by the author, has yet to be ascertained. The paper does not acknowledge implications of statistical considerations of using data to estimate indexes. The basis of the problem discussed in this paper is that of request for proposal (RFP) requirements which have appeared in very large dollar contracts which will dramatically affect government risk and contractor profit. One should keep in mind that on occasion an RFP will contain non-applicable effectiveness indexes or models, will be requesting performance measured by availability or some other index which is beyond the current state-of-the-art, or will be requesting contractual approaches which are beyond prudent business practices. The role of the potential client is indeed a privileged one but this does not necessarily make him an authoritative source of reasonable practices.

R69-14476 ASQC 813; 844; 851

ECONOMICAL RELIABILITY PROGRAM DESIGN.

B. L. Bair and A. Fox (General Electric Co., Semiconductor Products Dept., Syracuse, N. Y.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control New York, IEEE, Inc., 1969, p. 181–190. 9 refs.

Available under IEEE Catalog No. 69 C8-R; $8.00.

Emphasis is placed on the need for careful experimental design in order to meet reliability program objectives in an economical manner. Program design elements such as parameter measurements, control of the measurements, types of stress tests, levels of stress, and some techniques for analyzing the data to be generated are described. Several precautions to be used in generating and handling the data are also indicated. The goals of reliability evaluations are discussed, and a comparison program is developed which could be used by a manufacturer to assess the effects of a proposed process change, or by a user to aid in determining which of the competing types of devices to purchase. The design example employs step-stress tests to obtain the results in a short time. Stress tests which were found to be effective in revealing failure mechanisms are then combined in the design of a complex reliability program. Constant stress-in-time tests are employed, and some assumptions in using these tests are described. The use of device response modeling techniques, such as the Weibull and Arrhenius models, are also discussed. Author

Review: The title of this paper is somewhat misleading in that economic models are not explicitly introduced. The paper is rather a potpourri of ideas concerned with the testing of semiconductors. One of the very helpful things it does is mention some of the details to which the program manager must pay attention in order for the results to be useful and interpretable. In general, the discussion is good although on some of the points, individual experience and opinion will undoubtedly vary. Two examples of the minor difficulties in the report are the following: (1) On page 184, it is not necessary to make the authors' first major assumption about step-stress testing. They assert that cumulative degradation must be negligible on steps preceding the failure step. This is not a necessary condition of step-stress testing. It is a necessary condition only if one does not wish to use some theory of cumulative damage in analyzing the tests. Several of the very good papers on progressive- and step-stress testing do require an assumption of cumulative damage. (2) The curves asserted to be typical of Arrhenius models are true if the formulas are known ahead of time. If one has to estimate the hazard rate at each temperature from the data taken at that temperature, he often finds that the points do not lie on a nice neat straight line. There is usually a tremendous amount of scatter in the estimates of hazard rate at each temperature, so that drawing the lines solely on the basis of the data points is a difficult task. All in all, this is a good paper on the topic and will be useful to anyone trying to gather information on it.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14434 ASQC 824; 838

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

ESTIMATE OF THE RELIABILITY OF SCHEMES WITH PERMANENT REDUNDANCY UNDER CONSIDERATION OF THE POSSIBILITY OF A DEPARTURE OF THE SYSTEM PARAMETER BEYOND THE TOLERANCE LIMITS [OTSENKA NADEZHNOSTI SKHEM POSTOYANNOGO REZERVIROVANIYA S UCHETOM VOZMOZHNOSTI UKHODA PARAMETRA SISTEMY ZA PREDELY DOPUSKA]

A. M. Margulis 28 Nov. 1967 20 p refs Transl. into ENGLISH from Avtomat. i Vychislitelnaya Tekhn. (USSR), no. 11, 1965 p 199–214

(AD-673927; FTD-HT-23-998-67; N68-38137)

Constant redundancy represents one of the methods for improving system reliability; the failure of any of the elements however, results in a change in the output parameters. The author investigates the determination of the probability of failure-free operation of constant redundancy systems up to a specific time, provided the output parameter of the system remains within the limits of tolerance. The solution is presented and the case of small tolerances in the output parameters is discussed. The spread in parameters of individual elements is taken into account and illustrative examples cover the case of short circuits and of interruptions. TAB

Review: This paper treats a combination of series-parallel elements (series and parallel refer to the physical connection, not the logic diagram). Each element has a performance parameter such as resistance, and it is presumed possible to calculate the performance parameter of the system from that of the elements. The only way that elements fail is by having this parameter go to zero or infinity, and these are each presumed to be independent Poisson processes tied together in the appropriate Markov process. (In any given component, the two processes compete with each other.) The solution to the problem is given in the form of an equation involving integrals. An example is solved wherein it is presumed that there are enough elements so that the system performance has a Gaussian distribution. The paper itself is not detailed and it would be difficult to check the equations; however, one should do so before using the results. Between the original author, the translator, and several printers, mistakes could easily have crept in. No attempt was made to check the accuracy of the answers since it would involve much original work. This kind of process has been treated in the literature, perhaps not in this generality, but pieces of practical interest are likely to be found already worked out. (This document AD-674 334 is a translation of a later and shorter paper by the same author on the same topic. It contributes little extra toward understanding the subject. Neither paper refers to the other.)

R69-14435 ASQC 824; 433; 822

Research Analysis Corp., McLean, Va.

USE OF THE WEIBULL DISTRIBUTION IN BAYESIAN DECISION THEORY

Richard M. Soland Aug. 1966 21 p refs

(Contract DA-44-188-ARO-1)

(AD-668677; RAC-TP-225; N68-86505)

The Weibull distribution is useful in analyzing the probabilistic lifetimes of many electrical components and complex systems. It is attractive for Bayesian decision-making because its right-hand cumulative function is of an exponential form which allows all life-test data to be easily incorporated into the decision-making process. Unfortunately no natural conjugate prior distribution exists if both the shape and scale parameters of the Weibull distribution are assumed to be unknown. If the shape parameter is assumed known, however, Bayesian analysis becomes little more difficult than for the exponential distribution, a special case of the Weibull. Prior, posterior, and preposterior analyses are given for the case of known shape parameter. In connection with preposterior analysis several sampling plans are discussed. The paper concludes with an analysis of a problem in optical sampling. Author (TAB)

Review: This author has been investigating the use of the Weibull distribution in connection with Bayesian decision theory, and this report is an extension of that work. Even though it was issued as a company report about the same time as the one covered by R68-13651, it has only recently gotten into the publicly-distributed government reports. The two papers cover similar ground, but the emphasis in this one is on reasons why Bayesian analysis should be used in reliability problems and the usefulness of the Weibull distribution under those circumstances. In the body of the papers, the technical material has a very large overlap. An appendix in this paper briefly explores a prior density function where both Weibull parameters are unknown, and the difficulties are made clear. Many of the comments on the mathematics of the paper covered by R68-13651 apply to this paper also. The viewpoint itself is good and, by now, reasonably standard. Bayesian decision theory is useful in reliability problems, the Weibull distribution function is a reasonably flexible distribution for describing the lifetimes of many components, and conjugate prior distributions are most often used for the prior knowledge.

R69-14436 ASQC 824

Wisconsin Univ., Madison. Mathematics Research Center.

THE ESTIMATION OF RELIABILITY FROM STRESS-STRENGTH RELATIONSHIPS

J. D. Church and Bernard Harris Dec. 1967 13 p refs

(Contract DA-31-124-ARO(D)-462)

(AD-671605; MRC-TSR-814; N68-32635)

Confidence intervals for P(braces: Y <X) are obtained under the assumptions that X and Y are independently normally distributed and the distribution of Y is known. The procedures of this paper are compared with a procedure suggested by Z. Govindarajulu. Author (TAB)

Review: This is largely a mathematical paper written for theorists rather than for practicing design engineers. The topic of the paper is much narrower than the title, as is typical of this kind of mathematical paper. The calculations were not checked in detail, but they appear accurate. Specifically, the problem under attack is the following: (1) Stress and strength are independently and normally distributed, (2) one of the distributions is known and a random sample is obtained from the other, and (3) it is desired to put confidence bounds on the probability of no failure. Reliability engineers who are not too familiar with statistics should note that most often they are concerned with confidence bounds on such parameters as hazard rate or mean-time-to-failure rather than the reliability itself. These theoretical results are not in a form suitable for use by practicing engineers. It would be desirable for someone to reformulate them for reliability and design engineers.

R69-14438 ASQC 821; 844

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

EVALUATION METHODS AND SOME WAYS FOR INCREASING THE RELIABILITY OF AUTOMATIC CONTROL RESULTS [SPOSOBY OTSENKI I NEKOTORYE PUTI POVYSHENIYA DOSTOVERNOSTI REZULTATOV AVTOMATICHESKOGO KONTROLYA]

V. I. Perov and T. D. Zholkover 27 Oct. 1967 11 p refs Transl. into ENGLISH from Vsesoyuznaya Konf. Po Avtomat. Kontrolyu i Metodam Elektr. Izmen. 1966 p 78–84 Presented at the 5th All-Union Conf. on Autom. Control and Methods of Elec. Meas.

(AD-673390; FTD-HT-23-734-67; N68-36904)

Reliability is the decisive factor in automatic control since the information gathered during the control of technological devices must reflect accurately their actual state. The quantitative measure of reliability is expressed by the probability that the result is correct. Of all the possible factors affecting the reliability of automatic control, the authors investigate only the loss of information caused by the quality of the control devices. It is assumed that the initial information on the controlled plant is complete. The newly developed formalism is applied to the control of the operational readiness of devices. Author (TAB)

Review: As is typical of machine translations and many translations in general, this one is difficult to decipher although perhaps not worse than some that are written in English to begin with. Apparently, the author wishes to consider that a control system is in any one of four states: good or bad, with an indication of good or bad. Two of the four states are in error and two are correct. He then assigns a probability to each state and calculates an entropy for various conditions, entropy apparently being defined as $\Sigma P \log P$. The entropy is caluclated for different circumstances and compared but it is not clear exactly what is being done nor why. Possibly the author is trying to develop a figure of merit for a control system, but since probabilities of failure and success for the various states are the only things put into the entropy expression, it is not obvious how this is being done. The entropy calculation often does provide a useful figure of merit; so the intent of the paper seems worthwhile. A thorough analysis of what has been done here would require a considerable effort and contribution from the reader.

R69-14439 ASQC 824; 837

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

ASSURED EVALUATIONS OF SYSTEM RELIABILITY WITH INCOMPLETE INFORMATION CONCERNING RELIABILITY OF ELEMENTS [O GARANTIROVANNYKH OTSENKAKH NADEZHNOSTI SISTEMY PRI NEPOLNYKH SVEDENIYAKH O NADEZHNOSTI ELEMENTOV]

Yu. B. Germeyer, D. S. Irger, and E. P. Kalabukhova 20 Sep. 1967 25 p refs Transl. into ENGLISH from Zh. Vychislitel'noi Mat. i Mat. Fiz. (Moscow), v. 6, no. 4, 1966 p 733–747

(AD-673758; FTD-HT-67-463; N68-36666)

It is conventional to consider the complete characteristic of the reliability of a system (or element) to be function P(t), i.e., the probability of troublefree operation of the system (or element) during time t. Reliability theory examines the following basic operations on the laws of distribution of P(t), at any value of t: sequential combination of n elements; parallel combination of n elements; combination with replacement of elements; and averaging with respect to random operating conditions. The exponential law of reliability has acquired exceptional significance. If this is not used in estimating element reliability there naturally rises the question of how many and what characteristics of P sub e(t) must be known to give well-founded estimates of system reliability; the minimum number of such characteristics is of course desired. The specific problem in this paper is to explain what may be guaranteed in the sense of knowing P(t) in combinations of the above types if some of the listed characteristics are known about Pe(t). TAB

Review: This paper is concerned with setting bounds on the reliabilities of elements and a system, when only certain characteristics of a reliability function of the element are known. It is shown that if all that is known is the mean life, it does not help very much in setting bounds on the reliability. If the variance is also known, then by taking worst cases, some reasonable upper and lower bounds can be set for each element and also for the system. Several different systems are considered; for example: series, active redundancy, and standby redundancy. If the value of the reliability and some of its derivatives are known at time = 0, then additional information is available which can be helpful even in the worst-case situation. These calculations will be of interest largely to theorists rather than the practicing design engineer. It is interesting to contrast them with the E. T. Jaynes theory of maximum entropy wherein if only the mean is known, one would presume the exponential distribution; if the mean and the variance are known, one would presume the Gaussian distribution. Not all of the algebra was checked but it appears to be competent. The results will be of little practical value to design and reliability engineers.

R69-14442 ASQC 825; 612; 838

USE OF GEOMETRIC PROGRAMMING TO MAXIMIZE RELIABILITY ACHIEVED BY REDUNDANCY.

A. J. Federowicz and M. Mazumdar (Westinghouse Research Labs., Pittsburgh, Pa.). *Operations Research,* vol. 16, Sept./Oct. 1968, p. 948–954. 3 refs.

Consideration is given to the problem of optimum allocation of redundant elements in a simple series system (maximizing system reliability subject to several linear cost constraints). Under the approximation that the components of the redundancy vector can be treated as continuous variables, the paper formulates this optimization problem as a geometric programming problem, describes techniques for obtaining numerical solutions in general, and obtains asymptotic closed-form solutions. A standard numerical example is used to illustrate that the asymptotic solution, when suitably rounded, compares favorably with the discrete optimal solution. Author

Review: The principal interest of this paper lies in the analytical techniques which are used to obtain the approximate closed form solution to the active redundancy allocation problem. The technique has the desirable features of being able to handle multiple non-linear constraints and requiring less computational effort than some other methods. The fact that an approximate solution is obtained is not a real detriment since technical considerations other than those reflected in the objective and constraint models will also influence the actual decision. The test of whether or not this technique is a potentially useful tool for reliability purposes will be its successful application to more complex problems. The following comments apply to this class of paper, not just to this one in particular. The reliability problem treated in the example is that of active redundancy with two linear constraints. Problems of this simple type frequently appear in the literature. Insofar as applications in reliability and maintainability are concerned, these neat little problems are not very realistic. They will seldom arise in real-world design. For instance, if redundancy is possible, it could be active or standby, the latter with or without automatic switching. Also, there may be alternate reliability levels (various failure rates) for the functionally identical items as well as alternate maintainability levels (various repair rates). Consideration of repair leads to more realistic effectiveness models involving availability or availability and reliability simultaneously. Similarly, a realistic cost model will not likely be a simple linear one; it should reflect total lifetime costs. Those with interests and capabilities in the topic of allocation techniques should broaden the scope of decision variables and models. The objective function and constraint models for reliability and related areas should reflect real-world problems. Approximate solutions to realistic problems would be of much more design value than more precise solutions to very restricted reliability problems.

R69-14443 ASQC 821; 838

THE RELIABILITY OF DEPENDENT PARALLEL OR STANDBY N-UNIT REDUNDANCIES.

Joseph J. Eiss (Sperry Rand Corp., Sperry Gyroscope Div., Great Neck, N. Y.).

Operations Research, vol. 16, Sept./Oct. 1968, p 1068–1083.

(A68-45033)

The paper is concerned with evaluating the reliability of a redundant configuration, given that at any random time its surviving components are operating with failure distributions that are dependent upon the set of failed components. An expression is derived for the reliability of this class of configurations and is then generalized to obtain an expression for the reliability of a similar configuration whose component failure distributions are dependent also upon the time of the last such failure. These expressions are then applied to evaluating the reliability of standby configuration with off-line failures, and the reliability of a parallel configuration for which at least a certain number of components must survive in order that the configuration operate satisfactorily. Author (IAA)

Review: Reliability models in which failure densities are independent of failure times have been treated elsewhere. However, their inclusion in the first section of this paper constitutes a lead-in and serves as a check on other sources. The second section of the paper gets away from conventional assumptions and previously-treated problems. Only those with interests in structuring detailed reliability prediction models are likely to want to follow carefully all of the material in the paper. Realistic applications for most of it are likely to be scarce because of the lack of the necessary detailed conditional information. However, the paper serves as a reference item exploring the development of modeling in which the usual assumptions of independence are not made. It may simulate further work on the problem and the gathering of data necessary for experimental applications.

R69-14454 ASQC 821; 844

STOCHASTIC MODEL TO FATIGUE.

Octavio A. Rascón Chavez (Instituto de Ingeniería, UNAM, Mexico, D. F., Mexico).

(Reunión Conjunta ASCE-CICM, Feb. 1966, Mexico, D. F., Mexico.) Journal of the Engineering Mechanics Div., Proceedings of the American Society of Civil Engineers, vol. 93, June 1967, p. 147–155. 5 refs.

A probability distribution is proposed for the number of load applications of equal magnitude required to produce fatigue failure on a structural element. A unidimensional random walk of the logarithm of the number of load applications is used as a stochastic model. This mode, as all others, whether deterministic or stochastic, is subject to lack of precision because the hypotheses on which it is based are only partially fulfilled; they are better fulfilled for certain materials than for others and there are certain types and magnitudes of load for which the results obtained will be most satisfactory. Behavior of the risk function is studied and the results of the theoretical distributions are compared with those corresponding to some empirical distributions available. Author

Review: The stochastic model mentioned in the title is not the load (i.e., this is not random fatigue) but refers rather to the nature of the assumption of damage accumulation. Damage accumulation is considered to be a continuous variable and analogous to the area of a transverse crack. Failure presumably occurs when the crack has propagated all the way through. The crack change is proportional to the existing crack size (compare this with "Fatigue failure of a redundant structure," by R. A. Heller and R. C. Donat, ASTM STP404, 1967; see R69-14381). The stochastic part of the model arises from the fact that for each cycle the crack increase is assumed to happen only with probability p; with a probability 1–p, there is no crack increase at all on that cycle. These assumptions are followed through and compared with some actual data from the literature. The author claims that his model fits the data as well as the various models in the literature. The graphs shown are certainly not unreasonable, but this is to be expected with anything that finds its way into the published literature. This is an interesting and worthwhile attempt at a cumulative damage theory. There is no indication of how the author would extend it to other than constant load amplitudes although some extensions come reasonably readily to mind. The theory does not take into account the various stages of crack development and in that sense is empirical, but not more so than many extant cumulative damage theories. The physical basis for the theory is by rather loose analogy, again, in common with many in the literature.

R69-14456 ASQC 824; 838

OPTIMIZATION OF COMPLEX SYSTEM RELIABILITY WITH SEVERAL CONSTRAINTS.

O. G. Alekseev.

(Avtomatika i Telemekhanika, no. 12, Dec. 1967, p. 177–182.) *Automation and Remote Control,* no. 12, 1967, p. 1978–1983. 9 refs Translation.

A method is proposed for solving the problem of the optimization of the reliability characteristics of complex systems whose possible variants are defined by means of an oriented network graph. The method is based on the principle of "invariant embedding" and is illustrated by a numerical example. Author

Review: This paper is concerned with the problem of maximizing the reliability of complex systems while satisfying constraints on technico-economic characteristics such as volume, weight, and cost. An attempt is made to represent all possible realizations of a complex system by an oriented network graph. However, the explanation of this relationship is less than crystal clear. A later example helps clear up the difficulty to some extent. The procedure consists of finding an initial feasible solution X° with reliability P°. Then a sequential search is carried out by first locating all solutions which satisfy the first constraint only and have reliability greater than P°, then all solutions satisfying the first and second constraints with reliability greater than P°, etc. (At each stage in the search it is possible to decide if the optimal solution has been reached.) The methods for generating these solutions are not specified but references are made to publications where presumably these methods can be found. This paper is difficult to read. The formulation of the problem is vague due in large part to the lack of concreteness in terminology and notation. The method proposed appears to be worth a better presentation. As it stands, the paper will be of value only to those with prior knowledge of the subject, and they will have to devote a considerable amount of effort to derive that value.

R69-14457 ASQC 824

READINESS OF DORMANT SYSTEMS SUBJECT TO PERIODIC CHECKOUT.

Igor Bazovsky (Genge Industries, Inc., Scientific and Consulting Div., Sherman Oaks, Calif.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control, New York, IEEE, Inc., 1969, p. 1–4. 5 refs.
Available under IEEE Catalog No. 69 C 8-R; $8.00.

To predict the operational readiness of dormant missiles, a mathematical model is developed which shows the interdependence of three distinct time distributions which must be considered. These are: (1) the distribution of time to failure detection; (2) the distribution of time between tests; and (3) the distribution of time to failure occurrence. Field data are used to obtain the information on (1) and (2). After evaluating these two time distributions, the time to failure can be computed. Examples for some specific distributions are given, including the exponential distribution of time between tests, the Weibull distribution of time to failure detection, the gamma distribution of time to failure detection, and the exponential distribution of time to failure. The model presented implies that the probability distributions of the system do not change with time. Test frequencies and procedures remain essentially unchanged, and the system does not change its distribution of time to failure with age. M.G.J.

Review: This is a short paper (a virtue in any situation), one of whose main benefits to reliability engineers is to help them learn about renewal theory and some of the distinctions between it and time-to-first-failure. The mathematics appears straightforward. It is a theoretical paper; there are no comparisons with field data. The author has listed three assumptions. One of them is not quite the assumption actually made and other assumptions are not listed. Of course, it would be unreasonable to list all of the assumptions being made in any theory since some of them are trivial. Examples of difficulties with the paper are the following: (1) Instead of assumption 2, the derivation actually assumes that the test equipment will *never* declare a failed system good. (2) It is implicitly presumed that a repaired equipment is exactly the same as a piece of new equipment. This would seem to imply at the subsystem level at which checks are made, either (a) that the subsystems have the exponential behavior or (b) no damage accumulation, i.e., the simple stress-strength theory. (3) The meaning of the sentence, "These functions are best obtained by non-parametric or distribution-free methods, and then a known theoretical distribution may be fitted..." is not clear. It would seem that one would do one or the other but that by their nature, one could not do both. Nevertheless, the paper has pedagogical value for reliability engineers since it is reasonably clear, easy to follow, and short enough to read at one sitting.

R69-14458 ASQC 824; 832

MATHEMATICAL MODELING OF HUMAN PERFORMANCE RELIABILITY.

Thaddeus L. Regulinski (AF Institute of Technology, Wright-Patterson AFB, Ohio) and William B. Askren (AF Human Resources Lab., Wright-Patterson AFB, Ohio).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969. p 5–11. 16 refs.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

Consideration is given to time continuous tasks with the derivation of a general mathematical model of the probability of errorless performance which is equated to human performance reliability. The application of this model and the implications of the time to first error concept were tested with a laboratory experiment using a vigilance task. The observed times to first miss error, times to false alarm error, and times to combined miss and false alarm errors were ordered and, through classical inference theory, the underlying density functions were isolated. A number of distributions were tested for goodness of fit. The Weibull, gamma, and log–normal distributions emerged as relevant paradigms. The normal and exponential distributions were rejected. Computer output of distributions were rejected. Computer output of distribution parameters along with goodness of fit results are tabled. Comparison is shown of estimated and fitted means. It was concluded that the derived general mathematical model of human performance reliability, and the expected value of the random variable, time-to-first-human-error, are meaningful ways to quantify human performance of time continuous tasks. Author

Review: This paper is based on a straightforward idea, that of modeling human error mathematically by means of the analytic processes used in reliability engineering. It is concerned with time-continuous tasks, and the modeling is accomplished by equating the human error rate to the hazard rate in reliability theory. From there on the analysis makes use of existing methodology. The paper describes a laboratory experiment set up to measure the mean-time-to-first-human-error, outlines the analytic methodology, and presents results in some detail. The authors' Equation (5), presented as a fundamental result in the paper, is not unique to the reliability of human performance, since it is simply a defining equation for the hazard function. The paper uses standard statistical methodology, so that its contribution is the modeling of human performance reliability in this more detailed way. As the authors have pointed out, this was a preliminary study, and the sample sizes involved did not permit the making of distinctions between the distributions which were considered relevant. More extensive investigations will be needed to accomplish this. An interesting point which may come up in later investigations is that the log-Normal distribution (one of the distributions considered relevant by the authors) eventually has a decreasing hazard rate. In the case of human performance this would imply some sort of learning process or getting better at the task as time goes on.

R69-14472 ASQC 824; 882

APPROXIMATE SYSTEM AVAILABILITY MODELS.

Kenneth Grace, Jr. (Bell Telephone Lab., Inc., Whippany, N. J.).

In : Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 146–152. 6 refs.

Available under IEEE Catalog No. 69C 8-R; $8.00.

Consideration is given to the evaluation of steady-state system availability when there are a limited number of repairable spares for the various types of on-line units. The spare supply creates a statistical dependence among units of a given type. System availability is expressed in terms of unit availabilities using a procedure adapted from work of Messinger and Shooman. Availabilities of various numbers of units of a given type are obtained from an exact Markov model and from several approximate models. The models are compared by means of some simple examples. Author

Review: Approximation techniques which have been applied recently to reliability models are applied in this paper to availability models. This paper is well done from the viewpoints of organization, content, illustration, etc. The types of availability models treated are those for continuously-operating systems as opposed to those for systems which operate only on occasions. The latter models would be applied, for example, in determining missile checkout procedures. This is an informative article for those with an interest in availability analysis.

R69-14473 ASQC 824; 432; 882

WAITING LINE (QUEUEING) EFFECTS ON AVAILABILITY.

E. P. Virene (Boeing Co., Seattle, Wash.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 162–167.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

Details are given on how the effects of fluctuations in flow problems can be analyzed by waiting line theory, and on how to quantitatively predict the effects of such fluctuations in order to improve the design of systems based upon projected operational needs. Examples of the application of this method to numerical data, including data based on an investigation of a typical 1975 near-earth orbit spacecraft and mission, are included. A mathematical model in support of this method is presented, and the proof of the theory is given. Author

Review: The application of waiting-line (queueing) theory to maintainability–reliability analysis is introduced and illustrated in this paper. While the examples given are for spacecraft, this type of analysis is applicable to any repair environment. Queueing theory is a well-developed field, but availability analysis often uses only the simpler models such as those based on the assumption that a repairman is available. This paper is primarily suited for those unfamiliar with queueing theory. References expanding on the material presented are cited, and others are available.

R69-14475 ASQC 824; 872
INCREASING HAZARD FUNCTIONS AND OVERHAUL POLICY.
W. M. Bassin (Operations Research Inc., Silver Spring, Md.).
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 173–180. 9 refs.
Available under IEEE Catalog No. 69C8-R; $8.00.

Statistical methods for the detection and analysis of increasing hazard functions are proposed, and an application of these methods is illustrated. The implications of the rate of increase in the hazard function on overhaul policy are discussed and illustrated. Author

Review: The author is distinguishing between two kinds of repair processes. In a renewal process, after each repair the entire equipment is considered to have the statistical characteristics of a brand-new piece of equipment. In a restoration process, each repaired equipment is presumed to have the statistical characteristics of an unfailed piece of equipment with the same number of operating hours as the failed one had. In the author's main example, the process is apparently considered to be a renewal process at each overhaul, but his statistical tests show that it is a restoration process (as opposed to renewal) at each repair. It is important to remember that these are not the only two possible kinds of repair processes. For example, if the system is an assembly of light bulbs and each one is replaced when it is failed, the system itself will settle down to a constant renewal rate whereas the individual items themselves have increasing hazard rates. The reason that neither of the author's repair processes give this kind of situation is that he is presuming that the replacement parts in fact have been aged along with the equipment whereas this is rarely true. One does not take a set of bearings out of an old motor to use for repair parts. He rather uses a new set of bearings. The paper should be read and analyzed with these distinctions in mind. Even within these limitations, however, the paper does provide some useful information for the reliability and maintainability engineer.

83 DESIGN

R69-14445 ASQC 831; 782; 844; 851
Frankford Arsenal, Philadelphia, Pa. Quality Assurance Directorate.
ENVIRONMENTAL CRITERIA AND SIMULATION METHODS RESEARCH STUDY
Maurice H. Simpson and David Askin Dec. 1967 67 p refs
(AD-666185; R-1876; N68-21505)

The primary function of development and testing of Army materiel is to ensure that material scheduled for worldwide use satisfies minimum operational, technical, and safety requirements in all types of environments and troop operational employment. Accordingly, design and test criteria must provide factual bases for technical doctrine to support operational objectives and improved combat capability. The research program employs systems approach and operations analyses techniques applied to a viable environmental situation to develop environmental criteria and simulation methods. A model is developed that is devoid of arbitrary factors and is, thereby, realistic to natural environments of field and storage (standby) operations. Systems concepts are used to encompass the effects of multi-environmental complexes. Artificial and pseudo-environmental concepts are removed so that better correlation of laboratory testing with field performance is made possible. Fundamentally underlining this research approach is the concept that hardware failures are always symptomatic of disorder in a particular dynamic system. Emphasis is on the constructive method of research wherein it is considered that an event is always the result of an interaction of several coexisting factors, and that hazards are not haphazard but exhibit patterns that can be identified. The event is studied as a whole, then the operative factors are gradually sorted out by a series of increasingly precise approximations. Overall relationships are maintained intact, correctly placed in relationship with each other and held in contact, yet they are differentiated. Author (TAB)

Review: This is not a useful report. It is easy to infer from the early part of the paper that (a) Operations Research and Systems Engineering are going to solve all of the environmental problems associated with Army equipment, (b) the paper will solve the extraordinary cost problems of testing under multiple environments, and (c) it will make specifications real to life whereas they have not been in the past. The final part of the paper "solves" these problems by (1) giving names to them in a manner similar to that done by one of the authors in the paper covered by R67-13070 (it is as if the doctor cured you by merely naming your ailment), and (2) using complicated jargon to describe their thoughts, e.g., "... it consolidates information engendered as a totalizing effect for each climate ..." This report reminds one of the young mouse's solution to the cat problem—put a bell on the cat, and of the recipe for catching birds—sprinkle salt on their tails. The authors use "environment" in a limited sense. For example, it does not include any mechanical environments such as vibration and shock. The authors apparently do not understand the statistical usages of terms like "confidence." They want the statistical information to be summarized in one point estimate rather than in an interval estimate, even though the latter does give more information. (It gives some idea of the uncertainty involved in the point estimate.) It is not clear that the subdivisions of climate are the only possible ones; it is not even clear what is meant by each one of the climates being mutually exclusive since the climates have some subsets in common. Present methods *do* need improving. The complaints against the present system of "assuring" reliable ordnance *are* reasonable. But it is important to understand some of the major reasons for present inadequacies. These include the following: 1. Contractural requirements, to be effective, must be testable at reasonable cost to prove compliance. 2. Uncertainties in the total use-environment will undoubtedly remain with us. 3.

Uncertainties in the capabilities of a given manufactured item are inherent in our present state of engineering and physical knowledge. The further we push the state of the art, in both software and hardward, the greater will be these uncertainties. The goals for understanding which are desired by the authors are also wanted by everyone. They are good goals.

R69-14447 ASQC 830; 883
North American Rockwell Corp., Downey, Calif. Space Div.
A STUDY OF MISSION DURATION EXTENSION PROBLEMS Summary Report, 1 Oct. 1966–1 Oct. 1967
Roy B. Carpenter, Jr. 15 Dec. 1967 44 p
(Contract NAS2-4214)
(NASA-CR-73239; SID-67-478-4-Vol-4; N68-32163) Avail: CFSTI

Characteristics, constraints, and implications of extended duration space missions were investigated by applying an availability concept to mission/system design. Feasibility of this availability concept was demonstrated, and it was found that much of the required hardware is already availiable and nearly qualified. The operational concept is considered to exert a pronounced influence on mission success and crew safety. Maintenance and repair in space was found to be both feasible and desirable, and unscheduled maintenance and repair work load requirements to support critical systems are considered to be low. Chance of extravehicular maintenance action is expected to be less than 1 in 1000, and chance of more than 260 maintenance and repair actions during a two-year period expected to be less than 1 in 100. Spares weight decrement for unscheduled maintenance is estimated at about 900 lb. The module/assembly is considered the optimum level for most maintenance and replacement actions, and required maintenance can be accomplished within expected downtime constraints. M.W.R.

Review: This is a good paper; its easy readability belies the amount of information in it. It is a summary only; the other three volumes in the same series contain more of the details. Maintenance turns out to be required in many instances and much of the program revolved around how much, when, where, how, etc. The author uses "redundant" in a particular and narrow way, apparently meaning active redundancy on a reasonably low level. (*Active redundancy is where both parts operate all of the time.* The system is capable of surviving with fewer than the maximum number operating.) The conclusion shows that such missions are reasonably technically feasible. The main figure of merit is safe crew return since this is considered to be most important and since it involves the minimum functioning of the elements. It is interesting to speculate what the probability of safe return was for the Rogers and Clark expedition in our early history. (Less detailed papers by the same author on aspects of the same topic were covered by R68-13610 and R68-13901.)

R69-14448 ASQC 833; 835; 844
THERMAL MANAGEMENT OF INTEGRATED CIRCUITS: PART I. HEAT TRANSFER AND INTEGRATED CIRCUITS; PART II. CIRCUIT DESIGN FOR MINIMUM THERMAL EFFECTS; PART III. DEVICE FAILURE CAUSES BY HIGH TEMPERATURE; PART IV. ICS SELECTION AND THERMAL EFFECTS.
R. Gary Daniels, James W. Hively, James R. Black, and Bob Burlingame (Motorola Inc., Semiconductor Products Div., Phoenix, Ariz.).
Electro-Technology, vol. 83, Jan. 1969, p. 21–40.
(A69-17216; A69-17217; A69-17218; A69-17219)

Consideration is given in four parts to thermal effects on integrated circuit performance and reliability. The first part deals with the factors affecting IC heating and heat dissipation. Thermal and electrical analogs are developed for semiconductors, and semiconductor thermal properties are discussed. In the second part the thermal management of integrated circuits is studied, noting its dependence on the circuit and component configuration, and on the designer's knowledge of parameter variations with temperature. The third part describes temperature-dependent device failure modes involving bonds, metallization, and packaging, in order to indicate the interrelationship of device design and selection, and device application to reliable operation. Finally, factors involved in the selection of integrated circuits for minimum temperature effects are discussed. L.B.H.

Review: This is a good brief article; the four parts complement each other well. The information should be known by circuit designers and reliability engineers. There are a few references for further reading but unfortunately not many. The principles are, however, well stated so that the reasonably astute design and reliability engineer can find ways of getting the rest of the information he needs. In the first part, the discussion of convection is open to technical disputation but with regard to integrated circuits, it is good enough. For example, it should be noted that some of the best heat transfer devices yet invented are heat pipes which use convection along the length of the pipe rather than conduction. Part III on device failures is good. The caution by the author that the failure modes are not presented "... with the objective of influencing the user to a particular metallurgical or package system," is well taken. All packaging systems involve tradeoffs among different kinds of failure modes, performance, and cost. Those tradeoffs are such that a very large portion of the devices made by the manufacturer will not give trouble due to his tradeoffs. Unfortunately, the device manufacturers have the same kind of people-, cost-, and schedule-troubles that system houses have, and they put out more defective product than customers would like to see (as is true of the systems houses also). In designing systems which use integrated circuits where temperature variations are important, attention to detail is a must. Part IV shows some of the details which must be considered. It is necessary to remember that any characteristic which is not covered by a specification is a poor *thing upon which to rely in a design.*

R69-14450 ASQC 831
SURVEYING SYSTEM EFFECTIVENESS.
William E. Massaker (Martin Marietta Corp., Baltimore, Md.).
Quality Progress, vol. 11, Jan. 1969, p. 21, 22. refs.

System effectiveness is defined as a measure of the extent to which a system may be expected to achieve a set of specific mission requirements, and as a function of system availability, dependability, and capability. It is pointed out that to achieve system effectiveness all potential obstructions must be investigated, and that a management control system would be used to establish necessary steps to resolve such problems. The factors which must be considered in establishing such a system for problem analysis and resolution action are discussed in terms of customer considerations, development, production, and operation. Also included is the result of a survey of leading weapon and space system contractors on ways to resolve system effectiveness problems. The results indicate: (1) A Central Problem Control Center managed by the program management office or the reliability department would be established with the responsibility for controlling all system effectiveness problems. (2) The types of problems controlled would be those associated with the following attributes of system effectiveness: reliability, availability, dependability, capability, maintainability, quality, and human factors. M.G.J.

Review: This paper is easily divided into two parts. The first is a typical short summary of system effectiveness and its history, and by itself would not make a notable paper (although it is a good summary of system effectiveness). The second part and main interest for the paper lies in the questionnaire results that are listed and discussed. Twenty-four companies out of forty responded to the questionnaire which explored attitudes and practices about system effectiveness. The author has inserted the appropriate disclaimers about accuracy of the information and has indicated how it might be improved. Regardless of those considerations, most system effectiveness groups will be interested in the results of the survey. Those results will probably not change anyone's ways of doing things, but they will give one a better perspective from which to view his own organization.

R69-14455 ASQC 830; 844

IMPROVING FAIL-SAFE DESIGN OF PROCESS CONTROL LOOPS.

Edward S. Ida (Dupont Co., Engineering Service Div., Instrumentation Group., Wilmington, Del.).

Instrumentation Technology, vol. 16, Jan. 1969 p. 46–50.

A change in emphasis in the design of transmitters and sensors is recommended to improve the fail-safe features of most control loops. The necessity of providing fail-safe protection for the following malfunctions is stressed: loss of power or air supply to any element in the instrument loop; full or partial loss of control signal to a valve or instrument in the control loop, or between interconnected loops; and full or partial loss of signals from process sensors such as thermocouples and analyzers. Two rules are postulated to cover all conditions for simple loops: (1) When a high value of process variable is unsafe or costly, place the point of signal reversal as early in the loop as possible (in the transmitter or preferably in the sensor action itself). (2) When a low valve of process variable is unsafe or costly, apply only direct-acting sensors, transmitters, controllers, and other auxiliaries. The advantages of reverse-acting transmitters are discussed, along with the improvements attained through the use of redundant sensors. Problems associated with multiloop and feedforward systems are examined, and other types of hardware failures are identified. M.G.J.

Review: Reliability and safety are very much interwined and they use similar disciplines. While the paper is largely concerned specifically with safety, many of the same considerations apply to the reliability of the whole system since it is often affected by safety of a subsystem. In the jargon of the reliability engineer, the instrumentation engineer should run a failure modes and effects analysis, perhaps making a fault tree so that the system which is inherently the safest can be provided. If estimates are available for the probabilities of occurrence of the failure events, these can help in evaluating system design for tradeoff purposes. This paper is good in calling attention to the failsafe problem and in providing design/instrumentation engineers with an analytic procedure and some rules of thumb. Much of what the author has done in this paper is to show the importance of attention to detail and the kind of detail to which engineers must pay attention. Thus this is a helpful paper.

R69-14460 ASQC 831; 844

EVALUATING SYSTEM STATES IN THEIR MISSION PHASES.

Bernard Tiger (Radio Corp. of America, Defense Communication Systems Div., Camden, N. J.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 28–26. 5 refs.

Available under IEEE Catalog No. 69 C 8-R; $8.00

System state phase modeling is presented as a method for estimating both safety and reliability by evaluating the system states in each of the mission phases. It consists of preparing a phase-to-phase logic diagram which permits the evaluation of each component (i.e. failure modes and their occurrence probabilities) and possible human or signal errors in each phase and shows their effect on the system. This results in the identification and evaluation of the events (i.e. combinations of component failures, human errors and erroneous signals as they are influenced by environmental and operating conditions) which can lead to an accident or system failure in any mission phase. Author

Review: System State Phase Modeling (SSPM) is described in concise and straightforward manner in this paper. It is a new and useful technique for the qualitative and quantitative evaluation of system design, effectiveness, reliability, and safety. Like the Fault Tree approach (see, for example, R68-13806), SSPM involves a logic diagram of the system for the purpose of evaluating the failure modes of components and their probabilities of occurrence. In contrast to the Fault Tree, SSPM is a "bottom-up" rather than a "top-down" approach. SSPM is more tedious to apply than the Fault Tree, but provides a more complete analysis. Either of these presents a more detailed analysis than the worst-case approach based on a single set of assumed worst possible usage conditions. Those who are interested in an introductory description of SSPM will find this paper very useful. It contains an illustrative example, and the text closes with a listing of uses of SSPM, and of the features which the author feels make it superior to other methods. An illustrative model is presented in figures appended to the test. Both SSPM and the Fault Tree approach were originally developed for safety analysis, but have been found quite useful for reliability prediction purposes. Those who are interested in these logic-diagram methods will find that the paper covered by R68-13806 provides a useful, though brief, introduction to the Fault Tree approach, and cites a number of pertinent references. The use of that paper and the references cited therein, together with the present paper will be worthwhile for those who wish to get an introduction to these methods. The basic problem which is common to all of them is, of course, that of having valid input data, as the author of the present paper indicates.

R69-14480 ASQC 831; 414; 432; 614

AN OPERATIONS RESEARCH APPROACH TO SYSTEM EFFECTIVENESS.

A. Constantinides (Communications and Systems, Inc., Falls Church, Va.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 250–255. 15 refs.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

The desirability of utilizing operations research techniques in performing system effectiveness studies is discussed. Several examples illustrate the application of existing methods and tools that have been successfully employed in the operations research and system engineering disciplines. Based on this approach, the decision-maker can be presented with key decision models, wherein the most likely alternatives are optimized and compared on a consistent basis, thus enabling more meaningful decisions to be made. Author

Review: This paper is suitable for its stated purpose of bringing operations research techniques to the attention of systems-effectiveness analysts. However, only those readers with little prior familiarity with these techniques will find anything new in the paper. The techniques which are included (linear programming, queueing theory, and game theory) are cited in an introductory and elementary manner, and excellent references are given for more depth. The author calls for significantly increased sophistication in systems effectiveness analyses which include reliability and maintainability considerations. This is slowly coming about, but there are obstacles. Implementation requires a staff with high qualifications. It is difficult to obtain a competent staff and to support it through a management unfamiliar with such analyses. The data base must be developed, models structured, computer/programs written, and experience in all these must be gained. These are some of the obstacles in the path of the author's suggestions for the upgrading of reliability and maintainability analyses.

84 METHODS OF RELIABILITY ANALYSIS

R69-14437 ASQC 844; 837
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
THE QUESTION OF CALCULATING THE RELIABILITY OF ELECTRONIC COMPUTERS [KVOPROSU RASHETA NADEZHNOSTI ELEKTRONNYKH VYCHISLITELNYKH]
I. M. Malikov and A. N. Rokhmistrov 13 Jul. 1967 19 p Transl. into ENGLISH from Tr. Leningr. Inzh.-Ekon. Inst. (Leningrad), no. 55, 1965 p 79–84
(AD-673162; FTD-MT-67-13) Avail: CFSTI

Computer reliability is one of the major problems in computer technology today. The computer "BESH," "Strela," "Ural," and others have insufficient reliability. In the average month, three to nine percent of the elements will usually fail or be out of commission. Reliability criteria are discussed. The problem of aging and dependent parameters are mentioned. The notions of statistical and dynamic reliability are also explained. Calculation of computer reliability are given. Author (TAB)

Review: "The purpose of this work is to acquaint a wide circle of specialists with the vital problems of theory and calculations of EVM reliability." The paper has the usual difficulties of a post-edited machine translation of Russian text. The failure rates of the computers are on the order of 3% to 9% per month. The abstract suggests that the paper considers two different kinds of failure—catastrophic and drift—whereas the text itself discusses static and dynamic reliability. The static reliability considers the amount of drift allowable before the system performance will fail. Dynamic reliability apparently considers the ability of the system to work in the presence of noise and might be called a noise margin or be related to a signal-to-noise ratio. A bathtub curve, a Gaussian formula, and the exponential formula are given as models for computer failure. There is little in the paper except for those who wish to know the Russian state-of-the-art when this paper was written.

R69-14441 ASQC 844; 830
National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
FLIGHT SIMULATION AND PILOT DESCRIBING FUNCTION TECHNIQUES APPLIED TO THE ANALYSIS OF A PILOT CONTROL SYSTEM FOR A LARGE FLEXIBLE LAUNCH VEHICLE
Brent Y. Creer, Gordon H. Hardy, and Dallas G. Denery Washington [1966] 35 p refs Presented at the Symp. on the Human Operator in Aircraft and Spacecraft Control of AGARD, Paris, 5–6 Sep. 1966
(NASA-TM-X-59113; N68-27434) Avail: CFSTI

NASA had completed two phases of a general piloted launch vehicle study. The first phase studied the feasibility of using a pilot to guide and control a vehicle from earth lift-off through insertion into earth orbit. Two different study methods were used. One method was primarily a paper and pencil study, based on servo-analysis theory, wherein a mathematical model was used to describe pilot behavior. The other approach used simulators extensively. The first part of this paper discusses the relative adequacy of these methods. It was concluded that much can be learned by analytical procedures alone, but that assuming a linear pilot model has its pitfalls. In the second phase of the study, a ground-based flight simulator was used to measure the contribution to mission reliability of allowing the crew to participate actively in guiding and controlling the vehicle if certain primary flight control systems fail. The second part of this paper discusses the methods used in this reliability analysis. It was concluded that this procedure can systematically determine mission success for complex manual control problems. Author

Review: This is a discussion of launch vehicle reliability, of a kind not often seen in the reliability literature. In this study, the pilot was to take over portions of the flight control which failed during launch. The results of the analysis were in themselves encouraging in that the pilot can substantially improve the reliability. The authors also show that the launch vehicle and very large piloted planes tend to have many of the same characteristics, so that their work would be applicable to that situation also. The comparison and explanations of the theoretical work compared to the experimental will be helpful to others doing work in the field. In short, this is a valuable contribution to the field of reliability engineering.

R69-14444 ASQC 841
General Electric Corp., Schenectady, N. Y. Research and Development Center.
PROCEDURE FOR OBTAINING FLUID AMPLIFIER RELIABILITY DATA
J. N. Shinn, F. A. Underwood, and G. J. Hahn Nov. 1965 69 p
(Contract NAS8-5408)
(NASA-CR-61849; N68-27065)

Summary information is presented on the work performed to develop initial procedures by which data may be gathered and on which an assessment of fluid amplifier reliability may be made. A specific test directed toward evaluating the reliability of fluid amplifiers and a generalized failure report form were developed. Recommendations were submitted for procedural improvements and expanded scope, to better understand the physics of fluid amplifier failures. Author

Review: Unfortunately, this report has just found its way into the public government report literature. Since very little else has been published on the subject, this report is useful. These data are preliminary and can be explained in terms of manufacturing variabilities' swamping out the changes in operating conditions ("stresses"). The conclusions in the report appear reasonable based on the data. As the authors state, the data must be considered just a first stab at an historical collection. Unfortunately, that historical collection is slow in being published.

R69-14446 ASQC 844

National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.

FATIGUE OF STRUCTURAL MATERIALS SUITABLE FOR THE SUPERSONIC TRANSPORT

Herbert F. Hardrath [1967] 20 p refs Presented at the Symp. on Structural Mater. in the Environment of the Supersonic Transport, Los Angeles, 21–22 Feb. 1967, sponsored by AIME

(NASA-TM-X-59628; N68-25380) Avail: CFSTI

The paper reviews some of the fatigue design considerations for the materials of the supersonic transport. Of particular interest are the effects of the load and temperature environments to be encountered during a desired life of 50,000 hours. Experimental work conducted at Langley to study behavior of candidate materials in fatigue tests, in crack propagation, in residual static strength, in outdoor corrosion-fatigue tests, in programmed-load tests and others are cited as necessary to develop an assessment of the important parameters of the problem. Most of the Langley work has included thermal environments ranging from −110°F to 550°F; exposure times have ranged up to 3 years. While most of the data indicate that the effects of thermal exposure are negligible, some of the recent work indicates that beneficial effects of high load cycles on the subsequent fatigue behavior at lower loads can be decreased substantially by short-time exposure to elevated temperature. The need for continued research is indicated in order to allow a reliable design with a minimum of very costly testing. Author

Review: Fatigue is an important failure mode in aerospace structures. Furthermore, it rarely occurs by itself but takes place in a debilitating environment. The results are given under the following six headings: general fatigue, fatigue crack propagation, residual static strength, effect of aqueous environment, combined effect of elevated temperature and outdoor environment, and effect of preloading and exposure to elevated temperatue. Other kinds of tests are under way. This report shows that it is possible to write a readable, informative, short report in a way that many people can understand, without using an inordinate amount of technical jargon. (Often in the technical literature, the only people who can understand a report are the ones who already know the material.) It looks as if titanium can be about as fatigue-resistant and "efficient" as current aluminum alloys with a possible exception of corrosion fatigue. The presently-used alloys are being further developed to improve that characteristic.

R69-14449 ASQC 844; 864

ANALYZING FIELD FAILURE.

James A. Robertson (General Electric Co., Philadelphia, Pa.).

Quality Progress, vol. 11, Jan. 1969, p. 12, 13.

A simple manual method is proposed for analyzing field failures on new products and on those with an early failure pattern. The method is based on the linear assumption that failures will occur uniformly during the warranty period, and requires no assumption as to the type or degree of the failure pattern. It was found that after five to six months an estimate was obtained that held up as additional history accumulated. To use the procedure, multiply each month's sales by the fraction of the warranty period that each has been exposed to use, total the products and divide that figure into the total number of field failures to date. The quotient multiplied by 100 is the estimate in percent of the field failures for the total warranty period. For a product with a 12-month warranty an equation is given, and a typical example of a cumulative chart for analyzing failure is included. M.G.J.

Review: Predicting the failure rate (more precisely, the average hazard rate) for a product is one of the important tasks that may be assigned to reliability engineers. This article treats that subject in the situation where no prior information is available; the only data are field failures. Even though the author in one place says that "The method requires no assumption as to the type or degree of the failure pattern," the method implies a constant hazard rate. The estimate of the hazard rate (in units of percent per year) is made simply by dividing the total number of failures by the total number of product years—the well known maximum-likelihood estimate. The latter is calculated by taking the monthly sales figures and multiplying them individually by the fraction of a year that month's product has been on the market. At this point, the explanation in the text becomes long and involved. What is being done is to introduce a delay period of 1/2 month, 2/3 month or 1 month. For example, a delay period of 1/2 month means that product which was shipped four months ago has been in use for only 3-1/2 months. The paper suggests that the delay be adjusted so that the new estimate made each month agrees most closely with the estimate made in previous months. This forces the constant hazard rate hypothesis even more. If the process is continued, the author says that after twelve months, one should drop the early information, keeping only one year's worth (because of having only a one-year warranty). This is not necessary in the method; it will continue to give the appropriate answer for the average hazard rate no matter how long the failures and product-years are accumulated. If one wishes to use a moving average, he is quite at liberty to choose the period of time to be anything he wishes. All in all, the basic method being used is quite simple. The explanation is rather difficult and tedious to follow and tends to make the method appear more esoteric than it really is.

R69-14451 ASQC 844; 833

SC RELIABILITY: MANUFACTURERS HOLD THE KEY.

A. J. De Berardis (Unitrode Corp., Watertown, Mass.).

EDN, vol. 14, Jan. 1, 1968, p. 42–45.

Semiconductor failure mechanisms are categorized as thermally induced failure, mechanically induced failure, and those caused by surface or other failure mechanisms. Ways of forestalling or minimizing these failures are discussed in terms of proper design, diligent production control, and thorough testing procedures. Reliability screening as a final control check is discussed, and a tabulated list of screening procedures is included. The point is made that if a manufacturer is to deliver a reliable product, a continuous concentrated effort must be made to design in reliability, to control device quality during production, and to screen in quality by carefully controlled testing. In addition, feedback of information on device failure is considered a vital link in the reliability chain. M.G.J.

Review: This paper with its charts and tables provides additional useful information to reliability and design engineers and to parts specialists for semiconductors. It will be most useful as background supplemental information or for filling in the voids in one's knowledge. If the paper is to be used in strict detail, it should be remembered that many of the recommendations are tempered, for any given manufacturer, by a series of tradeoffs. For example, the proper bonding techniques and wires are usually a function of the individual tradeoffs a particular manufacturer has made. One of the biggest tradeoff factors is cost, and if the application is one in which the component cost is appreciable, especially in commercial equipment, one may well compromise considerably with what a vendor "ought" to be doing. Some simple screens such as suggested in the paper covered by R69-14378 can be effective. Finally, it should be remembered that there have been complaints in the literature that a large amount of product even from reputable manufacturers is at times faulty upon delivery. This article provides good sound advice and it should be considered seriously.

R69-14452 ASQC 844; 775

SIGNATURE ANALYSIS: PRODUCT EARLY-WARNING SYSTEM.

Francis J. Lavoie.

Machine Design, vol. 41, Jan. 23, 1969, p. 151–160.
(A69-17875)

Description of methods of signature monitoring and analysis–signatures being the secondary effects that always result from system operation. The monitoring of mechanically transmitted sound and vibration emitted by an operating system has probably received more attention in the last ten years than any other type of malfunction detection. Most widely known are ultrasonic techniques. The latest technique to come into wide use in thermal signature analysis is thermography, while spectroscopy and several nuclear techniques are used to examine lubricants for particle accumulation due to wear. Two techniques are currently used for induced electromagnetic signature analysis. In one, backscatter of electromagnetic energy is measured; in the second, eddy currents are monitored. IAA

Review: This is a good paper for reliability and design engineers. The topic is one with which they should become increasingly familiar. Obviously, the reliability, not to mention the ease of maintenance, can be improved by detecting incipient failures before they happen. Unfortunately, there are no references for further detailed reading but most of the points are covered in the area of nondestructive testing. The only thing reliability engineers have to watch out for in this article is the somewhat overly optimistic sub-title wherein it is easy to infer that the widespread, inexpensive use of signature analysis is just around the corner. However, if the text is read carefully as it should be, one finds that each application required much research and development. It is likely that this will continue to be the case for at least several years.

R69-14453 ASQC 844

THE FAILURE MODE AND LIFETIME OF STATIC CONTACTS.

Eisuke Takano and Kunio Mano (Tohoku Univ., Dept. of Electrical Communication, Sendai, Japan).

IEEE Transactions on Parts, Materials, and Packaging, vol. PMP-4, Jun. 1968, p. 51–55. 7 refs.

Details are given on the failure mode due to corrosion at the contacting surfaces of static contacts in connectors and mechanical wiring connections. Copper static contacts with no mechanical separation fail to maintain electrical continuity when temperature-cycled from 20° to 200°C. Electron diffraction analysis and microscopic inspection show that this failure mode is due to growth of Cu_2O film over all or part of the contacting surfaces. The layer between the contact members is estimated to be 15 to 3250 Å thick, and the lifetime of the copper static contact at light loads is proportional to load. Author

Review: Physics of failure investigations are of necessity often quite specialized. This paper is concerned with a failure mode caused by temperature cycling of copper–copper contacts. It is a rather complete discussion, but uses a fair amount of specialized language peculiar to the field. Another paper by the same authors, essentially on another phase of this topic, is [1]; this paper is not mentioned in the journal article but calculates a theoretical time to failure for the contact system. The authors state that in practice the conditions for this failure mode are rarely if ever found. This paper will be of interest mainly to contact specialists.

Reference: [1]Eisuke Takano and Kunio Mano, "The lifetime of static contacts," *Electronics and Communications in Japan,* vol. 50, no. 12 (1967), p. 134–136.

R69-14459 ASQC 844

FAULT TREE AND RELIABILITY ANALYSIS COMPARISON.

Kenneth H. Eagle (Boeing Co., System Effectiveness Assurance Organization, Huntsville, Ala.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 12–17. 5 refs.

Available under IEEE Catalog No. 69 C 8-R; $8.00

A comparative assessment is made of two related program analysis techniques: the Fault Tree multiple failure safety analysis to identify critical events, and the Reliability Analysis for hardware single failure analysis. The comparison shows: (1) The Fault Tree does not require analysis of failures which have no effect, whereas Reliability Analysis provides documentation to insure that every potential single failure was examined. (2) The Fault Tree is event oriented. It easily identifies higher level events or events subsequent to failure. The Reliability Analysis is hardware oriented. It easily identifies results of failure of any component, subsystem, or system. (3) The Fault Tree identifies all external influences which contribute to loss such as human errors, environment and test procedures. The Reliability Analysis does not require investigation of as many external influences, and the associated data are not required. (4) The Fault Tree has a restricted scope with analysis in depth. The Reliability Analysis has a broader scope with restricted depth of analysis. Author

Review: This paper analyzes the philosophic concepts behind two analytic techniques, each of which is concerned with a subset of the failure events. The discussion is worthwhile even though not everyone would agree on the distinctions the author is making. In particular, the reliability analyses performed by some people are sometimes much more extensive than the limited ones defined in the paper. The conclusion by the author that one can have a broad shallow analysis in the set of failure events or a narrow intensive analysis of a subset of these events is important. As he says, often one wishes to do one without the other in order to accomplish the needed analysis at minimum time and cost.

R69-14463 ASQC 844
ANALYSIS OF FAILURES IN SPACECRAFT AND AIRCRAFT COMPONENTS.
Thomas L. Pulliam (McDonnell Aircraft Co., Engineering Labs., St. Louis, Mo.).
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 40–47.
Available under IEEE Catalog No. 69 C 8-R; $8.00.

Details are given on a Failure Analysis Laboratory which was organized specifically to determine the cause of component failures from laboratory and production testing. Environmental simulation equipment includes vacuum and altitude chambers; temperature and humidity cabinets; vibration and shock systems; and hydraulic, pneumatic and electrical test equipment. The history of the component is reviewed so that the maximum information can be obtained to determine the correct analysis routine. These include the rejection documentation, personnel in the area where the malfunction occurred, previous failure analyses on similar components and similar failures, and vendor or service failure reports. It is pointed out that the success of the failure analysis is mainly dependent upon the functional test; at this stage, the analysts either verify or disprove the malfunction and determine the location of the failure within the component. Radiographic, dissection, and microscopic examination procedures are discussed. Several examples are given to prove that there are no random failures, and that failure analysis and corrective action improve overall reliability. M.G.J.

Review: This is a reasonably conventional treatment of failure analysis and the laboratory for performing such analysis. It is suitable introductory reading for anyone who is just becoming involved in such activity. The examples appended to the report are helpful in understanding the points the author makes.

R69-14478 ASQC 844
FAILURE ANALYSIS: ITS ROLE IN SCREENING DECISIONS.
Edgar A. Doyle, Jr. and Vincent C. Kapfer (Rome Air Development Center, Reliability Branch, Griffiss AFB, N. Y.).
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 211–234. 2 refs.
Available under IEEE Catalog No. 69 C 8-R; $8.00

Details are given on in-depth failure analyses performed by RADC on a quick reaction capability (QRC) basis in support of high-priority Air Force equipment and systems. The semiconductor devices analyzed represented several different vendors' products, both screened and unscreened. Included were junction field-effect transistors, high power bipolar transistors, and monolithic integrated circuits. Author

Review: This paper apparently has the following purposes: (1) to describe the quick reaction capability of performing in-depth failure analyses and tests, (2) to show what such tests have done for various Air Force systems, and (3) to recommend 100% screening of all semiconductors used in the system. The case histories are amply illustrated with photographs most of which are reproduced well enough to enable the reader to see the defects. Those who will have access to this service will of course wish to read the paper carefully. Others will find described in it the kinds of troubles that can be uncovered by such techniques and will be able to compare, to a certain extent, that capability with the one in this group. Those designers and reliability engineers who are new to the semiconductor field will profit from the case histories themselves since they may be somewhat too inclined to believe all of the advertising that they read.

R69-14479 ASQC 844
FLIGHT FAILURE ANALYSIS.
W. R. Abbott and L. E. Jenkins (Lockheed Missiles and Space Co., Sunnyvale, Calif.).
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 244–248.
Available under IEEE Catalog No. 69 C 8-R; $8.00

The special characteristics of an analysis of a failure occurring in flight are discussed. These are: unavailability of the hardware, minimum data, urgency, and publicity. In spite of all these, the requirements for care and completeness are very stringent. These restrictions and methods of planning, organizing, and operating to comply with them are discussed. Concentration is on a data room which is the tool most helpful in getting timely, accurate results second only to a competent team. Author

Review: One is fortunate to come across a paper which is not a rehash of the same old material in the same old way. One is delighted when the paper is well written. The bonus comes of course when the paper is competent. For this paper, the reader is fortunate, delighted, and gets the bonus. One gets the feeling that the authors "have been there before."

85 DEMONSTRATION/MEASUREMENT

R69-14461 ASQC 851; 782; 815
ENVIRONMENTAL TESTING: THE KEY TO HIGH RELIABILITY.
R. L. Vander Hamm (Collins Radio Co., Cedar Rapids, Iowa).
In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 27–33.
Available under IEEE Catalog No. 69 C 8-R; $8.00

Experiences with, and general results of, MIL-STD-781 (AGREE) testing on many military and commercial equipment types during the past 10 years are described. The benefits of AGREE testing are delineated, and the disciplines necessary to realize the maximum benefits from applying this testing philosophy are emphasized. Its application to reliability evaluation, demonstration, and burn-in testing is also discussed. The adoption of AGREE testing as a standard practice during the development and manufacturing phases of commercial electronic equipment program is also described. Economic benefits are explained. Recommendations are presented to the military and the commercial segment of the electronic industry for more efficient and effective utilization of the AGREE testing philosophy. Author

Review: Throughout the text, the author uses the phrase AGREE testing rather than environmental testing, since MIL-STD-781B is the embodiment of AGREE testing. The big difference between MIL-STD-781B tests and other high-stress tests is that in the former, severity levels must be within the specifications for the equipment, whereas in the latter, they are usually more severe than specifications. The article is a combination of description of these environmental tests, case histories showing the advantages accruing from them, and an exhortation for others to go out and do likewise. The author's exhortations are well taken; environmental testing should be an important part of military, aerospace and commerical ventures. Since MIL-STD-781B is mentioned several times in this paper, those not familiar with it might wish to look at the review by Neathammer, Pabst, and Wigginton in *Journal of Quality Technology*, vol. 1, Jan. 69, p. 58–67 for further information. (This Standard is a *set* of plans, not a single plan.) Even though the author points out that in the early days, some people had trouble with AGREE testing (an understatement to be sure) and that now it is a good idea, you should be very careful about accepting contracts involving MIL-STD-781B unless you have the *advice and consent* of those experienced in its application. If not, those early catastrophes could happen all over again to you. A discussion of the contractual hazards is given in the paper by Barber on pp. 34–39 in the same Proceedings. Other authors are concerned with testing under a sufficiently severe environment, including temperature-cycling and vibration, to induce failures in the reasonable length of time in most equipment. This over-stress testing, testing-to-failure, and step-stress to failure are also for the purpose of showing up equipment weaknesses. That is, there will be bugs in the prototype and early production equipment even under the best of circumstances and these are most readily found and eliminated by very severe tests early in the hardware cycle. Whether MIL-STD-781B testing or overstress testing is more effective in producing good equipment is not a matter on which there is unanimous opinion.

(This paper was abstracted in *Electronics*, vol. 42, 3 Mar. 69, pp. 222, 225.)

R69-14462 ASQC 851; 782; 815

ENVIRONMENTAL AND RELIABILITY DEMONSTRATION TESTING.

Walter J. Barber, Jr. (LTV Aerospace Corp., Missiles and Space Div., Dallas, Tex.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 34–39. 3 refs.

Available under IEEE Catalog No. 69 C 8-R; $8.00.

Observations are presented concerning both (1) the role of environmental testing in qualification, acceptance, burn-in and reliability demonstration testing, and (2) some potential problem areas for MIL-STD-781A Reliability Demonstration Testing. The test program requires both careful consideration and complete description/definition before commencing reliability demonstration testing and, preferably, even before negotiating procurements which specify/require reliability demonstration testing. Early consideration and complete definition of these items are both extremely important in order to preclude or minimize both hard feelings between participants, the necessity for after-the-fact negotiations and/or imposition of incentive penalties, and to maximize the probability of obtaining realistic costs by properly defining the demonstration program requirements and thereby identifiying the degree of risk being taken by the participants. Author

Review: This is a frankly tutorial paper both for newcomers to the reliability field and for those old-timers who need some refreshing. The paper serves its purpose well. The names given to some kinds of testing are a jargon that varies from place to place. A valuable service is provided by trying to explain in detail the ramifications of including MIL-STD-781 in the contract. These ramificatons are of two kinds, viz., (1) things which are logically implied but not spelled out in the contract, but of which the customer may be unaware; and (2) things which are not spelled out in the Standard but must be specified in the contract, if catastrophe is to be avoided. Reading papers like this is most helpful but is no substitute for experience when actually negotiating such a contract. If necessary, a consultant with experience should be hired for this purpose.

R69-14469 ASQC 851

A TECHNIQUE FOR DETERMINING THE LIFE CAPABILITY OF INDIVIDUAL SEMICONDUCTORS.

T. M. Walsh (General Electric Co., Space Systems Organization, Valley Forge, Pa.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 86–99. 8 refs.

Available under IEEE Catalog No. 69 C 8-R; $8.00

A technique is defined for determining the life capability of individual semiconductors at the screening test level. The approach is derived from an understanding of the fundamental circuit activity of all electronic parts, i.e., the manipulation of the flow of electrical charges. The charge conduction characteristics for the ideal part of a particular type are first defined in terms of readily measurable electrical parameters; then, a comparison is made of the single part parameters to those of the ideal. By using this approach, parts with incident low-level charge conduction defects which can grow in time are immediately identified and removed without the expense of the traditional screening tests. The remaining ideal parts are expected to maintain a stable charge conduction activity and, thus, have an inherent long-life capability. The technique also has an application as a process control tool, and may be applied to other electronic part types. Author

Review: This paper contains a good idea; namely, measure the electrical characteristics of a device (over a wide range, and also outside of specification limits) at several widely-spaced temperatures, especially low temperatures, and compare the temperature response with that predicted by theory. In practice, one has some constraints on this process. The theory is usually poorly developed even for a semiconductor diode; for example, the temperature dependence of the reverse current is not predicted accurately but only the general form of this temperature dependence is theoretically derivable. If the majority of devices have a very similar response (perhaps this is what the author means by "... empirically derived description ... of the 'ideal' part ..."), one can use that response as a standard against which to measure deviants. The only examples given in the text are for reverse current of a diode. Applying this principle to three-terminal semiconductors such as transistors is going to be much more complicated. Any reasonable theoretical relationships will be very difficult to come by unless they are for two-terminal behaviors of some of the devices. Thus, the author has a good idea but his detailed explanations and prognostications are sometimes over-enthusiastic and not well expressed. For example, it is pointed out that the reverse diode current has the form of the Arrhenius equation, and there is some discussion which takes off from there somewhat irrelevantly. More to the point is the observation that the current follows the Maxwell–Boltzmann distribution in which the Arrhenius equation also has its source. Applying the idea in this paper to all electronic parts will not be as simple as the author implies but nevertheless the basic idea is worth pursuing vigorously.

R69-14477 ASQC 851

RELIABILITY OF EPOXY TRANSISTORS.

Erwin A. Herr and Albert Fox (General Electric Co., Semiconductor Products Dept., Syracuse, N. Y.).

In: Proceedings on the 1969 Annual Symposium on Reliability, Chicago, Ill., Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 202–210. 6 refs.
Available under IEEE Catalog No. 69 C 8-R; $8.00.

A review is made of the experience obtained in the manufacture and evaluation of plastic semiconductor devices. Device studies have been made, based on the accelerated testing, long term tests and physics of failure techniques developed while conducting a number of reliability improvement and reliability physics programs on metal enclosed semiconductors. The technique of using valid accelerated tests for product improvement and reliability evaluation has shortened the design improvement cycle on plastic encapsulated devices. The results of long term tests and several product line reliability monitoring tests are described. The evaluation of four primary device properties which are related to device packaging by the use of accelerated activation stresses is outlined. Some recommendations for the present and future use of silicone plastic and epoxy devices are made. Author

Review: Plastic encapsulated transistors have been a subject both of much interest and of much controversy in recent years. Generally speaking, the manufacturers have been contending that certain types of plastic encapsulants were quite satisfactory substitutes for hermetically sealed devices whereas users have been skeptical—perhaps largely on the basis of earlier efforts which used materials and techniques not as well developed as the current ones. This paper is a contribution by a manufacturer giving his experience with some epoxy encapsulated transistors. They are not compared directly with hermetically sealed ones and the authors seem to steer clear of value judgments; for the most part they have presented and explained the test results. While the paper does those things well, it would have been interesting to see the results compared with those for hermetically sealed transistors. However, publishing these data is worthwhile since it is very likely that eventually the materials and techniques will be sufficiently well developed to replace the metal cans even for the more exacting requirements.

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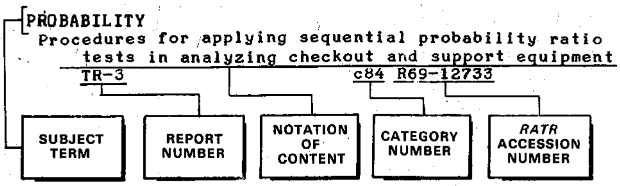

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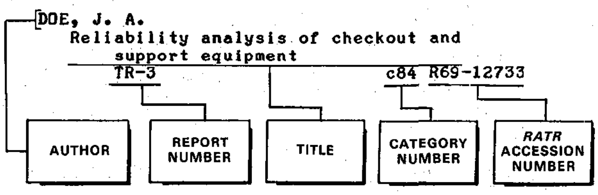

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NASA-Langley, 1969

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Reliability Abstracts and Technical Reviews

JULY 1969

Volume 9
Number 7

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	RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT	
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TITLE →	**SEMICONDUCTOR RELIABILITY.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	← **AUTHOR AND AFFILIATION**
JOURNAL REFERENCE →	*Electric Journal,* vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	← ***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER** →	R69-12765 ASQC 773; 221; 823	← **ASQC CODES**
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CONFERENCE OR SYMPOSIUM REFERENCE →	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*	
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VOLUME 9 NUMBER 7

Reliability Abstracts and Technical Reviews

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July 1969

80 RELIABILITY

No abstracts in this issue.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14508 ASQC 815; 851
MIL-STD-781B RELIABILITY TESTS: EXPONENTIAL DISTRIBUTION.
Robert D. Neathammer (Naval Ammunition Depot, Crane, Ind.), William R. Pabst, Jr. (Naval Ordnance Systems Command, Washington, D.C.) and Carl G. Wigginton (Naval Air Systems Command, Washington, D.C.).
Journal of Quality Technology, vol. 1, Jan. 1969, p. 58–67. 21 refs.

The B revision of MIL-STD-781 introduces in this standard a concept of reduced and tightened testing based on prior history. In all tests the specified parameter is mean-time-between-failures (MTBF), or some equivalent expression. The introduction of switching rules allows a reduction in testing when reliability expressed in MTBF exceeds requirements and imposes tightened testing on inferior products. The sampling plans are used for both reliability production acceptance tests and for reliability qualification tests. MIL-STD-781B is directly applicable only when the times-to-failure are distributed in accordance with the exponential distribution, and thus may be applied to equipment exhibiting a constant failure rate. Ten environmental test levels and thirty test plans are included in the standard, allowing 300 possible choices of environmental test levels and test plans for every specified equipment MTBF. These test levels and test plans are presented in tabular form and discussed. Decision risks and their discrimination ratios, the operating characteristic curves, the changes made in the revision, and examples concerning the application of the standard are described. The derivation of the test plans is considered in the appendix. P.A.B.

Review: This is a good discussion of the standard. It provides much background and explanation for the tests. There are a few cautions to those who will incorporate this standard into a specification. These could have been expanded, since many people apparently do not appreciate the full implications of the tests or of the importance of the myriads of ground rules that must be established before the wording of the standard can have meaning. In the middle of testing is a poor time to have to work out ground rules between the manufacturer and the customer. If you are planning on incorporating such a standard into a specification and no one on the staff has had experience in this line, it would be wise to employ a consultant who has. This paper is valuable because the authors are associated with the government agencies that were involved in the revision. (There is a minor typographical error on page 66; it is the failure time that is assumed to be distributed exponentially, not the MTBF.). While some of Aroian's work is listed in the references, it is not referred to in the text; many tables of truncated sequential tests for the exponential distribution were published under his guidance.

R69-14509 ASQC 812; 830; 844
FAILURE PREVENTION STARTS WITH EDUCATION.
Donald J. Wulpi (International Harvester Co., Engineering Research, Fort Wayne, Ind.).
Metal Progress, vol 95, Jan. 1969, p. 105–109.

The philosophy and content of a failure analysis and prevention course, which is given to technical personnel, are described. It is believed that failure prevention is the responsibility of all technical personnel having any connection with a product, whether they are in design, testing, metallurgy, or manufacturing. The course consists of 16 hours of lecture and group discussion; a number of models and teaching aids are used, in addition to many examples of failures and slides which illustrate various types of failure. The subject matter covers techniques of failure analysis, deformation without fracture, state of stress, brittle fracture due to low applied stress, mechanical properties, residual stresses, temperature effects, typical fatigue characteristics, wear, contact stress fatigue, corrosion, examples of shaft fractures, and examples of gear failures. The students handle and study a number of typical failed parts, and the importance of visual examination in any failure analysis is emphasized. M.G.J.

Review: Good design, good materials, and good manufacturing are essential to high reliability; and the techniques of good design are learned, not inherited. The paper deals with metallurgical mechanical failures which are important in aerospace (as well as other) applications; electronic failures are not considered. Presenting a course like this to designers and test engineers is worthwhile. This paper shows it need not be done in a big expensive way but can be done in a manner which uses the present talents of the company to best advantage. One need not be an expert in education to take the initiative in helping designers help themselves, but one must have knowledge of materials, failure mechanisms, strength of materials, manufacturing processes, etc. Using the syllabus given in the text and the material described therein (covered by R68-13702) almost any group can lift itself by its bootstraps. Even many engineers have had at least a nominal exposure to the material in college, the year or two of practical experience in the meantime gives them a much better appreciation for and desire to learn these facts. Even experienced designers can stand the review and they can offer help of their own in design guidelines. Studies by the armed services have shown that the same kinds of failures occur decade after decade. Courses of this type can help break that pattern.

R69-14521 ASQC 814

COST EFFECTIVENESS VIA WEIGHTED FACTOR ANALYSIS.

Nicholas Salatino and Myron Feistman (Radio Corp. of America, Defense Communications System Div., Camden, N.J.)

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEE, Inc., 1969, p. 256–262.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00

A mathematical index model is presented as a management criterion for selecting work tasks with fixed funds for satisfying a number of desired objectives. The model, which weights the work tasks, is based primarily upon the data showing the relationship between program objectives and work tasks. It is assumed that the events are repetitive even though it really represents only one sample in the total sample population space. Tasks are weighted according to an acceptability index of number associated with each work task to indicate the level or degree of acceptability of the task in the program structure. The major parameters of need, fit, probability of achievement, and time sensitivity are defined, and axioms for the probability distribution are postulated. M.G.J.

Review: This paper is concerned with using a quantitative approach for the problem of selecting work tasks where there are multiple objectives. The relation of the material which is presented to existing management quantification approaches is not readily apparent, and no references are cited. Thus it is difficult to put the contents in perspective. The inclusion of some basic probability laws and the statement that "a mathematical model is an analogue of an actual situation" suggest a rather elementary level. This paper will be of interest only to those who try to read everything that is printed concerning the quantification of management scheduling problems. It seems that it would be very difficult to get management to use the approach which is presented. No actual applications are cited. Reliability is one of a large number of work tasks which are identified, but its bearing on the approach is not developed.

R69-14522 ASQC 810; 831; 841

OPERATIONAL SYSTEM EFFECTIVENESS STUDY: A LAYMAN'S APPROACH.

Hans Reiche (Canadian Forces Headquarters, Directorate Communications Systems Engineering, Ottawa, Canada.)

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969.

Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 263–269.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

A project to develop a simple method for providing operational system effectiveness information is described, including the design, development, and production of a reconnaissance drone. A simple model was formulated and special recording forms were prepared. A feedback system was developed to indicate the need for, and to assist in design changes made to, the system. The information was also used to plot the growth potential or reliability and maintainability parameters. The results of the study helped in making decisions on trade-offs in the final production configuration. The limited manpower effort provided project management with sufficient data for management decisions. Author

Review: The essence of this paper is that for projects with limited funds the preferred approach for operational system effectiveness is simply to collect and analyze the data for various maintainability and reliability indexes. This approach was applied to several Canadian projects and the various forms used for collecting the data are shown. This approach for the low-budget program of relying on follow-up of failures for corrective action is compatible with what others are saying. Two important points made in the paper are that logistic supportability is a vital factor in system effectiveness which has often been left out of other models, and that a more cooperative effort by the government and their vendors may bring about a better cost-effective approach on contracts. The message of this paper is a sensible one.

R69-14523 ASQC 814; 844; 871

WARRANTY COST ESTIMATES FOR AVIONIC SUBSYSTEMS.

P. O. Nerber (International Business Machines Corp. Electronics Systems Center, Owego, N.Y.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control New York IEEE, Inc. 1969, p. 170–275.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

A general analytical technique is presented for estimating the failure and cost exposures associated with a warranty commitment on avionic subsystems. The discussion addresses the reliability-sensitive variables to be accounted for in the basic reliability prediction as well as the major cost elements resulting from hardware recycle. Author

Review: The main body of the paper is straightforward enough; what is not as clear is the emphasis in the introduction on why this method is so different from what one would like to do. The paper lists important details and discusses problems associated with evaluating and estimating some of the elements that go into the cost equation. It appears to be adequate for its intended purpose. Obviously, it is not long enough to go into extreme detail on each point, so that anyone who intends to compare this plan with his own, or to see if this would be an adequate plan for his own use, will still need to do an appreciable amount of work.

R69-14524 ASQC 813

MILITARY VEHICLES RELIABILITY ASSESSMENT.

Arlen L. Dillin (U.S. Army, Tank-Automotive Command, Warren, Mich.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 276–279.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Reliability assessment of military vehicles is discussed, and details are given on a computerized analytical model of the Army's mechanical mule. The model provides for the effectiveness in terms of reliability and availability, illustrates the use of the model in considering alternative maintenance plans, and permits a value engineering–parametric design analysis of the drop gear subsystem with the idea of reducing costs while improving effectiveness. The vehicle was considered as an aggregate of independent units, referred to in the model as elemental reliability units (ERU). The ERU concept permitted the isolated unit to be considered as operating in its vehicular environment while being serviced in accordance its specific maintenance program. It also permitted all the independent units to be aggregated even though their individual modes of operation are different. Consideration is also given to the importance of reliability status reports, the evaluation of proving ground test results, and mission reliability estimates based on preventive maintenance policies. M.G.J.

Review: This paper is a general description of the program and as such is adequate. Unfortunately, the slides which accompaniec the oral presentation are not reproduced in the printed paper. Therefore allusions to various equations and diagrams are frustrating. As far as one can tell from the description, the program appears reasonable and conventional. One point which is not clear is: the effective reliability unit (ERU) when originally defined on page 277 was such that all units were logically in series; yet on page 279 it is suggested that some ERU's may fail and the system survive when there is redundancy. (The latter situation apparently makes use of a *generalized ERU*.) This paper will be useful only to those who wish a very general description of the reliability assessment portion of this reliability program. The author can provide more details on the mathematical model.

R69-14525 ASQC 815

WANTED—REALISTIC ALTERNATIVES TO MIL-STD-781.

Peter B. Brigham (Martin Marietta Corp., Reliability Div., Orlando, Fla.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 280–287.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

MIL-STD-781, which established a standardized set of methods for reliability demonstration, is discussed, and it is concluded that the standards do not work well for all equipment as well as for mean-time-between-failures which force extended testing. MIL-STD-781 test methods become increasingly difficult to use as systems become increasingly complex and our capability to build reliable hardware increases. It is noted that where MIL-STD-781 is readily applied, the penalty for failure may force an impossible high design reliability goal, thus creating a situation in which the demonstration requirement, not the mission, set the design reliability goal. Some specific problems with the standard are discussed and some useful alternatives are proposed. Author

Review: Most of the author's warnings are essentially, "Don't buy a pig in a poke". Naturally this advice holds true whether one is concerned about MIL-STD-781 or anything else. Probably the difficulty the author is trying to emphasize is that with MIL-STD-781 it is extremely easy not to realize what you are letting yourself in for—words and phrases will not necessarily have their lay meanings and many statements will have implications which are not obvious. One should probably never accept a contract wherein MIL-STD-781 is specified without having appreciable advice from someone who has actually gone through a similar contractual experience. The title is meant to imply that under circumstances where MIL-STD-781 is going to get the contractor in severe trouble due to finances and/or schedules, he needs less risky alternatives which will still satisfy the customer. Obviously, the customer is going to have to be satisfied with something less than provided in MIL-STD-781; and how realistic this something less is going to be depends on who is doing the talking. But regardless of any of those problems that the customer may have, the contractor should *clearly understand* all of the implications of calling out a MIL-STD-781 test. If he does not understand and consider them, he is extremely likely to be in for an inordinate amount of trouble and expense. Just from reading the paper, one does not get the impression there is anything wrong with MIL-STD-781; the thing that seems to be wrong is that some contractors are foolish enough to go blindfolded into a situation involving it.

R69-14526 ASQC 813

PREFAILURE ANALYSIS ENHANCES PRODUCT RELIABILITY.

Robert E. Pederson (Honeywell Inc., Ordnance Div., Reliability Group, Hopkins, Minn.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 288–293.

Avail: Available under IEEE Catalog no. 69 C 8-R $8.00.

PREfailure Analysis approach is described, which permits early detection of unreliable electronic parts. This early detection provides valuable lead time during which interim and final corrective action can be taken on affected parts prior to installation into products. PREfailure Analysis is performed by reliability part specialists on samples drawn from received part lots. The analysis effort is aimed at identifying unacceptable supplier process controls or those which may contain latent defects. The effectivity of this approach is noted to be evidenced by the significant cost saving and other benefits realized on the programs on which it has been implemented. Author

Review: This paper is a good description of the reasonable program. It is very similar to a program described in the paper covered by R69-14468, and the comments on this topic that are made there apply also to this paper. Basically, what these programs do is to trust the manufacturer somewhat less and insist on analyzing his product before using it rather than after it has caused trouble. The justification for this kind of activity is usually an economic one or one based on very tight schedules.

R69-14530 ASQC 813; 851

STANDARD AGENA PRODUCTION RELIABILITY EVALUATION PROGRAM.

Robert E. Ross (Lockheed Missiles and Space Co., Sunnyvale, Calif.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 347–355.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

The Product Reliability Evaluation Program (PREP) evolved from a need to ensure that mass produced vehicles would attain all design and reliability objectives as established during the original design phase. The objectives for the program are (1) to assure that vehicle equipment is produced at the quality and reliability levels established by initial qualification and reliability testing, and (2) to provide additional reliability data which can be used to determine design marginality. To maintain objectivity in the evaluation, specific types of equipment were selected at random from production stores and were intended to be representative of a block or lot of vehicles. Each block sampled was considered a round of testing. Short case histories illustrate how the testing employed disclosed defects in equipment that otherwise would have gone undetected; and, in several instances, how vehicle launches were directly affected. Author

Review: As with most case studies, and in constrast to some papers on reliability, the contents of this paper are tangible. Also, as with most meaningful reliability test programs, some failures are uncovered which are subject to corrective action. This test program has certainly contributed to the reliability which has been achieved by the standardized Agena vehicle. The requalification and overstress production tests reported here appear to be worthwhile. Such tests are worth considering on other programs where there is a high reliability requirement and at least a moderate quantity to be produced. It should be noted, however, that the level of hardware complexity at which such tests are performed is still largely a matter of subjective technical judgment. It would seem that some of the failures uncovered by the test program reported in this paper could have been revealed by similar testing at lower levels of hardware aggregation; e.g., screening at the non-repairable piece-part level.

R69-14532 ASQC 810

RELIABILITY, THE MANAGEMENT OF IMPERFECTION.

H. E. Fewtrell and R. W. Parcel (Lockheed Missiles and Space Co., Sunnyvale, Calif.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 375–382. 3 refs.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Space vehicles are noted as having an enviable performance record in spite of a structural safety factor which is low by conventional standards. Accordingly, reliability problems that do not always compromise performance are discussed. It is pointed out that defects can sometimes be harmless and are better left uncorrected. Examples are given where the most obvious methods of repair or rework is the least desirable. Warning is made that industry-wide specifications may be either too broad or too conservative and that company-generated specifications instead usually insure a more efficient, more reliable, and less costly structure. The use of such tailored specifications is illustrated. Each new test method or improvement on an old one, it is recommended, should signal a reappraisal of specifications. Author

Review: This paper deals well with an important topic. In discussing the question, "when is a defect not a defect" the semantics can become overpowering if one is not careful. The authors rightly point out that getting rid of some discrepancies may cause more harm to the structure than the discrepancy itself would have. The newer more sensitive methods of nondestructive testing are exacerbating the problem. People can find almost any kind of departure from some "idealized" state, and the difficulty is to decide how great such a departure can be without causing the structure to be inadequate. Two quotations from the authors' conclusions are worth repeating: "A structure is often more forgiving of an imperfection than of the means employed to remove it. Knowledge of critical failure modes at the affected area is needed for intelligent decision." "New NDT methods will make us aware of flaws which have have always existed, heretofore unseen. ... We must soon cease to specify 'no cracks' or 'no defects', and define acceptable magnitudes."

R69-14533 ASQC 810

RELIABILITY PREDICTION: HELP OR HOAX ?

Ernest O. Codier (General Electric Co., Aerospace Electronics Dept., Utica, N.Y.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 383–390. 19 refs.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

The point is made that reliability prediction is theoretical abstraction, and that it is the degree of attention to detail in circuit and package design, procurement and screening of materials, controlled care in manufacturing processes, and effective corrective action which controls the failure rate. Some characteristic data on the actual behavior of equipment, parts, and reliability are reviewed, and six areas are identified as containing the keys to effective use of these data. The recommendations proposed are: (1) Knowledgeable reliability planning is essential. (2) A spectra of effective actions are available. (3) Testing is essential. (4) Communication and management buy-in are essential. (5) Contracting needs some improvement. (6) Reliability forecasting is possible. However, predictions or program forecasts must provide answers directly relevant to controlling a program, and must permit meaningful comparison between different equipments and programs. M.G.J.

Review: This is a difficult paper to review because the author has caricatured the situation. The caricature is effective and makes its points well, which, of course, is one of the purposes of a caricature. A caricature is not meant, however, to give a balanced appraisal of the situation and one should not look to this paper for such. The literary device of using many quotations and giving the references therefore lends an aura of respectability and forcefulness to the paper. The quotations should be interpreted as the author's opinions and judgments since if one is looking to the literature to prove his point, he can find almost anything there. Some of the papers referenced are excellent, some are very poor. Many people do make worthwhile use of numerical reliability predictions in their work. Needless to say, the slavish addiction to useless predictions which the author abhors has been only too common. If anyone was unaware of the grave disadvantages involved in such numerical predictions, this paper can awaken him to them and usefully so.

R69-14535 ASQC 813, 833

WHAT PARTS LESSON FROM LUNAR ORBITER?

William A. Murray (Boeing Co., Seattle, Wash.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 453–464 3 refs.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Details are given on the program for the selection and control of electronic and electrical parts for the Lunar Orbiter. The major elements of the program involved part selection, specifications, application, qualification, acceptance testing and screening, and failure analysis and feedback; each is discussed in terms of certain critical parts program experiences. In suggesting methods for achieving parts reliability in future programs, the following recommendations are proposed: (1) To be effective, maximum use should be made of parts with an established history of successful operation in similar applications. (2) High standards of selection qualification and screening should be established. (3) The number of different part types should be minimized and controlled throughout the subcontractor and supplier activity. (4) To ensure sameness of parts procured over a span of time, a sample of each received lot should be internally examined. M.G.J.

Review: This paper is a case report on a thorough parts program for a space system. The concept of what such a parts program should contain has not changed much in the past ten or fifteen years; however, the meaningful difference is that there are currently more actual implementations, such as the one described in this paper. Some actual in-flight and pre-flight test data and experiences are presented. Such data are always welcome. This paper is well suited for someone who is interested in a concise description of a "solid" parts reliability program.

R69-14538 ASQC 810; 612; 844

SOFTWARE RELIABILITY.

Richard B. Mulock (Lockheed Missiles and Space Co., Sunnyvale, Calif.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 495–498. 5 refs.

Available under *IEEE* Catalog no. 69 C 8-R; $8.00.

Although methods similar to those used by the reliability engineer on hardware may be applied to the problem of software reliability, areas for further development of reliability techniques are delineated. Examples of random computer program failures are discussed, and the question of how to prevent these intermittent problems from surviving into operational situations is considered. An approach to software documentation, developed by the Air Force Space and Missile Systems Organization, is described. The exhibit is attached to most computer program contracts so that a standardized development method will be used which is easily tracked by procurement and integrating organizations. The value of the compilers to the reliability engineer is pointed out, along with the need to be aware of the inaccuracies often introduced by digital computers. The techniques required are identified as (1) a measure of how fast errors can be detected, (2) a good failure mode and effects analysis, (3) the ability to design test programs in a manner that does not require the computer to test itself, and (4) the development of good simulation models. M.G.J.

Review: The reliability of computer programs has not been treated extensively in the reliability literature although, of course, it is of concern in the programming profession. As this paper implies, unreliability is a difficulty for the programmer to cure with specialist help from the reliability engineer. The reliability engineer knows the kinds of questions to ask but it is up to the programmer to generate the answers. As in other areas, superhigh performance, pushing the state of the art, and short time-schedules are not conducive to high reliability. Thus, the author notes that extensive use of machine language in order to minimize memory space, etc. are conducive to errors. More use of higher-level languages is equivalent in the hardware field to commonality and is to be encouraged as one of the more cost-effective ways of buying *reliable* performance in generating a program. Just why the author drags in the bathtub curve and asserts that the error rate in use of a program becomes constant as time goes by is not obvious. The bathtub curve, while holding very true for people's lives, is not necessarily fundamental to reliability engineering. All in all, the paper performs a useful service in calling attention to reliability problems with computer programs and in suggesting means for improving the situation. (Another paper discussing the reliability of computer programs was covered by R69-14309 and is listed as a reference in this paper.)

R69-14542 ASQC 817

EFFECT OF RELIABILITY ON LIFE CYCLE INVENTORY COST.

Allan Dushman (Dynamics Research Corp., Wilmington, Mass.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 549–561. 11 refs.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Life cycle costs are discussed in relation to logistics cost; i.e., the cost of maintaining an inventory of spare parts over the life cycle of some equipment. Several control policies are considered, and their effect on overall inventory costs are shown. Optimal inventory control policies, which minimize the overall inventory cost, are discussed and developed. An analytical approach is first taken using several models for the life cycle inventory problem. A simulation approach is also taken based on several years of logistic data compiled from a gyro supply system. The results of this simulation are presented and compared to the results obtained by approximating the actual logistics data by the simple inventory control models described. Author

Review: The main interest of this paper from the strict reliability viewpoint is that of tradeoff of the cost of item reliability against inventory cost for spares. The paper touches but does not dwell on this point. It does illustrate the application of the concepts of classical inventory theory to determining stock levels for a certain type of item. Those with an interest in this type of problem may find some of the contents directly applicable. (The example in the paper, involving a gyroscope, illustrates the type of problem.) For other types of spares problems as well as for general realibility/maintainability tradeoff problems, the contents of the paper may be suggestive. A good feature is that it discusses some of the economic reasoning comprising the rationale for the techniques used.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14481 ASQC 824
EFFICIENCY OF REPAIRABLE CONTROL SYSTEMS.
K. S. Zherbin and A. A. Pervozanskiy.
(Tekhnicheskaia Kibernetika, Mar.–Apr. 1967, p. 38–43. 8 refs. In Russian.) Engineering Cybernetics, no. 2, Mar.–Apr. 1967, p. 36–51. 7 refs. Translation.
(A67-30919)

Discussion of a scheme for estimating the effectiveness of automatic control systems by comparing their performance with the performance of optimal ideally functioning systems. The mathematical expectation of the system quality functional under conditions of incomplete reliability is used as the efficiency criterion. Expressions for this criterion are derived for a class of self-adaptive control systems in the case of self-adaptation circuit failure of the switch-off type. IAA

Review: For reasons not entirely clear, this paper is not very readable. The problem seems to be a combination of translation difficulty, different word usage, and lack of mathematical preciseness. Thus it will be of value only to those with a special interest in the topic indicated in the title, and a willingness to devote much of their own time and effort to deriving information from it.

R69-14482 ASQC 824
THE LOWER CONFIDENCE BOUND FOR THE PROBABILITY OF TROUBLE FREE OPERATION OF COMPLEX SYSTEMS.
Yu. K. Belyayev, T. N. Dugina, and Ye. V. Chepurin.
Engineering Cybernetics, no. 2, Mar.–Apr. 1967, p. 52–59. 5 refs. Translation.

Description is given of the algorithm for calculating the lower confidence bound of the probability of trouble-free system operation with respect to component testing results. The algorithm is intended for application when there are insufficient data on the reliability of the elements, and the numbers of breakdowns recorded during tests run on the elements are small. The class of systems for which the proposed algorithm is applicable includes the systems of the series-parallel-series type with a loaded reserve. A short description is presented of the concept on which construction of the algorithm is based, as well as the results of numerical calculations obtained using a computer. A comparison of the proposed method with earlier known methods is carried out. Author

Review: This is a mathematical paper which treats a continuing thorny problem in reliability theory, namely, estimating a lower bound for reliability, given the results of tests on the parts. The translation is nominally a good one but the language used is nevertheless not customary in American papers of this type; therefore it is somewhat awkward to follow. The description of the kinds of systems being considered is reasonably clear; they are essentially series-parallel structures. Some of the generality introduced in describing the graphs of systems is later taken out as far as the analysis is concerned. The paper does not give the complete algorithm for calculating this lower bound on probability but gives only a very rough outline of it. It would still require a considerable effort on someone's part to write down the complete algorithm and translate it into a computer program. A few results from the author's computation are given and compared with other methods of estimating the lower reliability bound. In general, the authors' method appears superior; that is, it gives a higher value of the bound and presumably still is a legitimate estimate thereof. This paper will be of value to theorists but not as much as it would if the complete algorithm were listed.

R69-14483 ASQC 824
THE AVERAGE TIME OF TROUBLE-FREE OPERATION OF A COMPLEX SYSTEM.
Sh. L. Bebiashvili, O. M. Namicheyshvili, and A. P. Khuskivadze.
Engineering Cybernetics, no. 2, Mar.–Apr. 1967. p. 59–65. 2 refs. Translation.

Calculations are presented for the average time of trouble-free operation of a complex system, taking into account planned preventive maintenance and functional importance of its elements with an exponential law of their being trouble-free. Under the assumption that the average time of trouble-free operation of the system is given and conditions are ensured in it which are required for maximum efficiency, the problem of determining the average time of trouble-free operation of individual elements taking these factors into account is solved. Author

Review: A more descriptive title for this paper would have been, "Some Mathematical Approximations Useful in Calculating the Average Time of Trouble-Free Operation." The equations for average time and system reliability are straightforward. Each element is assumed to have exponential behavior and to be very reliable in the time period considered. Maintenance is perfect and requires no time. Appropriate approximations are then made for calculating the required parameters. Unfortunately, for the simple series system with exponential elements, the formula should reduce to "one divided by the sum of the hazard rates" since maintenance makes no difference to such a system. The formula does not reduce to that and so is obviously in error. The error may be small but, if it is, the formula could be simplified. A formula which would have been at least as satisfactory is: $T = \tau/Q(\tau)\ [1 - \bar{Q}(\tau)] \approx \tau/Q(\tau)$, where T = mean time to failure, Q = failure probability of system, τ = scheduled repair interval, and $\bar{Q}(\tau)$ = average failure probability over τ. The fractional error in T is then just $\bar{Q}$. It is presumed in the authors' approximation that $\bar{Q}$ is much less than 1 so that this is a reasonably accurate approximation for T. If Q(T) is exponential and the appropriate approximation is made, the approximation does reduce to the exact formula. Since Q(T) is a monotonically increasing function, $\bar{Q}(\tau)$ is always less than $Q(\tau)$. This helps to put an upper bound on the error of the approximation. As is reasonably common, the translation apparently was not done by someone very familiar with this subject, so that the text is somewhat hard to follow; although unlike the machine translations this text flows smoothly and is ungarbled. The author introduces several terms such as efficiency and importance. The word definitions of these are vague; they are in actuality defined by Equations 1 and 2. Equation 1 defines the importance factor and Equation 2 defines the efficiency. This is contrary to the implication of the text where the formulas are presumed to follow from the definitions. The paper may be of some value to theoretically-induced reliability engineers.

R69-14484 ASQC 824; 431

DETERMINATION OF THE PROBABILITY THAT A ONE-DIMENSIONAL MARKOV PROCESS WILL NOT REACH THE FIXED BOUNDARIES.

V. S. Zaritskiy.

Teknicheskaia Kibernetika, Mar.–Apr. 1967, p. 66–71, 8 refs. In Russian.) Engineering Cybernetics, no. 2, Mar–Apr. 1967, p. 65–71 8 refs. Translation.

(A67-30920)

Determination of the probability that a random function u(t) with a known correlation function will not fall outside a region with given boundaries within a given time T. The position of the boundaries may be arbitrary with respect to the mathematical expectation of the function u(t). It is also shown that this function remains inside a unilaterally restricted area during the time T. IAA

Review: This paper presents a solution to an interesting problem with reliability implications. The analysis is, however, restricted to stationary Normal Markov processes which implies an exponential correlation function. The results obtained are rather involved, employing infinite series of integrals of confluent hypergeometric functions. Some numerical examples are given which show that in interesting cases only the first few terms of the series are needed. The translation is a little rough but readable.

R69-14493 ASQC 824

STRESS-STRENGTH INTERFERENCE.

Charles Lipson and Narendra J. Sheth (University of Michigan, Dept. of Mechanical Engineering, Ann Arbor, Mich.).

The SAE Journal, vol. 77, Apr. 1969, p 38–45. 3 refs.

For a realistic prediction of failure probability, it is pointed out that the scatter which exists in strength and stress should not be ignored. An estimate must be made of both the mean value and the dispersion characteristics of the two distributions; the Weibull distribution is found to fit the strength data best, while the stress distribution is assumed to be normal. A stress-life diagram is depicted for converting life data to strength data. It is assumed that to each specimen of the population an individual S–N curve can be assigned, and that for any population of specimens a family of nonintersecting S–N curves exist. An example illustrates how the three Weibull strength parameters are determined. The statistical distribution of stress is discussed in terms of stress spectrum versus stress distribution. Based on these stress and strength distribution data, the percent interference is computed. M.G.J.

Review: This is an adaptation for the SAE Journal of the paper covered by R68-14082. It contains much of the essential information and many of the more important tables and graphs of the original paper.

R69-14495 ASQC 825

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

ASSIGNMENT OF RELIABILITY NORMS FOR THE INDIVIDUAL UNITS OF A DIGITAL COMPUTER IN THE INITIAL DESIGN STATE OF AGREEING ON THE TACTICAL-TECHNICAL DESIGNATION

L. V. Surkov et al

30 Nov. 1967 10 p refs Transl. into ENGLISH from Vyssheye Teknol. Uchilishche. Vychislitel'naya Tekhn. (Moscow), no. 5, 1966 p 164–169

(AD-677242; FTD-HT-23-1510-67; N69-14559) Avail: CFSTI

Two approaches are analyzed for achieving the efficient assignment of reliability norms to the various units of a digital computer, e.g., the arithmetic unit (AU), the control unit (CU), and the main memory unit (MU). The problem consists in finding the failure rate of these units which will satisfy a given probability of machine failure Q(T) in time T. In the first approach the approximate failure rates are expressed as functions of the complexity of units and the relative failure rates of the components. A more realistic view of the failure rates of the units must take into account their manufacturing and operating costs. The authors derive an expression for finding the failure rate of individual units for which the cost of a unit is minimum taking into account the cost of the entire computer complex. TAB

Review: This paper deals with reliability goal allocation to subsystems given the reliability goal for the computer. Even though the paper is written in terms of a computer, it would apply to any system. The usual constant hazard rate assumptions are made, with statistical independence of failures, etc. Two methods of apportionment are shown. First, the reliability goal is apportioned merely on the basis of the estimated hazard rates of each subsystem (based on a parts count and hazard rate for each part). The second method calculates the cost of the computer as a function of the hazard rate of each part (a suitable formula for cost of an element vs. its hazard rate must be known, also the cost of upkeep vs. its hazard rate must be known). The hazard rates are then allocated to the subsystem such that the cost of the entire system is a minimum. These are fairly straightforward techniques and have been known in the literature for some time. Since reliability apportionment is usually approximate and since the methods shown here are reasonably easy to use, one would guess that they are in fact often used on many systems. The more complex a system, usually the more simple the method used in reliability calculation and apportionment. Otherwise, the calculations would get completely out of hand.

R69-14496 ASQC 821; 838

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

SIGNALING AND PREDICTION OF FAILURES IN DISCRETE CONTROL DEVICES WITH STRUCTURAL REDUNDANCE

M. A. Gavrilov 7 Dec. 1967 17 p refs Transl. into ENGLISH from Russian

(AD-678343; FTD-HT-23-1454-67; N69-15499) Avail: CFSTI

Methods involving structural redundancy are of great importance in solving the problem of reliable operation of automatic control devices. This article examines certain fundamental possibilities of signaling or predicting breakdowns in automatic control devices. One principle previously described by the author which governs these possibilities is that determination of the minimum number of extra internal elements necessary to provide requisite reliability completely coincides with the problem of determining the minimum number of supplementary symbols needed to construct correction codes for the corresponding number of mistakes. This method involves construction of tables of states and relates to the case where failure probability is the same for all internal elements element failures are symmetrical, and individual failures are independent. Other conditions demand a different approach. The discussion expands the application of this method. TAB

Review: This paper deals with Boolean logic devices and systems for realizing Boolean functions. Only those who are reasonably expert in the field will get much from it since some of the terminology used in the translation is somewhat strange and since the paper uses a considerable amount of jargon per se. There is some discussion at the end of the paper by various other people attending the conference and this discussion helps to evaluate the contribution of this paper. Some of the discussion indicates that the author has not sufficiently considered timing problems (that is, not all devices change state at exactly the same time). Another difficulty with the paper is that the author asserts that no additional equipment is necessary, yet he seems to be adding hardware. The author refers to an earlier paper of his wherein he claims to have shown that the number of redundant elements necessary to keep the circuit operating properly in the presence of some failed elements is exactly the same as the number of redundant digits in a code which is required to correct some errors in that code. All in all, those interested in the design of computers will find this paper of interest. This particular topic is not often discussed in the American literature on reliability.

R69-14502 ASCQ 824; 822
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
APPLICATIONS OF EXTREME VALUE THEORY IN THE RELIABILITY ANALYSIS OF NON-ELECTRONIC COMPONENTS
Cletus Bonaventure Kuhla (M.S. Thesis)
Dec. 1967 90 p refs
(AD-675545; GRE/MATH/67-8; N69-12376) Avail: CFSTI

Manufacturers of non-electronic components and systems are required to accurately determine the reliability of their products in order to meet the demands of government weapon system contracts, safety programs and commercial product warranties. In an effort to establish simple but accurate techniques for determining reliability factors of mechanical components, increased use of statistical theory is being made in analyzing component failure data. This thesis illustrates the application of extreme value theory in the reliability analysis of mechanical systems and components. The basic theory of extreme values is presented and the exact and asymptotic forms of the extreme value distributions are developed. Applications of the extreme value distributions are presented in example problems. The Type I extreme value distribution is applicable to the analysis of corrosive pitting of aluminum and the analysis of maximum loads. The Type III extreme value distribution is useful in the failure analysis of step motors, automobile door lock mechanisms, corrosion resistance of magnesium, automobile structural components and electromagnetic relays. Author (TAB)

Review: This master's thesis is adequate for its purpose. The introductory material on extreme value distributions is very helpful and provides a good description for the reliability engineer who wishes to learn more about them. The main value of the thesis is in showing that some data can be represented by one of the two applicable distributions, although it has been well known that the Type 3 extreme value distribution (Weibull distribution) can be used to describe the behavior of mechanical parts. The Type 1 distribution is less often used because it is less tractable. Parts of the thesis then go on to show how, given a distribution, one can solve a practical problem using it. This kind of material will be helpful to engineers who are novices in statistics but not to anyone else. No claim is made for originality; the examples are derived from the literature. For those who were not previously acquainted with these distributions and their uses, this paper can be a big help since it uses a minimum of jargon and explains the various situations rather well. The more adjustable-parameters there are in the distribution and the fewer data, the more likely one is to get a close meaningless fit of the data to the distribution. For this reason, among others, the location parameter is often set to zero unless there is an extremely good reason on physical grounds to believe that it has a different value. Some of the literature has used several Weibull distributions to fit, segment by segment, one given set of data. Fortunately, the author does not use this poor technique. It is one that ordinarily does exceptional violence to sound statistical reasoning. (Naturally the segmenting technique is quite suitable for interpolation. It is usually disastrous for extrapolation.)

R69-14507 ASQC 824; 540; 552; 822
HAZARD PLOTTING FOR INCOMPLETE FAILURE DATA.
Wayne Nelson (General Electric Co., Schenectady, N.Y.).
Journal of Quality Technology, vol. 1, Jan. 1969, p 27–52. 21 refs.

Incomplete failure data consisting of times to failure on failed units and differing running times on unfailed units are called multiply censored. Data on units operating in the field, for example, are usually multiply censored. A method is presented of plotting multiply censored data on hazard paper to obtain engineering information on the distribution of time to failure. Step-by-step instructions on how to plot and interpret data on hazard paper are given with the aid of examples based on real and simulated data. Hazard paper is presented here for the exponential, Weibull, normal, log normal, and extreme value distributions. The theory underlying hazard paper and plotting is given in an appendix. Author

Review: This paper describes a simple graphical method of data analysis which appears to be both reasonable and very useful. Since no statistical analysis of the estimates so obtained was presented, it is not possible to say what the statistical properties of the estimates actually are. But the analysis is of a *kind* often used by engineers to great advantage. They need only remind themselves that the line they finally draw by eye through these points has an appreciable uncertainty involved in it when there is a lot of scatter in the data points. The method is described well and the author provides many examples; so even engineers who lack statistical training can use it in cookbook fashion, i.e., you follow the author's *recipe* and the results will be useful. The author further provides many practical tips on the plotting and *eyeball* analysis of data. Many engineers are familiar with *probability* paper on which cumulative sample probability is plotted. As the author points out, by showing both the cumulative hazard and cumulative probability scales, the two methods can be statistically equivalent. The author's contribution is in finding a statistic (a statistic is any number obtained from sample data) that is easy to calculate even when many potential data points have been lost. One could of course take the negative exponential of his number and plot it directly on cumulative probability paper, but it is easier to make those calculations once and for all and use the cumulative hazard scale shown by the author. Most engineers are well aware that *eyeball* lines are drawn differently by different people, and search for something less subjective. *Least squares* lines are in vogue for this purpose but are often misused. One should not attempt such a *least squares* fit when a complete statistical analysis of the properties of such a fit is not available, because the results really are not more *objective* or *accurate* than the *eyeball* line. (Such will be the case with the present analysis, as the author has implied.)

R69-14510 ASQC 824

A BAYESIAN RELIABILITY GROWTH MODEL.

Stephen M. Pollock (U.S. Naval Postgraduate School, Dept. of Operations Analysis, Monterey, Calif.).

IEEE Transactions on Reliability, vol. R-17, Dec. 1968, p. 187–198. 19 refs. Navy-supported research.

(A69-21912)

Description of a model for the change (growth) in the reliability of a system during a test program. Parameters of the model are assumed to be random variables with appropriate prior density functions. Expressions are then derived that enable estimates (in the form of expectations) and precision statements (in the form of variances) to be made of: (1) projected system reliability at time τ after the start of the test program, and (2) system reliability after the observation of failure data. Numerical examples are presented, and extension to multimode failures is indicated. Author (IAA)

Review: This is a long and somewhat detailed paper. It treats a specific conceptual model; the assumptions in this model are clearly defined. Not all of the mathematics was checked but it appears to be accurate. The prior distribution is not given a specific form in many of the equations; therefore, the solutions are not available in a specific closed equation. Anyone using the results will want to review all the material carefully to be sure that the model will fit his situation reasonably well. Some of the nomenclature is awkward and there are a few editorial errors. The terms *repaired* and *unrepaired* states are used, and a reader dilemma arises because obviously after each failure, the system is repaired. What the author apparently means by the *repaired* and *unrepaired* states is: the particular failure mode has either been removed or not removed; but in any event, after each failure the offending subsystem has been removed and replaced with a statistically similar one, so that the entire system is again "on the air." The model does allow for the situation wherein after the offending failure mode is removed it may be replaced with a less—or more—obnoxious one. Those who are concerned with reliability growth (or degradation) models should be aware of the contents of this paper. The author's reference 15 is an earlier government report and is essentially the same as this paper, although a few changes have been made.

R69-14511 ASQC 824; 838

A GENERALIZED RELIABILITY FUNCTION FOR SYSTEMS OF PARALLEL COMPONENTS.

Wah-Chun Chan (University of Calgary, Dept. of Electrical Engineering, Calgary, Canada).

IEEE Transactions in Reliability, vol. R-17, Dec. 1968, p. 199–201. 4 refs. Supported by NRC of Canada.

Grant A-5127.

In systems of parallel components, the system reliability function is usually defined as the probability that not all the parallel components fail in a time interval, given that all the components are operating at the beginning of the interval. This definition implies that if there is one component which operates throughout the whole interval in question, then the system reliability is perfect. Consider the system *S* which always requires $M > 1$ components to do its job. It is obvious that the system is not reliable if there are only κ, $1 \leq \kappa < M$, components working in the time interval. The conventional reliability function is then insufficient for studying the reliability of the system *S*. A generalized reliability function is presented, and it is shown that the conventional reliability function is a special case of the generalized reliability function. The practical application of this generalized reliability function is also discussed. Author

Review: The author presents some results which are quite straightforward and which have been published before. Unfortunately, the paper implies that the results are new. In the discussion of the reliability function in the presence of redundancy (where only one element is required to work), the cart is before the horse. One derives the particular reliability function on the basis of requiring that only one out of n must work. If this presumption is not made, the formula cannot be derived. It is not something that one finds out from the formula afterwards except in the sense that it is implied by the formula (which it must be since it was an essential assumption). The formula for reliability in the presence of redundancy with unlike devices is also accurate, but unfortunately in a situation like that, about all a formula can do is restate the problem. No algorithm is presented, for example, for finding all of the cases, or for simplifying the calculations. Thus while the results are true, they are not new.

R69-14512 ASQC 820

ON THE NEED FOR NEW RELIABILITY PARAMETERS.

George T. Jacobi (IIT Research Institute, Chicago, Ill.).

IEEE Transactions on Reliability, vol. R-17, Dec. 1968, p. 202.

Ontology, which treats the relation between objects and events, is proposed as a concept which may be profitable to reliability engineering. It is pointed out that more qualitative methods must be devised, and that predictions should not be clothed in pseudo-scientific precision. A decision is required as to which parameters are worthy of comparison not over a time span for one specimen, but among specimens derived from different times, different designs, and different configurations. M.G.J.

Review: This is a philosophic paper; *metaphysics* is the word the author uses. It is an interesting description of what reliability physics is all about. Reliability physics has descended from physics-of-failure, and the description given in this paper is quite different from that envisaged by some of its founders in the early sixties. The present description is not one with which everyone would agree, but it introduces useful, reasonable, and thoughtful concepts which are worthy of further exploration. (It is not immediately obvious why "...Heisenberg's uncertainty principle prevents prediction of the slope of a presumed linear progression." That principle is limited to certain rather specific sets of variables.)

R69-14513 ASQC 822

BEWARE OF THE WEIBULL EUPHORIA.

Andrew C. Gorski (Singer-General Precision, Inc., GPL Div., Pleasantville, N.Y.).

IEEE Transactions on Reliability, vol. R-17, Dec. 1968, p. 202, 203. 1 ref.

Arguments are presented against the use of the Weibull function for predicting the reliability of parts, equipment, and systems. These are based on the premise that the three parameters of Weibull distribution (the scale, the shape, and the location) are so elusive as to be void of any true meaning, and that the physics of failure mechanism does not support its use. In cases where failure rates do not seem to be constant, two approaches are recom-

mended: (1) Limit the time interval to a period in which the average failure rate can be treated as if derived from a Poisson process. This approach may lead to a step function. (2) Utilize the old concept of the learning curve of the form ax^{-b} . The power curve has only one exponent. The parameter b is normally derived empirically. The view is offered that in all cases where a reliability growth model is desired, the learning curve seems to be the perfect tool.
M.G.J.

Review: This letter is presumably an expression of opinion rather than article refereed by the journal. It is an overenthusiastic deprecation of the use of the Weibull distribution for the reliability function. The paper seems, in one place, also to deprecate the use of the Weibull distribution for the change in mission reliability as a function of calendar time (during which improvements to the system are being made). It is difficult to give general criticisms of such an article because of its amorphous nature. Some specific difficulties are the following: (1) The paper demonstrates a lack of understanding of the legitimate uses of statistical procedure. (2) It uses the hypothesized truth of the bathtub curve to "prove" that the Weibull distribution cannot be true because its hazard rate does not have that shape. (3) Variations in estimated parameters are unfairly attacked. The estimation of parameters by statistical methods is a concept well described in statistical texts. Statisticians have picked many words to describe the adequacies and inadequacies of their estimates and in general are well aware of them. Perhaps many reliability engineers are not. The author does state a good case against fitting a function with too many adjustable parameters. Indeed, the Weibull distribution is often misused in the reliability literature especially by those who have not calculated the uncertainties in their estimates of the parameters. Good cases can be made against the use of the Weibull distribution in particular situations; this paper is not one of those cases. The Weibull distribution is extremely useful sometimes; this paper should not discourage one from using it in such situations.

R69-14515 ASQC 824; 844
IMPROVEMENT OF RELIABILITY OF POWER SYSTEMS.
S. Yoshino (Kinki University, Faculty of Science and Engineering, Japan).
Electrical Engineering in Japan, vol. 88, 1968, p. 34–44. 7 refs.
Problems with power transmission systems have led to studies on (1) control of a power system in an emergency and (2) improving the reliability of power systems to avoid large failures. Discussion is based on digital computer calculations and analysis of large failures. It is noted that the probabilistic distribution of load loss can be expressed in terms of an exponential or a Weibull function and that advance detection of system defects is vital. A strong interconnection is also presented as a means of preventing cascade shut-downs. Author

Review: The general techniques used by reliability analysts in the aerospace industries appear to be different from those used by the power utilities, yet both are concerned with complex systems. It is important for both groups to be aware of the work of the other, so that they can see what techniques they have in common (which in some cases are different only because of a different language used to talk about them) and perhaps more importantly they can see what the other has that might be useful. This paper on power system reliability demonstrates that the behavior of the system under unusual conditions is difficult to calculate due to the absence of tractable analytic descriptions for many of the elements in the power system. The author wisely points out that simple probabilistic calculations are not really sufficient for determining the behavior of the system, that a detailed physical/electrical knowledge is necessary if the failures are to be prevented. This kind of work is akin to *failure modes, effects,* and *criticality* analysis often performed on large space hardware systems; although in the latter, the timing of various events is apparently not quite as important as it is in power systems. It will undoubtedly be a distinct advantage to both power system and aerospace reliability engineers to exchange their techniques more freely.

R69-14516 ASQC 824
ON EXPECTATIONS OF SOME FUNCTIONS OF POISSON VARIATES.
John J. Bartko (National Institute of Mental Health, Bethesda, Md.), Samuel W. Greenhouse (National Institute of Child Health and Human Development, Bethesda, Md.) and Clifford S. Patlak (National Institute of Mental Health, Bethesda, Md.).
Biometrics, vol. 24, Mar. 1968, p. 97–102. 8 refs.
Some functions of the sample mean and variance of Poisson variates are presented. Several exact results on Poisson expectations are considered, followed by limiting process results depending on an approach to normality. Results of a computer study are included as supporting evidence. Author

Review: The Poisson distribution is used widely in reliability theory. Occasionally, experimental results are such that the experimenter questions the validity of the Poisson distribution hypothesis. This paper deals with the expected value of the statistic *sample variance over sample mean* and shows that its expected value is 1. The expected value and variance of the square root of that quantity are also listed, so that deviations in a statistic can be evaluated for statistical fluctuation versus inapplicability of the model. The complete rigor of the derivation for the expected value of *sample variance over sample mean* is not obvious (with regard to the boundary condition) but the authors claim that the result can be derived in other ways. This result will be of most concern to reliability theoreticians. It is doubtful that practicing engineers will run across considerations wherein these facts are important.

R69-14527 ASQC 824
THE ANALYSIS OF ACCELERATED TEMPERATURE-TESTS.
Ralph A. Evans (Research Triangle Institute, Research Triangle Park, N.C.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 294–302.
Contract NAS7-100.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.
A method is derived for calculating the activation energy of a failure mechanism directly from the failure times and number of failures. Exponential (time) and Arrhenius (temperature) behaviors are presumed; hazard rates need not be calculated at each temperature as a part of the analysis; temperatures at which no failures occur are easily handled; and the uncertainties involved in the estimates of activation energy and hazard rates are easily calculated. Several examples illustrate the method and show that the uncertainties in the activation energy and operating hazard rate

are more than one would expect from reading the literature. The two parameters cannot be obtained explicitly, but the iterative calculation is very simple, especially on a computer (the Fortran II program is appended). Author

Review: This interesting little paper concerns the application of maximum likelihood estimation of the (temperature-dependent) parameter of an exponential distribution, in life testing experiments which are accelerated by using different temperatures. The experimental procedure used is to life test an item assumed to have a negative exponential failure distribution. (It would have been helpful if the author had described explicitly the life testing procedures to be used.) It is assumed that the parameter $\lambda = \lambda$ (T) of the exponential distribution depends on the (absolute) temperature T through the "Arrhenius" equation $\lambda(T) = Ae^{-E/kT}$, where E is referred to as the "activation energy", A is a constant and k is Boltzmann's constant. The problem considered is that of maximum likelihood estimation of the parameters in $\lambda(T)$ by conducting the life tests at different temperatures (presumably usually high to give a large value of $\lambda(T)$ and hence an accelerated test). The above equation for $\lambda(T)$ may then be used to give estimates for $\lambda(T)$ at temperatures of interest. The maximum likelihood equations turn out not to be explicitly soluble. However, a computer simulation procedure is used to demonstrate approximate normality of the estimates of the constants (E and log λ) considered. Some of the expressions and notations read just a little quaintly (though this may be due to the difference of interests between the reviewer and the intended reader). For example, the use of "tru" to abbreviate "true" seems scarcely worthwhile, the dt on the left of Equation 3 seems oddly placed, and the similarity noted between Equations 2 and 3 is hardly surprising. Further, the author's remark that the paper "analyzes a certain picture of the way the world might be" seems rather an overstatement in view of the special problem considered, relative to the world. The usefulness of this work will depend on how well exponential assumptions fit in practice and how well the given "Arrhenius" relation between λ and T holds. Given that these assumptions are satisfied, it seems to the reviewer that the author has given a useful application of the maximum likelihood estimation procedure. From an engineering point of view, people are going to make some kind of analysis anyway, usually by estimating λ_i for each T_i, then passing a straight line through the points. The proposed method is superior to that one.

R69-14531 ASQC 824; 844

EVALUATION OF FAILURE DETECTION METHODS.

Harland F. Romberg (McDonnell Douglas Astronautics Co., Western Div. Santa Monica, Calif.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 356–362. 5 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

A technique is discussed for evaluating the ability of checkout equipment to detect failures. It was developed to provide a means for estimating percent checkout, defined as the ratio of the number of detected failures to the total number of failures expected during system life. Percent checkout is determined from component failure rates, sensitivity of test point voltages to component failure modes, and tolerances of test equipment measurements. Several methods for evaluating sensitivity of test points to component failures are discussed for use in the technique for evaluation of percent checkout. The technique for determining percent checkout is illustrated for a typical flight control amplifier circuit. It is expected that this technique will provide a means for comparing the capabilities of sophisticated failure detection sensors. Author

Review: This is a poor paper. Two major difficulties are (1) the mathematical definitions do not agree with the verbal definitions and (2) some of the mathematics is wrong. Examples of the first of these are: (a) the equations do not allow for drift failures; (b) the tolerance is defined by equation 4 as being the maximum fractional change, not the maximum change; (c) the percent checkout is defined in words as the ratio of detectable failures to the total number of possible failures, whereas the equations do it differently. The major example of the second kind of difficulty is that equation 2 for the expected value of voltage is incorrect. One has to take an exhaustive mutually-exclusive set of states, multiply the voltage for each state by the probability of that state, and then add all of those together. Unfortunately, the zero state has been assumed to have a probability of one whereas it does not. There is also an implicit assumption that only one failure can happen, that the probability of multiple failures is zero; while this is not an unreasonable assumption, it is implicit in the mathematics, not stated explicitly anywhere. Another mathematical difficulty is that the tolerance of a test point measurement is a random variable as defined in equation 4. By the time it gets to equation 6, it is no longer a random variable. If all of the various inconsistencies were cleaned up, the paper would be interesting and worthwhile, but it would be a different paper.

R69-14540 ASQC 824; 431

DISCRETE-TIME RENEWAL THEORY AND APPLICATIONS.

John H. K. Kao (New York University, Dept. of Industrial Engineering and Operations Research, Bronx, N.Y.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 522–534. 8 refs.
Contracts Nonr-285(62); DA31-124-AROD-338.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

The discrete counterparts of the renewal continuous time theory are presented. The continuous case is reviewed briefly, and the renewal equations for this case are derived. Some examples are given to illustrate the calculations. Using discrete counterpart equations, the case is solved for an automobile parts warranty program under the assumption of the Weibull life expectancy. It was found that the results compared favorably with those obtained by the more difficult continuous method. Author

Review: It is important and overdue that reliability workers develop a better appreciation of reliability definitions and models for replaced items and repairable equipment. The material in this paper is a worthwhile contribution for this purpose. It is an expository treatment of material which has been well analyzed in the more theoretical literature; this is acknowledged by the author. The presentation in this paper may still be a bit heavy for some, but it will be more readable for the practical person than the sources which are referenced in the paper. The case of identical and independent distributions of replaced items is emphasized. The situation where succeeding distributions of failures of a repaired equipment are not identical is not emphasized, but with some extensions it can be treated in general. From the applications viewpoint it is perhaps more important than the case of replacement. The concept of discrete-time renewal models which is emphasized in this paper when applied with modern digital computers can treat the general repaired-equipment problem just as readily as it can the more restricted replaced-item problem.

R69-14543 ASQC 824; 844; 851
TESTING OF MECHANISMS WITH SMALL SAMPLE SIZES.
Don C. Price (Boeing Co., Huntsville, Ala.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 562–566. 4 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Some principles of testing are suggested which will yield the maximum amount of information relative to a mechanism's capability of performing its intended function, using a small sample size of completed products. The basic idea is to test extensively at lower levels of functioning units and to use these results to find the distributions of the higher order elements. Four methods of doing this are discussed. The testing itself has two purposes: (1) to find weaknesses, the correction of which strengthens the product, and (2) to discover how reliable the product is. Author

Review: The material presented in this paper, while adequate, is not new, and does not seem specifically tailored to mechanisms with small sample sizes although it is appropriate. Largely, the paper is a description of several well-known statistical methods which have been well covered in the reliability literature. However, if reliability engineers are unaware of them, this article will be useful. The uncertainty in answers which are generated by these techniques increases appreciably with decreasing sample size. Very often for high-reliability work, one is concerned about the tails of the distribution and virtually none of these methods will give much information about them. One must be especially careful about making approximations, such as assuming that the distribution is Normal. Assuming Normality is quite satisfactory for the central portion of the distribution, but often fails miserably in the tails. The best piece of advice given in the paper is to test extensively at the part level where more parts are available, so that the sample size is no longer small. No mention is made of accelerated testing, testing to failure, etc. All in all, the paper offers little on the topic in the title that will be new to competent experienced reliability engineers.

83 DESIGN

R69-14487 ASQC 830
THE CHALLENGE OF RELIABILITY: IMPROVE TODAY'S HYDRAULICS AND TOMORROW'S DESIGNS.
George F. Moore (Trans World Airlines, Inc., Aircraft Systems Engineering Section, Kansas City, Mo.).
Hydraulics and Pneumatics, vol. 21, Feb. 1968, p 96–98, 100. (A68-20472)

Discussion of the possibility for the designers and manufacturers of aircraft and of hydraulic components, as well as aircraft operators, to improve the reliability level of the hydraulic systems of commercial jet transport aircraft. Some of the problems that directly affect the reliability of hydraulic systems on commercial jet aircraft are examined, and the corrective measures taken by industry are discussed. IAA

Review: While this paper is nominally limited to hydraulic subsystems on commercial aircraft, the kinds of questions discussed have a much broader applicability. The paper is divided into three parts: problem areas, corrective measures, and guidelines for the future. The first area is a straightforward summary of the main problems. It has fewer implications for the whole reliability discipline. The next section on corrective measures shows that in some of these systems, the design work is not all done when the finished product rolls off the line; i.e., some redesign will be done in the field. This has big implications for reliability and design engineers. There has been an extremely worthwhile modification of engineering goals in terms of preventive maintenance and the increasing use of reasonable statistical methods to help achieve those goals. It is important that designers and reliability engineers be aware of these. In the guidelines for the future, the checklist for airframe and component manufacturers is especially important. It is apparent that those who have been asserting that a designer is a professional who need never have skinned his knuckles while using a wrench to repair equipment are kidding themselves. A designer who has never had bench experience just cannot do his job adequately. Checklists are no substitute for personal motivation. *Reliability engineers, too, need to be aware of the effect on* equipment reliability that poor servicing conditions can have. Nor can the electronics designers sit back and say, "I'm glad I don't have that kind of problem," because electronic equipment too must be repaired in the field.

R69-14489 ASQC 838
MAINTENANCE DETERMINES RELIABILITY IN DIGITAL SYSTEMS.
Paul A. Hurney (Digital Technology, Inc.).
Control Engineering, vol. 16, Feb. 1969, p 102–105.

A two-out-of-three redundant system with redundancy at the module level is discussed in terms of the advantages which it offers over the nonredundant and the overall function (black box) redundancy. It is pointed out that the use of modules is possible only if the complete digital function can be broken down into a reasonable number of subsystems comprising a module with several inputs or outputs. Details are given on a model with eight modules, each assumed equal in failure rate. Tables and graphs are presented which compare the probability of success between redundant and nonredundant systems for various time periods with various maintenance cycles. It is shown that if the mean-time-to-repair is kept low, then the reliability can be made extremely high. Author

Review: While many of the general conclusions of the paper are true (for example, maintenance can increase reliability of a redundant system), not enough of the assumptions are stated explicitly to enable the reader to check on the accuracy of the author's computations. Examples of the difficulties in the paper are the following: (1) After equation 1, the mean time to failure is defined as "...the probability of no system failure of 0.37." Probably what the author meant to say was that the mean time to failure is the *time* at which the probability of no system failure is 0.37. This still would be true only where the system itself has the exponential failure characteristics; if there is redundancy in the elements as suggested in the paper, this definition would not be accurate. (2) In the description of redundant module failure rate, not only must a pair of correct signals appear at the inputs of one AND gate but the subsequent gates in that module must also continue to work. It should also be noted that the last item in the module (see figure 2) is not redundant; so if it had the same failure (hazard) rate as modules A, B or C, the entire redundant module would have exactly the same hazard rate as the nonredundant unit. (3) The comparisons of hazard rate are made without reference to cost or weight. (4) The section on second failure rate is not clear, especially the detailed assumptions on which the calculations are based. The equation associated with the section on overall system reliability apparently has a misprint. (5) One should be very careful about putting redundant elements on the same integrated circuit. The failures may well not be statistically independent and in that case, the presumed benefits will not arise. (6) It is presumed that maintenance does no damage to the system. Would that that were always so! The general conclusions of the paper are often true, granted that the simplified picture of the system is accurate. The exact equations in this paper should not be accepted unless the detailed assumptions in the conceptual model are made available for checking.

R69-14490 ASQC 838; 873

SELF-REPAIR IN A TMR COMPUTER.

Michael Ball and Fred Hardie (International Business Machines Corp., Owego, N.Y.).

Computer Design, vol. 8, Feb. 1969, p 54–57.

Self-repair is discussed in the context of the automatic reconfiguration of the computer circuitry to bypass the failure either by a change of mode or by functional replacement of the failed part with a built-in spare. Consideration is given to the triple modular redundancy (TMR) method of instrumenting a two-out-of-three voting function for electrical logic and control circuits. To incorporate an automatic error detection and fault isolation capability into a TMR-organized computer system, a voting element was placed at the outputs of the three identical channels to compare the output signals and to select the signal on which at least two of the channels agree. A procedure is described for constructing a practical set of tests for error detection and fault isolation, and the addition of error detecting circuitry is discussed. Expressions for the reliability of the basic TMR module and for the self-repairing versions are derived by summing the possible failure states for each configuration. It is concluded that self-repair in a TMR computer system is feasible and produces significant increase in system reliability over the basic TMR configuration. M.G.J.

Review: An earlier paper by the same two authors dealt with the same topic and was covered by R68-14106. Self-repair is essentially a method of redundancy. The calculations are reasonably standard ones and involve triple modular redundancy. The most reliable technique is: upon failure of one element, to deactivate the failed element and one of the other good elements in the same stage; then if the active one fails, substitute for it the unfailed one which had been deactivated; failure in a stage does not occur until all three elements have failed. It should be noted that in the first failure, the system continues to operate properly. If the second failure occurs in the operating element during operation there will be some transient malfunctions. Furthermore, all but the conventional triple modular redundancy analysis assumes that the switching functions are perfect (or at the very least, much closer to unity than is the reliability of any particular element). Within those assumptions, the analysis is quite straightforward and is of a kind that has appeared before. No hardware considerations are presented. No references are given.

R69-14494 ASQC 838; 821

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

CONTROL AND DIAGNOSTICS OF FAULTS IN A REDUNDANT DIGITAL COMPUTER CONSTRUCTED ON THE MAJORITY PRINCIPLE

E. M. Mamedli

30 Nov. 1967 11 p refs Transl. into ENGLISH from Izv. Akad. Nauk Azerb. SSR, Ser. Fiz.-Mat. i Tekhn. Nauk (BAKU), no. 1, 1966 p 56–62

(AD-677694; FTD-HT-23-1507-67; N69-14560) Avail: CFSTI

Majority redundance to increase the reliability of a control computer is effected by breaking up the computer into S equally reliable blocks, at the level at which the redundance is introduced. The number of redundant blocks (R) may or may not be equal to the number of functional blocks (M). An expression is given for the reliability of the redundant computer with allowance for the fact that in practice it is impossible to subdivide the computer into blocks of equivalent reliability. The monitoring of faults in such a redundant computer is based on the fact that in the case when all the functional and majority elements operate correctly, the outputs of the redundant networks should have identical states. Any disagreement between the outputs of the redundance blocks can be described by a certain function made up of two-threshold functions, each of which can be realized by a single two-threshold element. A block diagram for the monitoring of the computer, based on this principle, is presented. TAB

Review: This paper is typical of the kind of delays experienced in having Russian translations available to reliability engineers; the paper was published in early 1966, translated in late 1967, and made available through DDC in late 1968. This paper is a fairly brief and straightforward analysis of triplicated majority logic wherein (a) each nonredundant function is presumed to have a constant hazard rate; (b) all failures are statistically independent, (c) both the logic and voters are triplicated; and (d) each block is either good or bad. It is shown that, for a given probability of failure of voters and logic elements, there is an optimum block size for voting. (Optimatility is determined by the maximum reliability without any constraints as to size, weight, cost, etc.) The paper then goes on to point out that failure indicators are needed to assure that the computer is in fact redundant at all times. A brief description is given of such a failure-indicating circuit. Three of the four references are to the American literature prior to 1964. It is doubtful if anyone need look up this article to improve his knowledge about majority-voting systems.

R69-14504 ASQC 830; 612; 844

COMPUTER-AIDED DESIGN. PART 13: DEFINING FAULTS WITH A DICTIONARY.

Walter J. Stahl, John M. Maenpaa, and Carl J. Stehman (Scully International Inc., Downers Grove, Ill.).

Electronics, vol. 41, Jan. 22, 1968, p 64–68. 8 refs.

Details are given on a fault diagnosis program developed to identify failures in a linear circuit. Written in FORTRAN 4 for the IBM 7094 computer, the program is based on the circuit's topology and nominal component values. Major computational functions include generating a symbolic transfer function for the network, selecting test frequencies, simulating component failure, and generating fault signatures. To be meaningful, the program must include definitions of what is an acceptable operating region or zero signature and what is a failure. These definitions, usually derived from the circuit's performance specifications, are used as a basis for rating and sorting faults. Diagrams are included to illustrate how the technique simplifies fault finding. M.G.J.

Review: The topic of this paper is an important one in reliability. The idea is to make circuit measurements at various frequencies and to compare the test results with a known dictionary of faults. If enough measurements can be programmed, the faults can be located uniquely. This paper describes how a computer can be used to generate the fault dictionary. In any such use of the computer, the running time of the program and the required memory size are very important. The authors have demonstrated ways of keeping both of these within manageable proportions. A paper on the same topic but somewhat different in nature appears in the IEEE Transactions on Reliability, Feb. 69, p. 12-14. Most of the discussion deals with the method in principle; a few results are stated on practical applications. Reliability engineers and designers should seriously consider this kind of method of generating a fault dictionary to see if it can be applied to their own problems.

R69-14506 ASQC 838; 824

Royal Aircraft Establishment, Farnborough (England).

TWO CONTRIBUTIONS TO REDUNDANCY THEORY

Theresa F. Klaschka

Dec. 1967 23 p refs

(RAE-TR-67306; N68-34151) Avail: CFSTI

By analysing an ideal model of a redundancy scheme, a measure for the reliability improvement produced by a redundancy scheme is found; and it is shown that for real redundancy schemes this measure is effectively independent of the size of system to which the scheme is applied. Other advantages of the measure are that it is relatively easy to evaluate, and has a good sensitivity characteristic. This measure, together with a redundancy cost factor, represents the performance of a redundancy scheme more generally than was previously possible. A new high performance redundancy scheme—radial logic is described, and its error correcting action explained. It can be applied to combinational and sequential logic circuitry, and in this application appears to have a better performance than other schemes, as well as being simple to design, and offering considerable flexibility in the degree of error correction. Author

Review: This paper is divided into two parts and will be reviewed that way. The first part introduces a measure of reliability improvement due to redundancy. The measure is independent of the number of elements in the non-redundant system. It is defined as the ratio of logarithms of reliability with and without redundancy. This of course is equivalent to the ratio of hazard functions (hazard function ≡ integral of hazard rate) and for reasonably high reliabilities is the same as the ratio of failure probabilities. It would be difficult to say that no one had ever used this ratio before (the author claims novelty); but regardless of its newness, it is a useful measure and is essentially the ratio by which the failure probability is reduced. It would have made the description of the *ideal generalized redundancy scheme* clearer if it were stated that (v) there is no redundancy except inside of an elementary segment; therefore all elementary segments are in series on the logic diagram whether in the redundant or non-redundant systems. (Statement v possibly is implied by i and ii, but making it explicit helps in either event.) It is then property iv and statement v which imply that the reliability of the system is equal to the product of the reliabilities of the segments. The following additional property is not critical to the scheme, but it is critical to the numerical examples and probably to most applications, viz., "(vi) Failures of redundant elements within an elementary segment are statistically independent." This may not be true especially for integrated circuits where several of the redundant elements are on one wafer. The second part presents a *radial logic;* it was not analyzed in great detail for this review. The redundancy appears adequate to do what is claimed for it. The only manifestation of it is given in element-by-element redundancy rather than subsystem redundancy. It is surely one of the systems that should be considered by a designer of logic systems who needs redundancy. Two later reports which describe the redundancy scheme assessment and radial logic in more detail are Royal Aircraft Establishment Technical Reports 68130, May 68 and 69045, Mar. 69.

R69-14520 ASQC 833; 715; 844

SELECTION OF RELIABLE RADIATION HARD COMPONENTS.

Gary E. Schmitz (UNIVAC Federal Systems Div., St. Paul, Minn.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, The American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 100–107. 5 refs.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

The radiation environment and its effects, including radiation testing and test facilities, are discussed, followed by analysis of a method of making initial component selections for a hardened system. Desired construction features of radiation hardened semiconductors are presented to aid in component selection, and the effect on reliability of selecting hardened devices is considered. A discussion is also presented on the quantity procurement of radiation hardened devices. Author

Review: This paper is qualitative and written for the reader not previously familiar with circuit operation in a radiation environment. The points made are basic —types of radiation and their interaction with components are reviewed as are units for measuring radiation; the relative sensitivities of various components are assessed (linear integrated circuits and power transistors are concluded to be the most susceptible components). Various rules and guidelines for finding satisfactory, radiation-hard components are presented (use existing, pre-qualified components wherever possible, because screening tests and sampling methods, although needed to help select new components, are both expensive and time-consuming). The paper gives reasonable, first-thought ideas on radiation hardening but does not go beyond this level. Table II, which attempts to show the conflicting demands of radiation resistance and high reliability upon component design does mislead in regard to size. Small size improves yield and reliability by lowering the defect density per component. Consequently both radiation resistance and high reliability are aided by small dimensions—the smaller the better on both counts until positioning errors decrease yield.

R69-14541 ASQC 831; 431; 824

COMPUTERIZED MARKOV SYSTEM EFFECTIVENESS MODELS.

E. H. Barnett, R. N. Miller, and M. J. Smith (TRW Systems, Redondo Beach, Calif.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 535–542.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Analysis techniques, utilizing the concepts of Markov processes, are presented for evaluating the effectiveness of complex aerospace systems. These techniques relate system design characteristics to the relative efficiency with which user functional requirements can be accomplished. The procedures required to prepare the problem for analysis and the computational processes are described. Recommended techniques for computing Markov state probabilities for non-repairable and repairable systems are developed. The utility of these techniques in defining and evaluating alternate design and operational procedures as well as applications to the repairable and non-repairable cases are illustrated by examples. Author

Review: This paper presents a good discussion of the practical aspects of using continuous-time Markov chain models in reliability analyses. The paper does presume a basic working knowledge of such models since, for example, their definition does not appear in the paper. A reasonably realistic numerical example helps to illustrate the techniques considered.

84 METHODS OF RELIABILITY ANALYSIS

R69-14485 ASQC 844

RANDOM-LOAD FATIGUE TESTS ON A FAIL-SAFE STRUCTURAL MODEL.

R. A. Heller (Columbia University, Institute for the Study of Fatigue and Reliability, New York, N.Y.) and R. C. Donat (USAF Systems Command, Research and Technology Div., Materials Laboratory, Dayton, Ohio).

(Society for Experimental Stress Analysis, Annual Meeting, Chicago, Oct. 31–Nov. 3, 1967, Paper.) Experimental Mechanics, vol. 7, Oct. 1967, p 409–418. 19 refs.

Contract Nonr-266(91).

(A67-40735)

Experiments performed on a 20-member redundant fail-safe structural model subjected to randomized load sequences confirm predictions of fatigue life and reliability based on a probabilistic approach. The statistical variation in ultimate strength of 2024-T4 aluminum alloy combined with an exponentially distributed, Markovian, bending load-amplitude sequence with a constant-amplitude S-N relation for single specimens is utilized in the analysis. Experimental results are presented for the statistical distribution of ultimate bending strength of 2024-T4 aluminum alloy. Constant load-amplitude flat-bending fatigue tests on single specimens and on multimember structures and variable-amplitude flat-bending tests on fail-safe structures are reported. Life to failure of the weakest member, as well as the remaining fail-safe life in the parallel structure, are examined. Author (IAA)

Review: A similar paper by the same authors but dealing with constant amplitude loading was covered by R69-14381. The review of that paper applies to the present one insofar as the papers are the same (the cumulative damage theories used in the two are identical). The present paper contains extensive experimental results on both the strength distribution of the alloys and the fatigue behavior. In the conclusions, the authors point out that experimentally there is "...a 'failsafe' capacity after failure of the weakest member," further that "...theoretical computations do not support the observed 'failsafe' capacity," and finally that "studies are currently in progress towards examining this behavior." The experimental work especially is valuable since it can be used to test many cumulative damage theories (and the literature is replete with them).

R69-14491 ASQC 844

PREVENTION OF CATASTROPHIC BRITTLE FRACTURE OF HEAVY-WALL PRESSURE VESSELS.

W. B. Bedesem and J. S. Clarke (Esso Research and Engineering Co., Florham Park, N.J.).

Joint Conference of the Pressure Vessels and Piping Div. and the Petroleum Div., American Society of Mechanical Engineers, Dallas, Sept. 22–25, 1968, Paper. New York American Society of Mechanical Engineers [1968] 12 p Members, $0.75, nonmembers $1.50.

(ASME-68-PVP-4)

Due to the increasing availability of higher strength materials, studies were conducted to determine the applicability of the fracture mechanics approach for brittle fracture prevention in common pressure vessel steels. The results show: (1) Valid fracture mechanics parameters can be obtained with common pressure steels at room temperature with reasonable size specimens when dynamic initiation is used. (2) Crack-like defects as small as 1 in. in size can be critical at typical hydrostatic test temperatures for the material examined. (3) For a leak-before-break criterion, notch-toughness requirements for prevention of brittle fracture increase as the thickness increases. Below certain thickness limits, the material will have sufficient toughness to behave in a leak-before-break manner and thus give evidence of incipient brittle fracture prior to catastrophic failure. Based on the test data, requirements are proposed for minimizing the risk of brittle fracture in heavy-wall pressure vessels. M.G.J.

Review: The authors of this paper state that their objectives were (a) to develop an understanding of the basic mechanics of fracture rather than extend existing toughness correlations, and (b) to develop a concept of fracture mechanics that can be understood by the engineer and, at the same time, be acceptable to the scientist. The results which are presented, although somewhat speculative, appear to satisfy these two objectives and to provide a realistic approach to fracture-safe pressure vessel design. Confirmation of the results will, however, be dependent upon continuation of the investigation. The paper is well written and easy to read. Design engineers, materials engineers, and test engineers who are concerned with pressure vessels will find the paper useful. Some limited fracture-toughness data for A387D steel plate are presented.

R69-14492 ASQC 844

Aeronautical Research Labs., Melbourne (Australia).

VARIATIONS IN FATIGUE PROPERTIES BETWEEN BATCHES OF D.T.D. 363A ALUMINIUM ALLOY

J. Y. Mann and A. Vann

Dec. 1967 13 p refs

(ARL/SM-321; N68-31987) Avail: CFSTI

A rotating cantilever fatigue investigation has been carried out on unnotched and notched specimens ($K = 2.3$ and 4.9) of D.T.D. 363A (D.T.D. 5064), aluminium alloy taken from material having average ultimate tensile strengths of 78,200, 88,000 and 92,000 p.s.i. In all cases the respective fatigue strengths reflected the differences in U.T.S. between the various batches, and it is therefore concluded that the order of the U.T.S. for various batches of an alloy may be a useful guide in selecting the batch of highest fatigue strength. Author

Review: This document is a very short report (two printed pages of text) which describes measured variations in the fatigue strength for three batches of D.T.D. 363A aluminum alloy. The report is well supported with graphical and tabular data. The S/N curves which are included in the report were fitted to the data through the median endurances rather than by statistical calculations. The actual data points for each of the load conditions are plotted, however. This work would be of greatest value to design or materials engineers.

R69-14497 ASCQ 844

FRACTURE MECHANICS. PART 1: THE SEARCH FOR SAFETY IN NUMBERS. PART 2: REDUCING THEORY TO PRACTICE.

John L. Shannon, Jr. (NASA Lewis Research Center, Cleveland, Ohio).

Machine Design, vol. 39, Sept. 28, 1967 and Oct. 12, 1967, p. 122–127; 188–194. 5 refs.

(A67-39982; A67-41413)

Review of plane-strain fracture mechanics shows how a stress-intensity factor is determined from crack geometry and applied stress. This factor is independent of the polar coordinates for opening-mode crack-surface displacements, and therefore gives a single description of the stress intensity at any point near the crack tip. It is pointed out that the problems associated with plane stress and plane strain have not as yet been solved. Description is presented of how to conduct fracture-toughness tests and how to transform fracture data into allowable design stresses. The first requirement for a valid K_{Ic} test is that the specimen, whatever its geometry, contain a sharp crack. Crack starters are machined into the specimen to facilitate the production of such cracks by fatigue. The apparent K_{Ic} values depend strongly on the fatigue strength/yield strength (F/Y) ratio. Many different specimens were developed, each designed for a particular purpose or, in some instances, a limitation on either the testing or service requirements. Test instrumentation, test procedure, and methods of using fracture mechanics are discussed. IAA

Review: Fracture mechanics is a relatively new concept of evaluating structural reliability by defining and providing a quantitative measure, an actual number, for the resistance of materials to unstable crack propagation. This paper summarizes the development of the theory of fracture mechanics, defines fracture-mechanics parameters, describes how to conduct fracture–toughness tests, and demonstrates how to transform fracture data into allowable design stresses. It is a well written, easy to read tutorial paper which contains sufficient handbook data to make it a useful reference for design and test engineers who now have only an awareness of the problem. These data are mathematical equations, tabulations of coefficients and constants for the mathematical equations, test specimen design and geometrical factors, test instrumentation, test procedures, and application parameters. Two other articles [1], [2] are related to this one. For example, this paper and [1] deal with the concepts of fracture mechanics. While this paper summarizes the development of the theory and treats the subject matter in a broad fasion, [1] is more rigorous mathematically and includes specific fracture toughness data for 4340, 17-7PH, H11, 300M, D6AC, 18Ni maraging, and 2219 aluminum. [2], with case histories and specific examples, shows how processing influences the fracture toughness of these same materials. These three papers would be useful references for design engineers, material engineers, test engineers, and process engineers; particularly those who are novices. The recommended reading sequence for the papers is this one first, then [1] followed by [2].

References: [1] Edward A. Steigerwald, "Designer/Materials Engineer: What you Should Know About Fracture Toughness," *Metal Progress*, Nov 67, p. 96–101. (R69-14498) [2] George R. Sippel, "Designer/Materials Engineer: Processing Affects Fracture Toughness," *Metal Progress*, Nov 67, p. 102–106, 108, 110, 112, 114, 116, 118, 119. (R69-14499)

R69-14498 ASQC 844

WHAT YOU SHOULD KNOW ABOUT FRACTURE TOUGHNESS.

Edward A. Steigerwald (TRW, Inc., TRW Equipment Laboratories, Cleveland, Ohio).

Metal Progress, vol. 92, Nov. 1967, p. 96–101.

(A68-11272)

Description of a method of fracture analysis which allows the designer to predict both component failure in terms of applied stress and (probably) defect size. When this fracture toughness method is applied to problems of design, the critical stress intensity factor is determined at fracture using a relatively simple laboratory specimen where the relationship between applied stress and crack size is known from a suitable stress analysis. In addition to this method, five other common methods which are used to determine plane-strain fracture toughness are described. These testing techniques include: (1) tensile test on a center-notched sheet specimen; (2) tensile test on a circumferentially notched round specimen; (3) tensile test with a surface-cracked sheet or plate specimen; (4) notch bend test using a precracked specimen; and (5) tensile test on a single-edge-notch specimen. IAA

Review: This is a brief presentation of the concepts of fracture mechanics. It includes: the assumptions that lead to the development of the theory; fracture-mechanics parameters; test specimen designs; mathematical equations; and examples of applications of fracture mechanics for design of structures, including welded structures. The author speculates as to how fracture mechanics could be used to predict time-dependent failures; i.e., stress corrosion or fatigue. He also cautions against the use of fracture toughness data when the procedure on how they were obtained is not specified. Fracture toughness data for the following materials are included: 4340, 17-7PH, H11, 300M, D6AC, and 18% Ni-maraging steels and 2219 aluminum. This paper will be useful to design, material, and test engineers who have only an awareness of the problem. The review for "Fracture Mechanics, Parts 1 and 2," by John L. Shannon, Jr., which appears in this issue of RATR (R69-14497) contains an evaluation of several papers in this field.

R69-14499 ASQC 844
PROCESSING AFFECTS FRACTURE TOUGHNESS.
George R. Sippel (General Motors Corp., Allison Div., Materials Science Laboratory, Indianapolis, Ind.).
Metal Progress, vol. 92, Nov. 1967, p. 102–106, 108, 110, 112, 114, 116, 118, 119.
(A68-11273)

Examination of data collected on low-alloy steels, maraging steels and a titanium alloy in order to indicate how fracture toughness is used to measure a metal's suitability for highly stressed components, and to demonstrate the influence on these metals of processing variables such as different tempering temperature, welding, and cold working. Values of notch strength as a function of temperature are compared for the two low-alloy steels H11 and D6AC, and the effects of various processing procedures on the maraging steel 18Ni-CoMo and the titanium alloy Ti-6Al-4V are investigated. IAA

Review: This paper shows how fracture toughness is used to evaluate a metal's suitability for highly stressed components; and it also demonstrates the influence of processing variables (tempering temperature, welding, cold working, etc.) on the fracture of toughness of low-alloy steels, maraging steels, and titanium. Several specific examples and case histories are quoted. Apparently all of the fracture toughness data were obtained from partial-thickness, fatigue-crack (PTC) tests, which are described in considerable detail in the paper. This document will be useful for design engineers, materials engineers, and test engineers who have only a basic awareness of the problem. Process engineers, particularly those concerned with the processing of AISI 4130, D6AC; H11, 18 Ni–CoMo maraging, Ti–6Al–4V, and 410 stainless, will find the paper to be a useful reference. The review for "Fracture Mechanics, Parts 1 and 2," by John L. Shannon, Jr., which appears in this issue of RATR (R69-14497) contains an evaluation of several papers in this field.

R69-14500 ASQC 844; 782
EFFECT OF ATMOSPHERIC HUMIDITY ON AIRCRAFT STRUCTURAL ALLOY FATIGUE LIFE.
J. A. Dunsby and W. Wiebe (National Research Council, Structures Materials Laboratory, Ottawa, Canada).
Materials Research and Standards, vol. 9, Feb. 1969, p. 15–22. 11 refs.
(A69-21390)

Investigation of the effect of atmospheric humidity upon the fatigue life at room temperature of both clad and bare specimens of aircraft structural aluminum alloy. The ratio between the fatigue life at 12 and 90% relative humidities was found to be of the order of two. This ratio was not significantly affected by the stress level. The parameter controlling the magnitude of the effect of atmospheric humidity on fatigue life is the absolute rather than the relative humidity. If the air temperature is increased by as little as 17°C above the normal value, the amount of moisture that can be contained by a given quantity of air can be almost tripled. Under these conditions, the ratio between the fatigue life at low absolute humidity and that at high absolute humidity is increased by at least as much as 5.5. IAA

Review: This is a good paper on its topic. The previous literature is well referenced and the results are presented in a reasonable manner. The various factors affecting fatigue life are important in aerospace reliability since fatigue is one of the major causes of machine and airframe failures. The results are of more concern to laboratory analysts and theoreticians than to aircraft designers. (The use of the phrase "statistical significance" in describing the need for a reasonable number of specimens is debatable. The results can always be stated in a *statistically* significant fashion no matter what the number of specimens. The important thing is that the differences have *engineering* significance.)

R69-14503 ASQC 844; 775
Benson (Robert W.) and Associates, Inc., Nashville, Tenn.
DEVELOPMENT OF NON-DESTRUCTIVE METHODS FOR DETERMINING RESIDUAL STRESS AND FATIGUE DAMAGE IN METALS Final Report
8 Mar. 1968 157 p refs
(Contract NAS8-20208)
(NASA-CR-61584; N68-21875) Avail: CFSTI

Methods of measuring stress within various alloys of aluminum using both shear and surface waves were developed. Transducers were designed for determining the relative ultrasonic velocities along the principal axes of stress. Relationships were established for a number of aluminum alloys between the ultrasonic velocity and stress. From the relationships, it is possible to determine the magnitude of stress that exists within a particular portion of a metallic structure. A special instrument has been designed and constructed which allows for the measurement of ultrasonic frequency differences which are also related to stress. Microwave frequencies and techniques were used to take advantage of small, high "Q" resonators, and to confine the resistance measurements to a few millionths of an inch of the surface. An increase in surface resistance was found to precede any visual evidence of fatigue damage and impending fatigue. Author

Review: This report appears to be a description of good work on an important topic. Some of the mild claims for practicality may not be borne out, but the techniques which are described are useful. The report is written so that the ordinary engineer will not have too much difficulty in understanding it. It is in no sense a cookbook but rather follows the research along its path, as befits a final report. Even though it occupies a very small portion of the report, the work on microwave surface loss versus fatigue damage is interesting (but not conclusive). Laboratory men and maintenance engineers alike are extremely interested in ways of measuring the fatigue damage in a part before it fails, so that appropriate remedial action may be taken or to aid in substantiating a theory. This work by the authors is one more step in a long path related to this problem.

R69-14505 ASQC 844
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
EVALUATING THE RELIABILITY OF REMOTE-CONTROL SYSTEMS
V. G. Bekhbudov et al
21 Sep. 1967 7 p refs Transl. into ENGLISH from Za Tekhn. Progress (USSR), no. 11, 1965 p 3–6
(AD-678462; FTD-HT-23-645-67; N69-72647)

The authors investigate methods of determining quantitative indicators in the reliability of remote control systems (wherein the failure of the system and its components have an incidental catastrophic character) during the period prior to initial breakdown. The systems are considered as nonrestorable systems for which the following reliability indicators are used: λ, probability of failure in unit of time; T_0, average mathematical expectancy of operating life; and P(t), probability of trouble-free performance. The following conditions are assumed: (1) system failure occurs due to failure of any component of the system; (2) all reference is to the elementary part of the system; (3) component breakdown is an independent occurrence; (4) the system is in an established operating mode; (5) the probability of trouble-free operation is exponential. The actual failure rate is found for each component by the formula where $P_{sys}(t)$ is the probability of trouble-free operation of the system during the time t; $p_i(t)$ is the probability of trouble-free operation of the i-th component during the same period of time; and n is the number of components. The rate of failure for the whole system is also found. Author (TAB)

Review: This translation from the Russian literature uses the very simple concepts of constant hazard rates for individual parts which are modified by application factors which depend on the severity of the environment the parts see. A brief reference is made to reliability allocation for subsystems on the basis of calculated hazard rates. A 1964 Russian document is referred to several times. It apparently contains suggested hazard rates for many electronic components and methods for calculating derating factors. This method is not sophisticated compared to many of the methods in the American literature today but it is undoubtedly equivalent to much of the reliability prediction that is actually done in this country. The method is the elementary approach which is most often taught in introductory courses. The paper per se has nothing to do with remote control systems; it is applicable to any kind of system.

R69-14514 ASQC 844; 824

Toronto Univ. (Ontario). Inst. for Aerospace Studies.

STATISTICAL AND METALLOGRAPHIC ASPECTS OF FATIGUE FAILURE MECHANISMS IN METALS

R. Ravindran

Feb. 1968 84 p refs Sponsored in part by NRC of Can.

(Grant NGR-52-026-008)

(NASA-CR-66578; AD-665530; UTIAS-TN-123; N68-18735) Avail: CFSTI

Copper specimens were tested at stress levels of 10.0 ksi, 16.5 ksi, and 19.0 ksi, and the results were analyzed using a single log-normal distribution, a single Weibull distribution, a truncated log-normal distribution, and the mathematical dissection method. Metallographic and X-ray examinations of the fatigued specimens were also carried out. The conclusions drawn include: (1) Both at the 16.5 ksi and the 19.0 ksi stress levels, a single log-normal distribution fitted the data better than a single Weibull distribution. (2) The trunacation analysis did not indicate the existence of two distributions at these two stress levels. The mathematical dissection method showed the existence of only a single distribution which suggests that these two stress levels are above the bimodal transition region. (3) At 10.0 ksi, even though the life indicates that this stress level is in the low F range, there is some evidence of H range damage. (4) At 19.0 ksi there are about 60% H and 40% F range grains, thus indicating that there is no clear division between H and F. Author

Review: This paper is a good example of what reliability researchers like to call *physics of failure* or *reliability physics*. That is, the detailed behavior of the material is extensively investigated to see if one can learn more about it. This paper deals with fatigue, one of the important failure modes in aerospace vehicles. The work appears to have been carefully carried out and the results well analyzed. Trying to distinguish between the logNormal and Weibull distributions is often difficult. In these cases, there were over a hundred specimens for each group so that the fit can be determined out to about the 1% tails. It should be emphasized that the goodness of fit for these distributions is inside the data range rather than out in the tails. Just because one distribution fits better inside, does not mean that it is a better fit outside the data. Unfortunately, very often one wishes to extrapolate to very low fractions of failure. Apparently no statistical tests were made of the goodness of fit, although this may be irrelevant since both have a good fit from the engineering point of view, that is, the error one would make in assuming one distribution in preference to the other over the range of the data would be small compared to other uncertainties in the problem. (The author calculated correlation coefficients apparently for the straight lines on probability paper; no reference was given to a standard statistical text for the method, but most such methods require independent observations —which the cumulative points on probability paper are not, nor are they all weighted the same.) The report is quite complete, showing much original data and the curves, so that one who wishes to reexamine these data in light of his own hypotheses is able to do so. All in all, this is a good piece of fundamental work on an important topic. In a private communication the author has stated that (a) his references 14 and 17 provide sufficient statistical background for his work, and (b) his references 15 and 24 are earlier reports on the topic of this paper.

R69-14517 ASQC 844

Franklin Inst., Philadelphia, Pa. Research Labs.

EVALUATION OF THE LIFE MARGIN OF OSCILLATING NEEDLE ROLLER BEARINGS Final Report

John H. Rumbarger Feb. 1968 61 p

(Contract N00156-67-C-2452)

(AD-666588; F-C2077; N68-21592)

The life-margin of oscillating caged needle roller bearings is determined in an explicit non-statistical manner. Life-margin is the difference between the first macroscopic evidence of spalling fatigue and the end of useful bearing life. The bearings were life tested under service conditions closely duplicating those in helicopter rotor vertical and horizontal hinge pin locations. Author (TAB)

Review: This paper discusses an interesting reliability concept for oscillating needle bearings. It is in line with much work being done by commercial aircraft companies in which scheduled replacements are being extended and possible replacements are being made only upon indication of an impending failure. By this means, not only have maintenance costs been reduced but the reliability of the aircraft has been improved since useless maintenance actions are not taken. Very often a maintenance action tends to degrade the reliability for a short period immediately after that action. In this paper the author shows how the first signs of failure (spalling) can be detected by one of two means and that a sufficiently safe period of life exists after this point, so that the danger of waiting for the failure indication is minimized. While the immediate results hold only for the particular bearings tested under these specific conditions, etc., the hypothesis is well worth extending to other bearings and other usages.

R69-14518 ASQC 844; 711; 712

CUMULATIVE FATIGUE DAMAGE UNDER CYCLIC STRAIN CONTROL.

T. H. Topper (Waterloo University, Waterloo, Canada), B. I. Sandor (Illinois University, Urbana, Ill.), and Jo Dean Morrow (Illinois University, Urbana, Ill.).
(American Society for Testing and Materials, Annual Meeting, 70th, Boston, June 25-30, 1967.) Journal of Materials, vol. 4, Mar. 1969, p. 189–199. 9 refs.
Contract N-156-46083.
(A69-23983)

Cyclic deformation resistance and fatigue damage accumulation are investigated using multiple level strain control. Data are reported for 2024-T4 and 7075-T6 aluminum alloys, aircraft quality SAE 4340 steel, and titanium alloy Ti-8Al-1Mo-1V. Effects of cyclic strain level, sequence of straining, number of blocks, and mean stress are investigated. For combinations of relatively large cyclic strain ranges there is no mean stress present, and damage summations based on plots of completely reversed strain vs life are close to one. Tensile or compressive mean stresses may be induced when the cyclic strain sequence is from a high to a low level. Damage summations based on completely reversed strain vs life data are reduced if the mean stress is tensile and are generally increased if the mean stress is compressive. Author (IAA)

Review: This paper is virtually identical to the report covered by R69-14185.

R69-14519 ASQC 844
NEUBER'S RULE APPLIED TO FATIGUE OF NOTCHED SPECIMENS.
T. H. Topper (Waterloo University, Waterloo, Canada), R. M. Wetzel (Illinois University, Urbana, Ill.) and Jo Dean Morrow (Illinois University, Urbana, Ill.).
(American Society for Testing and Materials, Annual Meeting, 70th, Boston, June 25–30, 1967.) Journal of Materials, vol. 4, Mar. 1969, p. 200–209. 13 refs.
Contract N-156-46083.
(A69-23984)

Description and application of a method for predicting the fatigue life of notched members from smooth specimen fatigue data. Inelastic behavior of the material at the notch root is treated using Neuber's rule, which states that the theoretical stress concentration factor is equal to the geometric mean of the actual stress and strain concentration factors. This rule provides indices of equal fatigue damage for notched and unnotched members. Experimental results for notched aluminum alloy plates subjected to one or two levels of completely reversed loading are compared with predictions based on these indices. Measured notched fatigue lives and lives predicted from smooth specimens agree within a factor of two. Author (IAA)

Review: This paper is essentially the same as the report covered by R69-14273.

R69-14528 ASQC 844; 775
THE ASSURANCE OF RELIABILITY IN FABRICATED STEEL STRUCTURES THROUGH NONDESTRUCTIVE TESTING.
D. A. Olsson (Bethlehem Steel Corp., Bethlehem, Pa.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 323–328.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Reliability in steel fabricating and erection through nondestructive testing is described as an important part of various construction industries. As a result, nondestructive testing and in fact all inspection procedures should be evaluated, it is advised, based upon the end result desired. Rigid quality assurance requirements are differentiated from good quality control procedures, and acceptance standards chosen for a particular nondestructive test technique and application are analyzed. It is pointed out that criteria for fabricated steel structure reliability differ from those of other structures, and that reliability of welded structures at a cost commensurate with the value obtained can be achieved only when nondestructive tests, methods, techniques, and acceptance standards are designed around the specific application to which they will be applied. Author

Review: The burden of this paper is a familiar one these days, namely, that inspection methods are now so sensitive that with existing limits for allowable discrepancies many structures are being classified as defective whereas they are not. The general question would be "how large a deviation from a homogeneous or 'idealized' state can one allow before such deviation is called a defect?" There was a time when inspection methods were so insensitive that anything you could detect was a defect virtually without question. Some techniques were (and still are) sufficiently insensitive for some purposes that limits had to be set rather tight in order to be sure to find the defects. It will be quite expensive to perform all of the experiments that will be necessary to set adequate standards, and in some situations it is probably cheaper to make the allowable discrepancies small (lower than necessary) and allow a few erroneous rejects just to avoid the expense of all the preliminary experiments which would justify looser limits. The ideas in this paper are cogent and should be pursued, not only for structural metals but in virtually all places where nondestructive testing is needed.

R69-14529 ASQC 844; 775
THE USE OF ULTRASONIC TESTING IN THE STRUCTURAL STEEL INDUSTRY.
Allen E. Wehrmeister (Magnaflux Corp., Chicago, Ill.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 340–346.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Ultrasonic inspection is discussed as a means of detecting discontinuities in various types of welds found in the structural steel industry, and thereby of developing an understanding as to the validity of these tests as related to assuring weld reliability. Testing is performed during fabrication of structural members, erection of structures, and at periodic intervals during the service of the structure. Defects likely to occur in various weld configurations, and the techniques used to detect them, are illustrated. The advantages and limitations of ultrasound are discussed in relation to these illustrations. Examples of tests which have been performed on structures are presented to further illustrate the validity of ultrasonic inspection. Author

Review: This paper is concerned with the inspection of structural welds by using ultrasonics. Early in the paper, the author makes a distinction between quality and reliability in a weld. Apparently, the distinction is the following: One can imagine an "idealized" weld; any deviations from that "idealization" would be considered by the author a corresponding decrease of quality; if that deviation were great enough to become a defect, that is, if the structure is noticeably weaker than it would have been had the weld been more like the "ideal", then the weld reliability would be decreased. With the increased sensitivity of nondestructive test methods, people are becoming concerned that many of the deviations from the "ideal" being detected are not sufficient to weaken the structure, nor to cause poor performance, nor to shorten the life. Thus they feel there is no point in calling such minor deviations *defects* and have them be cause for rejection; therefore the distinction between quality and reliability. Structural welding is used in many places other than the structural steel industry and the same principles apply in all cases. This paper is a good general description of ultrasonic testing as related to structural welding, and is suitable for managers and others who wish an introduction to the topic. Two other papers on this and similar topics, also given at this Symposium, are those found on pp. 329-339 in the Proceedings.

R69-14534 ASQC 844

PUTTING PREDICTIONS INTO PERSPECTIVE.

Samuel J. Keene, Jr. (International Business Machines Corp., Systems Development Div., Boulder, Colo.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969. p. 404–411.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

The use of failure rates, the development of reliability models, and the mechanics of generating reliability predictions are discussed in terms of their effects on design decisions. The reasons for failure rate source variations are discussed, and the basic shortcomings in constructing failure rates are examined. To illustrate the importance of failure rates in design optimization, two optimization cases are considered for a four-stage remote radio station. It is concluded that although process and material problems make actual reliability lower than predicted reliability, the reliability estimation furnishes a basis for comparison of performance and aids in isolating process deficiencies. M.G.J.

Review: This paper tells some of the things reliability predictions are good for, in contrast to the paper by Codier on pp. 383-390 in the same Proceedings, and shows why failure (hazard) rates that are tabulated may differ from each other and be different from an application. While this paper does not have the emotional impact of Codier's paper, it does present a much more balanced point of view. Reliability is largely an engineering problem; it is not a statistics problem, but statistics is one of the languages engineers use to discuss reliability, and engineers must be aware of what statistics can do for them.

R69-14537 ASQC 844

AN INTRODUCTION TO LASER RELIABILITY.

H. R. Caldwell and R. S. Cazanjian (Sylvania Electric Products, Inc., Western Div., Mountainview, Calif.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 482–494. 14 refs.

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Current laser technology is discussed generally and reliability block diagrams for several types of systems are identified. The basic theory underlying laser action is briefly described. The breadth of laser application is also indicated. Probable failure modes of three types of laser systems—solid state, semiconductor, and gas—are discussed. Author

Review: The unclassified reliability literature contains very little about the reliability of lasers. The main contribution of this paper in that regard is to list the possible failure modes of typical solid, semiconductor, and CO_2-gas lasers. Some additional reliability information appears in the appendices but apparently at this time it is not even possible to rank the failure modes in order of conditional probability or to rank the different kinds of lasers in some reliability context. The need for adequate specification of these devices is emphasized. The reliability engineer can use the information contained in this paper as a basis for developing specification requirements for laser systems. Lasers are reportedly being used, at least in the development of new equipment, if not in some equipment in the field already, by the military. Perhaps the life data are classified and thus unavailable to the general public. if not, the data certainly ought to be published.

R69-14539 ASQC 844

DESIGN EFFECTIVE FAILURE MODE AND EFFECT ANALYSIS.

Peter L. Crown (Air Force Space and Missile Systems Organization, Technical Requirements and Standards Office).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronic Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. IEEE, Inc., 1969, p. 514–521.

Available under IEEE Catalog no. 69 C 8-R; $8.00.

One method of integrating the design engineer's work with that of the reliability engineer is presented. The step-by-step analysis of a design from piece part to final assembly is shown not only by an explanation of the method but by example of a common system. The management controls and interdisciplinary coordination necessary to make the method work in industrial environments is also presented. The techniques are non-mathematical in nature and suitable for implementation with only a short training or orientation lecture preceding the actual putting into practice. No changes in personnel are required, nor are contractor's organization or practices changed appreciably. Author

Review: This paper is a good, enthusiastic case for failure modes and effects analysis. The only difficulty a reader might encounter is that the paper seems to assert that the technique is new, whereas it has been known and applied for some time. Failure modes and effects analysis is an important worthwhile technique in the development of any kind of reliable equipment, whether mechanical, electro-mechanical, or electrical/electronic in nature. In addition to discussing the technique itself, the paper offers helpful advice to the reliability engineer on working with others and in making his own work effective.

85 DEMONSTRATION/MEASUREMENT

R69-14486 ASQC 851; 771; 773
SYNTHETIC LIFE TESTING OF AUTOMOBILE ELECTRICAL EQUIPMENT.
D. J. Barrow (Joseph Lucas (Electrical) Ltd., Birmingham, England).
Automotive Engineering Congress, Detroit, Jan. 8–12, 1968, Paper. Conference sponsored by the Society of Automotive Engineers. New York, Society of Automotive Engineers, Inc. [1968] 16 p. 3 refs.
(SAE-680126)

The need is discussed for synthetic life testing as an aid to early decisions in new automobile electrical product design and development. Means of collating vehicle usage and operating regime data and the statistical determination of population parameters from a small number of test vehicles are shown and used as a basis for the formulation of synthetic life test schedules. Special-purpose and multienvironmental laboratory facilities dedesigned to operate over a range of up-rated test levels are illustrated and the need is shown for obtaining correlation between the results of synthetic life testing and the predictions of service failure patterns obtained by road testing. Author

Review: Aerospace engineers should be aware of the reliability procedures of the automotive industry since (a) the two have much in common and (b) looking at the techniques from a different perspective often helps to understand them better. This paper shows how statistical techniques are used to ascertain a reasonable probability distribution, to determine the accuracy of certain parameters and results, and to see whether real differences exist between different treatments, for example bench-life and road-life. The problems of adequately simulating service life in laboratory tests is discussed. As is usual, the grass appears to be greener on the other side of the fence; virtually everyone has this kind of trouble. The author wisely stresses the importance of comparing service failures with life test failures to be sure that the life test is an adequate simulation. On mechanical components, there are two ways of accelerating the life test and the author has used both. They are: (1) increase the magnitude of the stresses and (2) increase the fraction of the time that the stresses are being applied. The paper is necessarily on a general level (although some of the statistical examples are worked out). Nevertheless, designers and reliability engineers, especially those new to the field, can find something of value in it.

R69-14488 ASQC 851; 773; 784
ENVIRONMENTAL CONTROL ACCESSORIES TEST FACILITIES NEEDED FOR LIFE AND RELIABILITY ON FUTURE PROJECTS.
D. E. Izon and E. H. Warne (Lucas Gas Turbine Equipment Ltd., Burnley, England).
Automotive Engineering Congress, Detroit, Jan. 8–12, 1968, Paper. Conference sponsored by the Society of Automotive Engineers. New York, Society of Automotive Engineers, Inc., [1968] 20 p. 3 refs.
(SAE-680056)

Increasing demands for larger aircraft that can fly faster, farther, and higher with assurance of reaching their destinations and returning to their points of origin have far outstripped the availability of in-service experience upon which to base design reliability requirements. Test facilities are described that can provide this needed information increasing component requirements beyond the known reliability criteria. Extended research and investigation are proposed into projected reliability parameters that will assume greater importance as flight ranges and altitudes are expanded for both military and civilian aircraft. Author

Review: This paper is largely concerned with the environmental testing of fuel systems for aircraft gas turbines. It describes the test facilities and the kinds of tests run thereon. It will help to provide a bridge between design, reliability, and test engineers who are involved with gas turbine engines. As befits the purpose of the paper, the descriptions are on a rather general but nevertheless adequate level.

R69-14501 ASQC 851; 775
BUBBLE LEAK TESTING.
Ronald P. Anjard (General Motors Corp., Delco Radio Div., Manufacturing Development Engineering Dept., Kokomo, Ind.).
Materials Research and Standards, vol. 9, Feb. 1969, p. 23–26. 11 refs.
(A69-21391)

Discussion of bubble testing as a convenient technique for leak testing of components, particularly in the electronics industry. Bubble testing can give a relative indication of leak rate and can locate the leak accurately. Higher sensitivities are achieved through the use of high pressure differentials, elevated liquid temperatures, liquids with low surface tension, and gases with low viscosities. Bubble testing results are complicated by the type of gas flow, the nature of the leak itself, and tendencies for the leak to become clogged. The test itself is very operator-dependent. In conclusion, bubble testing is not suitable for measuring the total leakage of a system but is generally limited to the measurement of large single leaks. IAA

Review: This is a good article on bubble leak testing. An important consideration in it is that the tests involved three different laboratories. The reproducibility between laboratories was apparently about the same as within laboratories and the uncertainties involved are small compared to the differences between methods. Even though the main interest in the paper centers on the mechanics of the testing itself, there is some discussion of the appropriateness of bubble testing for semiconductors and of reasons for choosing one type of bubble test over another. Thus, those who are concerned about the reliability of sealed semiconductor devices should be aware of the contents of this paper.

R69-14536 ASQC 851
AIRCRAFT RELIABILITY GROWTH CHARACTERISTICS.
D. O. Hamilton and W. G. Ness (Lockheed-Georgia Co., Marietta, Ga.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 465–471. 2 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

The reliability growth characteristics of the C-141 aircraft are discussed. The behavior of several reliability and reliability-related parameters is presented as a case history of a relatively complex system produced under an aggressive reliability engineering and management program. Data are examined for (1) fleet trends, (2) individual aircraft aging trends, and (3) trends based on aircraft delivery sequence. Author

Review: The data presented in this paper are a worthwhile addition to the aerospace reliability literature. The discussion will be helpful to those not intimately acquainted with these kinds of statistics for aircraft. But they should remember that the answers one gets are determined by the questions one asks, and that one should be careful about ascribing meaning to answers other than as direct consequences of the question and the physical situation. Some question/answer sets may be more meaningful than those in the text. For example, it has been shown elsewhere that the overall management system under which the aircraft and personnel operate can drastically affect the complaint and removal rates regardless of the actual condition of the hardware. (A pilot finds it convenient to blame improper mission performance on equipment. The maintenance personnel may well feel that if a complaint has been made, it is to their benefit to show a concrete maintenance action—a replacement of hardware—since they have nothing to lose by it, whereas they may have someting to lose by asserting that the complaint was not founded. Good equipment has then been pointlessly serviced and probably degraded.) The authors say that the curves in Figures 2, 3 and 4 are "...a natural outgrowth of the aggressive reliability program..." While the curves can be explained by such a program, it is not obvious that they could not occur under other situations. Some of the straight lines drawn through the data points in Figures 2 through 11 seem rather forced. Some data seem to show an oscillating trend; others exhibit a tremendous amount of scatter, making the uncertainties in calculated parameters very large. In Figure 11, a straight line seems rather inappropriate to describe the *existing* data, much less any extrapolation thereof.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 7

Typical Subject Index Listing

PROBABILITY
Procedures for applying sequential probability ratio tests in analyzing checkout and support equipment
TR-3 c84 R69-12733

SUBJECT TERM | REPORT NUMBER | NOTATION OF CONTENT | CATEGORY NUMBER | *RATR* ACCESSION NUMBER

The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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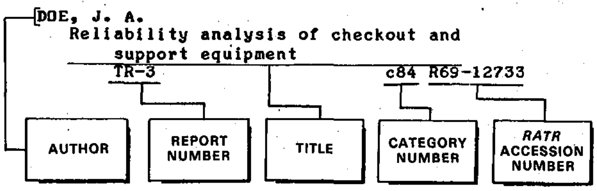
RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 7

Typical Personal Author Index Listing



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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 7

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 7

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AUGUST 1969

Volume 9

Number 8

R69-14544—R69-14593

Reliability Abstracts and Technical Reviews

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

***RATR* ACCESSION NUMBER**	R69-12733 ASQC 844; 413	**ASQC CODES**
	General Equipment Company, Banville, Calif.	**CORPORATE SOURCE**
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	**PUBLICATION DATE**
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	***TAB* AND *STAR* ACCESSION NUMBERS**
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	**AVAILABILITY SOURCE**

***RATR* ACCESSION NUMBER**	R69-12739 ASQC 814	**ASQC CODE**
TITLE	**SEMICONDUCTOR RELIABILITY.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	**AUTHOR AND AFFILIATION**
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER**	R69-12765 ASQC 773; 221; 823	**ASQC CODES**
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).	**AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*	
	Available from Assoc. of Reliability Eng., New York: $1.00	**AVAILABILITY AND PRICE**
***IAA* ACCESSION NUMBER**	(A69-12407)	

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Reliability Abstracts and Technical Reviews

A Monthly Publication

of the National Aeronautics and Space Administration

August 1969

80 RELIABILITY

No abstracts in this issue.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14565 ASQC 813

WANT TO BE A GOOD LOSER? GO ABOUT IT SYSTEMATICALLY.

Matthew W. Slate (Sedco Systems Inc., Farmingdale, N.Y.).

Electronics, Apr. 14, 1969, p. 112–115.

Failure is discussed as something which can, in fact, be planned for and expected in many instances. Design failure is defined as failure in equipment as it is produced and sold in volume, after it has looked good on paper and worked properly in the lab. It is pointed out that design engineers can guarantee failure by (1) assuming components are components and not wasting time analyzing them; (2) taking tolerances literally; (3) taking ratings literally; (4) staying out of production; (5) avoiding redesign; (6) skipping the details; (7) avoiding worry about temperature; and (9) ignoring problems that cannot be measured. L.B.H.

Review: This paper is written in a semi-humorous vein in that it tells how to make bad equipment and only obliquely tells how to make it reliable. The implied cautions are all good; some are even more severe than is implied. This is a general paper in that eight rules are given with a few specific examples for each one. In designing a reliable piece of equipment, the watchword is *attention to detail*. But it is the kinds of detail to which one must pay attention that need to be expressed (and this paper gives some of them). Engineers, especially new ones, are well advised to read this kind of article since it will require little effort for the increased understanding they will gain.

R69-14566 ASQC 814; 870; 880

Stanford Univ., Calif. Dept. of Operations Research.

JOINTLY OPTIMAL INVENTORY AND MAINTENANCE POLICIES

Charles H. Falkner

5 Jul. 1967 123 p refs

(Contract Nonr-225(77)(NR-347-010)

(AD-654721; TR-9)

A deterministic, continuous time, nonstationary inventory model is formulated to find the number of orders, the order quantities, and the times at which orders should be placed which minimize the total cost over a finite time horizon of meeting demand given by a requirements function. Conditions are given for the existence of an optimal policy with a regeneration point property. A deterministic, finite horizon inventory-maintenance system model is formulated to minimize total costs when the inventory demand is generated by choosing a sequence of equipment replacement intervals. Using the inventory results above, conditions are derived for the existence of an optimal policy such that orders are received only at times the equipment is replaced. Inventory and maintenance policies are determined which jointly minimize total avoidable cost when a single component of an equipment required to operate over a finite horizon fails stochastically with an increasing failure rate. The structure of the optimal replacement policies is characterized. TAB

Review: This is a good theoretical paper and can be of value to those doing research in the field of optimum inventory and maintenance policies. Even though examples are included, the results are not put in a form readily available to engineers who are making day-to-day decisions of this type. Of course not all possible problems are solved therein. Some items which have yet to be included are (1) effect of stochastic delivery times of ordered spares; (2) when reliability vs. cost of equipment is known ahead of time, what is the optimum reliability in connection with an optimum spares and maintenance policy? This kind of research is an important part of the solution to overall problems of optimum size of throw-away modules, inventory sizes where more than one level of repair depot is used, and of course the entire field of life-cycle costing. (Not all of the mathematics was checked, but it appears to be competent.) All in all, this is a valuable contribution to the body of theory, but of little use to practicing design and reliability engineers.

R69-14576 ASQC 814; 844

SLIDE METHODS FOR REDUNDANT MISSION AVAILABILITY.

M. Sasaki (Japan Defense Academy, Dept. of Electrical Engineering, Yokosuka, Japan).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium Sponsored by the Institute of Electrical and Electronics Engineers, The Institute of Environmental Sciences, The American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 580–607. 4 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Slide methods are presented of achieved desired values of duplex parallel and duplex switchover redundant mission availabilities with minimum cost through choice on system design (reliability) and system operation (maintainability). These slide methods involve sets of charts and sets of nomographs which provide insight into the trade-off characteristics between the two factors describing design and maintenance. When an increase in the mission availability is desired, there exists an infinite number of pairs of these two factors as solutions, of which the optimum solution with minimum cost can be selected through proper trade-off of design and maintenance efforts by the use of one slide method. Mission availability, mission availability of duplex parallel redundance, and mission availability of duplex switchover redundancy are cited as criteria for the method. The redundant systems can be maintained or repaired during mission at a sub-system level
Author

Review: This paper illustrates applications of two theorems in an earlier paper by the author which was covered by R66-12778. That paper, in turn, depended on previous publications. Thus this is not a presentation of new mathematical results. The "slide methods" referred to in the title involve sets of charts and nomographs which can be used in evaluating tradeoff characteristics between reliability and maintainability. These methods can be of use to designers of aerospace equipment and can be used by those who do not necessarily understand all of the mathematical details on which they are based; the explanations in the paper are adequate for this purpose. The paper consists of a brief statement of the pertinent mathematical results followed by eight examples. This text material occupies less than one fourth of the paper; the rest consists of charts and nomographs. These are presented on rather small scales, and those who wish to make practical use of them will probably wish to redraw them on larger scales to avoid eye-strain. (The charts and nomographs were not checked in detail, but on the basis of a spot check they appear reasonable.) Those who wish to delve into the mathematical background of these methods will need to refer to the earlier papers which, as pointed out in R66-12778, leave much to be desired in terms of clarity.

R69-14579 ASQC 813
Information Dynamics Corp., Reading, Mass.
AN INDEPENDENT MANAGEMENT CRITIQUE OF THE NASA MICROELECTRONIC RELIABILITY PROGRAM
Feb. 1967 85 p
(Contract NAS12-147)
(NASA-CR-97217; R-8090-2; N68-36668) Avail: CFSTI

The probable effectiveness of the microelectronic reliability program was evaluated, and an estimate was made of its acceptibility to potential participants. Field interviews were conducted to survey the potential user community's requirements for data bank services, and to gather in-depth attitudes toward the program among microelectronic manufacturers, NASA Centers, and contractors. It was concluded: (1) Preparation of specifications, standards, survey and procurement procedures, and the operation of the data bank as a communication system reaching all NASA participants will reduce unnecessary duplicate expense. (2) Program success probability can be increased if NASA combines forces with other government agencies and presents common procedural requirements to industry. (3) Acceptance by manufacturers, although ultimately favorable, will require careful presentation and implementation by highly trained personnel. (4) The most significant technical problems are identified as developing effective line certification procedures acceptable to industry, and developing a sufficient depth of technical understanding to allow for the introduction of abridged qualification tests on new devices that are members of a qualified family.
M.G.J.

Review: This document presents a detailed discussion of the thinking that led to the creation of the NASA Microelectronics Reliability Program and is of historical interest for this background alone. The major question being addressed, however, is whether this reliability program is worthwhile or will ever win acceptance, particularly from the manufacturers who will apparently be required by the program to open their operations to more outside scrutiny than they have been accustomed to in the past. The technique which was employed to answer this question was to interview a representative number of the people involved. The responses tabulated in the report indicate a surprisingly good acceptance of the program's goals on the part of everyone involved—NASA, users, and vendors—and not nearly as much disagreement as might have been expected on the details of implementing those goals. Indeed the attitude reflected in the report and since then put into limited practice (see R68-14164) is one that would be profitably emulated in contemporary civil strife—that of letting the controlled unit (here, the manufacturer) specify what he thinks are the critical control parameters for his process and how NASA should monitor them. Accepting this attitude by no means guarantees success but does permit the real task to begin. The Information Dynamics Corporation document reflects the difficulty of the problem and the concern of NASA over pushing too hard too soon. The NASA role is pictured as one of foresight with recognition of the urgency of the problem but tempered with restraint to avoid the obvious perils. Admittedly the agency authoring the report plays the "data bank" role in the program and has a stake in the continuation and success of the program, somewhat jeopardizing its intended role of disinterested evaluation and "independent critique" as promised in the title. The reader not familiar with the program should read the Appendix first since it contains much of the background information alluded to at the beginning of this review. As the title indicates, the major subject is the program philosophy and goals; no technical details are discussed.

R69-14580 ASQC 815
INDUSTRY'S MOST URGENT MATERIALS PROBLEM. . . CHARACTERIZATION.
Metal Progress, vol. 94, Apr. 1968, p. 60–78.

The results of industry-wide survey letters on characterization, described as the most urgent materials problem, are acknowledged and discussed. A summary of the NAS Materials Advisory Board pioneering study report on the topic provides an introduction to the individual as well as general comments which follow. Specific problems are pinpointed by materials users, such as proper characterization itself, processing procedures, reliability demands, the need for multilevel standards, design problems, information availability, safety factors, product misuse, and performance prediction.
L.B.H.

Review: This discussion on characterization of materials is essentially from the viewpoint of the manufacturer who buys things such as steel, plastics, and parts made therefrom; then he converts them into a machine which is used by the consumer. In other words, he takes the materials and from them creates a system. This assembly of opinions treats an extremely important portion of the reliability problem. Many of the comments are applicable not only to materials but to many components that any manufacturer buys. It is difficult in an assembly of short notes to bring out any specific positive suggestions that can be readily implemented and thus most of the complaints are in essence negative. Several comments upon that collection of opinions are: 1) There is of course an economic problem. The more you specify, the more it costs. This is especially true if not much material is supplied to your specification. This is the advantage of industry-wide specs. The properties of materials are not more variable than they "need be." If the properties were less variable, the product undoubtedly would be more expensive unless better processing could be found. 2) It is virtually impossible to write a complete specification for anything. All of the words we use are imbued with many cultural connotations. Many of our words to express properties are very qualitative, such as *ductile*. Many are only operationally defined, such as *hardness*, and often it is not clear whether a particular concept is being used in its specialized metallurgical sense or in its lay sense. An interesting enlightening puzzle for those who have not yet tried it is to write down as complete a characterization of some material as you can, say 4340 steel or a polycarbonate resin. Once that has been done, try to figure out how you could supply or make something, technically meeting those specifications, but which would be utterly unsuitable for the task for which that material is ordinarily used. 3) Even though we are interested in producing more complete specifications, it should be noted that many materials presently purchased to a spec do not always meet it. Cast metals are an excellent example of this problem. Admiral Rickover, of nuclear submarine fame, has had some emphatic and colorful things to say on this subject. 4) Several of the correspondents have suggested that there is much useful information locked up in laboratory files, and that if this were only accessible, many of their problems would be solved. In general, if the results of all these lab tests were made available, it would be a *Tower of Babel*. Some of the tests would have been made competently, others incompetently—how to distinguish them? Some were run with materials which are no longer made the same way as they used to be, but the name of the material has not changed. Under what exact conditions were the tests run? 5) Many of the writers felt that suppliers should characterize their materials much more. A question which these people might ask themselves is, "Do I characterize my product for its consumer as well as I wish my supplier to characterize his?" Many of the problems associated with this characterization of the manufactured product would not be cured by a complete specification of the materials. 6) One good suggestion is that somehow the standards should be made multi-level; that is, the variability of the specified parameters should become narrower as the level is increased. Thus a supplier could pick and pay for just what he needs. 7) Many of the writers felt that the information they need on characterization would pay for itself. The question an economist then asks is, "If that is true, why don't you find out that information and sell it at a profit?" 8) A philosophical outlook on the problem is that characterizing the material means finding constants which can be inserted into mathematical models of behavior so as to predict all the various performance attributes. The biggest difficulty is that we do not even have the mathematical models in which to put those constants, even if we had them. 9) In situations where it is economically viable to characterize a material much more completely than it is ordinarily done, often one finds that someone *is* willing to supply this material when the demand exists, although the price is usually higher. But what most of the correspondents wanted was this extra something, for nothing. All in all, those who are afflicted with the problem of incomplete specification of materials or components will find that this article reflects most of their plaints, but the only practical advice found therein is to have everybody get together and work on the problem.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14544 ASQC 820

RELIABLE INFORMATION STORAGE IN MEMORIES DESIGNED FROM UNRELIABLE COMPONENTS.

Michael G. Taylor (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Bell System Technical Journal, vol. 47, Dec. 1968, p 2299–2337. 10 refs

Grant NsG-334.

(A69-15455)

Analysis of the theoretical capabilities of computing systems designed from unreliable components with emphasis on the capabilities of memories. Existence theorems are given which are analogous to the existence theorems of information theory. The fundamental result of information theory is that communication channels have a capacity, C, such that for all information rates less than C, arbitrarily reliable communication can be achieved. In analogy with this result, it is shown that each type of memory has an information storage capacity, C, such that for all memory redundancies greater than 1/C arbitrarily reliable information storage can be achieved. Since memory components malfunction in many different ways, two representative models for component malfunctions are considered. The first is based on the assumption that malfunctions of a particular component are statistically independent from one use to another. The second is based on the assumption that components fail permanently but that bad components are periodically replaced with good ones. In both cases, malfunctions in different components are assumed to be independent. For both models, it is shown that there exist memories, constructed entirely from unreliable components of the assumed type, which have nonzero information storage capacities. Author (IAA)

Review: This is a theoretical paper and as such proves two useful theorems concerning computer memories. The theorems are intended to be analogous to those concerning the capacity of a communications channel. A large portion of the author's effort undoubtedly went into seeking out those concepts which would lend themselves to proofs of such theorems (and the finding of those concepts is a large portion of his contribution). It is important to remember that in theoretical papers such as this, the authors have defined certain phrases to mean very explicit, specific mathematical conditions—rather than to have the wide variety of meanings that lay language would ascribe to them. It is also important to remember that the theorems are mathematical in nature and do not bear upon any hardware, per se. (If they did they would not be universally true.) They merely apply to the hardware insofar as the hardware is able to duplicate the conceptual model laid down in the theory. It is difficult without a tremendous amount of applications effort to know how much practical use these theorems can/will be put. Their power, however, is not necessarily to be judged by how many times per day they are used by designers, but more by the kind of insight they give theoreticians into the design of computer memories.

R69-14545 ASQC 820
RELIABLE COMPUTATION IN COMPUTING SYSTEMS DESIGNED FROM UNRELIABLE COMPONENTS.
Michael G. Taylor (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).
Bell System Technical Journal, vol. 47, Dec. 1968, p 2299–2366. 3 refs.
Grant NsG-334.
(A69-15456)

This is the second of two papers which present information-theory-type results pertaining to the reliability of computing systems designed from unreliable components. Two models for component malfunctions are considered. The first is based on the assumption that malfunctions of a particular component are statistically independent from one use to another. The second is based on the assumption that components fail permanently but that the components which have failed are periodically replaced with good ones. In both cases, malfunctions in different components are assumed to be independent. Just as a channel capacity is defined for communication channels, a computing capacity is defined for computing systems. For both component failure models, it is shown that there are computing systems, designed entirely from unreliable components of the assumed type, which have nonzero computing capacities. Author (IAA)

Review: This paper is a companion to the one which precedes it in the same journal, and that paper is an essential reference for this one. Much of the review of the other paper applies as well to this one since that review considers the nature and utility of this kind of existence theorem. As the author states, he was interested in proving the existence of bounds rather than in finding efficient bounds. It should be especially noted that he has given explicit definitions to words which are often used more loosely in other engineering contexts; the specific meanings are an extension or restriction of the lay meaning (a very reasonable thing to do), but it does mean that the reader must be constantly aware of the exact mathematical meaning of these terms. As mentioned in the other review, these are not the kinds of theorems that design engineers use directly, but are of the kind that affect and guide other theoretical work. One should note that statistical independence of the errors in different components is a requirement in the proofs. Whether it is necessary or merely sufficient is not known, but it is the kind of restriction which can be unwittingly and disastrously glossed over. The fundamental importance of this work is difficult to evaluate readily because of the complexity of the concepts which are essential to it. Nevertheless, these existence theorems hold excellent promise of being important in guiding the direction of future research, as they give insight into the ultimate capabilities of computing systems designed from unreliable components.

R69-14547 ASQC 824; 831
Minnesota Univ., Minneapolis. Dept. of Electrical Engineering.
APPROXIMATE PREDICTION OF MULTIMODAL CREST STATISTICS AND SYSTEM RELIABILITY FOR IMPULSIVE NOISE LOADING Final Report, 1 Dec. 1965–30 Oct. 1967
George L. Hedin, Raymond A. Janssen, T. I. Smits, and R. F. Lambert
Wright-Patterson AFB, Ohio AF Mater. Lab. Feb. 1968 71 p refs
(Contract AF 33(615)-3365)
(AD-668767; AFML-TR-68-30; N68-27338)

The current analytical models of impulsive noise and system response thereto are found numerically intractable, indicating a need for engineering approximations. One, based on finding an 'equivalent' unimodal system having approximately the same response statistics—here the Crest statistics—is examined. It is found that fair agreement obtains, making it possible to use two reasonably accessible parameters to characterize any linear multimodel system response and thus predict its Crest statistics systematically, provided that 'standard' curves of unimodal response Crest statistics are available for statistically identical forcing. Limitations of this promising approach are explored, encouraging its use in reliability prediction pending further studies. Also, the need for further studies of impulsive noise response Crest distribution 'tails' is noted for prediction of overload and wearout reliability on the basis of wear-dependent failure rate concepts, since extrapolation of empirical data into the 'tail' (here done on the basis of a Weibull Crest Fit) is increasingly necessary the more 'impulsive' the response is (i.e., the more the parameter is less than unity). Author (TAB)

Review: This paper uses a considerable amount of local jargon which will make the paper more difficult to use for many reliability engineers. (Much of the unusual language is amplified and explained in three previous reports cited as References 5, 10, and 11 in the paper. Two articles arising from the same study and published after this paper are [1] and [2].) Nevertheless, it is a valuable contribution relative to the problems of mechanical reliability, at least partly because it discusses some unsuccessful approaches to evaluating system behavior. There is very little discussion in the paper of reliability per se. In the last section, there is some discussion of hazard rates for overload and wearout, but these two terms are not defined in the report. Thirty-five references are cited. The value of this work will be for other theorists rather than for design or reliability engineers. The energy methods for characterizing bandwidths appear promising. Their partially-empirical character is probably no worse than that of other methods for trying to predict the reliability of a system.

References: [1] G. L. Hedin and R. F. Lambert, "Numerical prediction of response-peak statistics of linear systems excited by impulsive noise," J. Acoust. Soc. Am., vol. 43, Jun 68, pp. 1319–1323.
[2] T. I. Smits and R. F. Lambert, "System-reliability prediction in impulsive-noise environments, based on wear-dependent failure rates, using response 'peak' statistics," J. Acoust. Soc. Am., vol. 43, Jun 68, pp. 1344–1350.

R69-14549 ASQC 821; 844
Battelle-Northwest, Richland, Wash. Pacific Northwest Lab.
PRELIMINARY RELIABILITY ANALYSIS FOR FFTF SAFETY CIRCUITS
Oscar B. Monteith
Mar. 1968 29 p refs
(Contract AT(45-1)-1830)
(BNWL-661; N68-26717) Avail: CFSTI

A preliminary reliability prediction for the Fast Flux Test Facility Reactor Safety System is reported. The system is analyzed for two failure modes; failures that cause spurious responses (reactor scrams), and failures that result in the inability to respond to unsafe

conditions. Results are preliminary because the system is a conceptual version and components have not been specified.
Author (NSA)

Review: This paper is an example of the kind of reliability analysis that is done often by many people. It is worthwhile reading for the neophyte because it shows the kinds of assumptions that are made and why they are made (usually because of ignorance). The analysis is not particularly sophisticated but is undoubtedly as detailed as the available data justify. The use of zero and very small probabilities is often justified but it should be approached cautiously. For example, if a model gives a 10^{-6} probability of failure for a redundant part and there is a 10^{-12} chance of a catastrophic environment, obviously the model would not have been sufficiently complete.

R69-14550 ASQC 824; 851

APPLICATION OF HYPOTHESES OF SUMMING FATIGUE DAMAGE TO THE ACCELERATED EVALUATION OF FATIGUE ENDURANCE.

B. S. Fresin

(Zavodskaya Laboratoriya, vol. 34, Mar. 1968, p. 336–340.)

Industrial Laboratory, vol. 34, Mar. 1968, p 403–406.

Accelerated determination of fatigue endurance in loading regimes is discussed. Tests in which a severe regime follows a low regime are designated accelerated tests with ultimate breakage at high load; those with severe regime preceding the low, accelerated tests with ultimate breakage at low load. Conversion of the test results are carried out. It is concluded that (1) evaluation of endurance can be obtained with sufficient accuracy by ultimate breakage with both high and low loading; (2) a criterion of the reliability of the evaluation of endurance is the correspondence within 20-25% of two successively calculated endurances; (3) accelerated tests to ultimate breakage at low load are more suitable; and (4) guaranteed advanced destruction of specimen indicators with sufficient reserve of fatigue strength makes this method preferable for accelerated evaluation of the operating life of structural elements.
L.B.H.

Review: Fatigue is one of the most important failure modes with regard to mechanical reliability and this paper apparently delves into the following two facets thereof: (1) comparing several formulas for cumulative damage and (2) selecting the more appropriate formulas for cumulative damage and using them in a special way for predicting the life of a structure. The first part proceeds rather straight-forwardly using the method of least squares to determine the adjustable parameters in a given expression for cumulative damage. It is not immediately obvious what all of the details of these calculations were but it seems reasonable to presume they were done well enough. Linear cumulative damage did not give as good a fit as some of the other formulas. Even though much of the work was programmed on a computer, if an analytic solution for the parameters of a given fatigue formula was not available the author did not use the formula since the extra numerical methods would apparently take much too long on his computer. The method of accelerated evaluation of fatigue life of a structure involves taking a specimen of the same material as the structure, fatiguing it to a known number of cycles at a fairly high load so that its life is reduced by a "known" amount. The specimen is then attached to the structure and will then fail in some known fraction of the life of the structure itself. When the specimen fails (presumably before the structure fails) the remaining life in the structure can be calculated. This method for evaluating the fatigue life of a structure has not recently appeared in the American literature. It is not possible to say (without trying it) what its accuracy and convenience is with respect to other methods for accomplishing the same thing. The author claims that an empirical formula similar to one given by Manson, Nachtigal, and Frisch is easy to use and gives results accurately enough. Presumably many specimens in structural elements of steel, cast iron, and light alloys were tested under different loading conditions. In actual loading spectra, the author glosses over the methods that are used to translate an actual spectrum into one involving complete reversals (with the same number of cycles) so that the ordinary S-N curves can be used. All in all, those doing laboratory work in fatigue are well advised to look at this paper and to see how well the results fit in with their own practices. Some theoreticians may even wish to study this further.

R69-14551 ASQC 824; 553

Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.

SIMULTANEOUS LINEAR ESTIMATION OF THE MEAN AND STANDARD DEVIATION OF THE NORMAL AND LOGISTIC DISTRIBUTIONS BY THE USE OF SELECTED ORDER STATISTICS FROM DOUBLY CENSORED SAMPLES

Jackson S. Simpson (M. S. Thesis)

Dec. 1967 312 p refs

(AD-675544; GRE/MATH/67-10; N69-12387) Avail: CFSTI

The method of least squares can be applied to order statistics of the Normal and Logistic distributions to estimate linearly the mean and standard deviation. For doubly censored samples of ordered observations, coefficients of estimation using the best L order statistics, where L is less than or equal to m (the number of observations remaining after censoring) were calculated and tabled. The efficiencies of the L-order-statistic estimators relative to the m-order statistic estimators are also tabled. Information concerning the Normal and Logistic distributions, their moments, and order statistics is given general coverage.
Author (TAB)

Review: This thesis is yet another step in the compilation of tables which make it easier for engineers to calculate the parameters of reliability distributions by means of order statistics. The two distributions in this thesis (Normal and Logistic) are both useful in reliability problems (mostly those involving strength of materials and wearout life). The text gives a good, though abbreviated, discussion of the principles involved in calculating the numbers that appear in the tables and gives an explanation of how to use them. The example is not as clear as it might be, since the table headings are not explained well; the example contains a misprint and some incompleteness which may confuse the novice. Once one knows that the items in the column labeled ST represent the number of the *order statistic*, the explanation of the tables becomes much clearer. A great many tables of this kind have been generated. It remains for someone to pull this information together in a form that is readily usable by engineers.

R69-14552 ASQC 821

Southern Methodist Univ., Dallas, Tex. Dept. of Statistics.

RECENT PROBABILITY RESULTS FOR EXTREME AGES

John E. Walsh

20 Sep. 1968 11 p refs

(Grant NGR-44-007-028; Contract N00014-68-A-0515)

(AD-680019; TR-11)

Consider a very large number of persons, and probability distributions for the age at death of the last survivor, next to last survivor, etc. First, suppose that the persons are statistically independent with the same probability distribution for age at death (random sample case). Then, some approximations to distributions of extremes are often usable. These approximations are completely specified except for at most three parameters. This simplifies distribution estimation to estimation of the parameters. Moreover, previous large samples (possibly different sizes) from the same population of persons, and much of their data on extremes, can be used for estimation. Also, the sample results often remain applicable for the more general case of independence (or mild dependence) but possibly different distributions for the ages at death. Here, the average of these distributions is sampled. Very recent results show that distributions of extremes are of the sample type for any joint distribution of the ages at death. However, the distribution sampled can be greatly different for the last survivor, next to last survivor, etc. This effectively limits estimation of parameters to previous groups having very nearly the same joint distribution and use of one observed extreme per group. TAB

Review: There is a direct analogy between the lives of people and the lives of equipment—mortality and reliability are directly associated. This paper refers largely to previously published works. Its most important contribution for aerospace reliability seems to be in pointing out that events which have mild statistical dependence can be fitted by the extreme value distributions as if the data were independent. Such fitting of curves, for example to the Weibull distribution which is often used in reliability activities, is a very uncertain affair especially when not many data are available. Although this paper addresses itself to the individuals with the longest lives, reliability is usually concerned with the individuals with the shortest lives. The calculations and equations for both order statistics are usually quivalent.

R69-14553 ASQC 824; 851

RAND Corp., Santa Monica, Calif.

JET FIGHTER ACCIDENT/ATTRITION RATES IN PEACETIME: AN APPLICATION OF RELIABILITY GROWTH MODELLING

Milton Kamins

Mar. 1968 38 p refs

(Contract F44620-67-C-0045; Proj. RAND)

(AD-667784, RM-5563-PR; N68-24231)

Two statistical examinations were made of accident and attrition data for all jet fighters that had seen substantial Air Force usage by 1963: the first to distinguish gross factors affecting safety (landing speed, single versus twin engines, similarity to a previous model, and age): the second to compare different methods for analysis and prediction. The first examination showed that (1) aircraft reliability affecting safety improves with years of service as long as routine, comprehensive maintenance and product improvement programs are pursued; (2) during the last 20 years, materiel failures have become more important in jet fighter accidents; (3) two engines may be no more beneficial to safety than a heavy carry-over of technical experience from one model to the next made by the same company; (4) landing speed is less important than either. The second examination confirmed these conclusions and also indicated that the hyperbolic model of reliability growth developed in RM-5346-PR is preferable to a learning-curve model in three respects: It can represent trends more accurately, is easier to use, and permits statistically and practically meaningful confidence limits to be calculated for past experience or future projections of accident or attrition rates. Author (TAB)

Review: The accident/attrition rates that are being modelled in this report are analogous to modelling the reliability growth of aircraft and missiles. The report referred to in the preface was covered by R68-13858 and R69-13913. As the author mentions in several places, the methodology being used in this report is applicable elsewhere. Also (and something he does not mention), the cautions he states about drawing conclusions based on the data and engineering judgment are always useful. Some correlations are obvious, but as statisticians are fond of warning, correlation and cause and effect are far from the same thing. Another important potential implication for reliability growth is in the fact that aircraft which were closely related to a preceding model had a lower accident rate. The same kind of thing has been observed in reliability; the closer you can build something to a previous product, the more likely it is to be more reliable and the more rapidly it will approach the desired reliability. The $\chi 2$ test was used for goodness of fit. While it is a valid statistical test, one should remember that the data had a great deal of scatter, so that in any event it was probably not worth splitting too many hairs over which prediction formula is the best. One is reasonably justified in using the simpler of the two.

R69-14555 ASQC 824; 412; 433

Center for Naval Analyses, Washington, D.C. Operations Evaluation Group.

CONFIDENCE LIMITS FOR SYSTEM RELIABILITY

Joseph Bram

2 Feb. 1968 16 p *Its* OEG Res. Contrib. No. 79

(Contract N00014-68-A-0091

(AD-666560; N69-12231) Avail: CFSTI

Formulas are derived for estimating the reliability P of a system containing r independent components with reliabilities P1, . . ., Pr, and confidence intervals for P. The use of the formulas is illustrated by an example. Author (TAB)

Review: This report presents an interesting solution to a problem that has been with us a long time. The approach taken is the Bayesian one wherein the conjugate prior distribution is used. The final formula for the density function of the variable is an approximation, but one which has received the blessing of the statistical literature. Assuming that one wishes to follow the Bayesian approach, the only arguments with the paper are those with a choice of prior distribution. The author has a self-contradiction in which he first asserts that the prior ". . . is diffuse (or spread out) rather than peaked near one particular p_0." He then goes on to choose the parameters of the binomial distribution so that it consists solely of two spikes—one at $p = 0$ and the other at $p = 1$ with the value 0 in between. Part of this difficulty stems from the fact that he uses an unnormalizable prior distribution which, while also blessed by some of the statistical literature, is still fortunately controversial. His particular assumptions are not necessary to the further development of the approximation. In fact, as long as the second of the parameters in the prior (β) is an integer, his discussion can be modified merely by inserting the appropriate new values; viz., $n + \alpha + \beta + 2$ replaces n, and $s + \alpha + 1$ replaces s. Even if β is not an integer, one can still use the final formulas if he is willing to fudge a little (and since the whole thing is an approximation, there is no serious objection to the fudging). It should be noted that because of the author's choice of values for the parameters ($\alpha = -1$, $\beta = -1$) of the prior, his formulas are not defined for the situation wherein the experiment on any one component is all failures or all successes, namely, the *posterior* distribution is not normalizable either. Assuming that one wishes to leave the Bayesian prior parameters in the final formula and use them as a measure of prior knowledge, the resulting formula is quite straightforward and should prove useful to reliability engineers. It is almost necessary to use some prior information to get an answer that is worth it. Even in the author's example, for 95% confidence limits, $0.2 < P < 0.7$, which is a very wide range indeed, especially in view of the fact that there were almost forty test runs on the unconnected components.

R69-14556 ASQC 823; 413

A NOTE ON TESTS FOR MONOTONE FAILURE RATE BASED ON INCOMPLETE DATA.

R. E. Barlow (University of California, Berkeley, Calif.) and F. Proschan (Boeing Scientific Research Labs., Seattle, Wash.).

The Annals of Mathematical Statistics, vol. 40, 1969, p 595–600. 6 refs.

Research partially supported by Boeing Scientific Research Labs. Nonr-3656(18).

Certain tests of constant failure rate versus failure rate increasing on the average are noted to be unbiased when complete samples of observations are available. Unbiasedness is proved when incomplete samples of failure data are available. A similar result is obtained for monotone tests of constant versus increasing failure rate. Finally, a table of percentiles is given to facilitate application of the total time on test statistic for testing constant failure rate versus failure rate increasing on the average.

Review: This paper is the same as the report covered by R68-14139. (The same report was also published as Boeing Scientific Research Laboratories Mathematical Note No. 555, Apr. 68, and none of the papers makes reference to the other publications of the document.)

R69-14557 ASQC 824; 882

Naval Electronics Lab. Center for Command Control and Communications, San Diego, Calif.

STATISTICAL PRECISION LEVELS AND POINTWISE AVAILABILITY OF SYSTEMS AND PROCESSES

G. V. Nolde

19 Feb. 1968 45 p

(AD-671769; NELC-R-1536)

An extension of theory of availability applicable to a broad class of sojourn and coincidence probabilistic models is presented. The extension comprises derivation of formulas for pointwise availability of processes starting from the inoperative state. Asymptotic and current values are computed. A notion of statistical precision level is explored and formulas are derived for applying such levels to a large class of probabilistic models in operations research. The numerical values for levels of 94-percent and 97-percent precision are computed. The properties of these levels are investigated both in generalized manner and in application to computations of availability.

Review: The author explores rather deeply several predetermined boundary values of *Availability* and derives formulas for some of these bounds. He is dealing largely with pointwise availability, which is the probability of finding the system up at time t_2 given the state of the system at time $t_1 \angle t_2$ The usual expression for *Availability* is being extended to accommodate various initial conditions and different thresholds of performance; time interval from the initial conditions is a variable. The term *statistical precision factor* is introduced. It is a well known concept in statistics but has no generally accepted name (if any name at all). It is related to an interval around the binomial probability parameter and to the fraction of samples that will have a sample parameter near the true value. It amounts to calculating the required true parameter of a population, so that a certain fraction of given size samples will have sample parameters near a certain value. This is a straightforward, although in this case tedious (as the author points out), problem in classical statistics. While not all of the mathematics was checked in detail, it appears to be accurate; nevertheless, some of the actual definitions are much more clearly implied by the mathematical expressions than by the words used to describe them. All of the formulas and concepts assume that up/down is a sufficient description of the system. Four general cases, corresponding to two different initial states of systems and two time intervals from the initial point, are calculated. A *statistical precision level* is applied to all of them. These calculations are rather detailed and use the author's own nomenclature; thus, they are not easy to follow. Those willing to undertake the intensive effort necessary to follow the paper will find in it some worthwhile extended concepts on availability.

R69-14559 ASQC 821; 414

FINDING THE LEAST FAVORABLE A PRIORI PROBABILITY DISTRIBUTION

V. G. Repin.

Engineering Cybernetics, vol. 6, 1968 p. 52–57. 1 ref.

For the risk function r(x), which depends on a random parameter x, the least favorable probability distribution is obtained which satisfies a number of restrictions, corresponding to the available a priori information relative to x, and the value of the mean risk to a maximum is converted. The problem of the maximum of a linear functional $\int r(x)w(x)dx$ with respect to a function w(x) is solved, subject to certain restrictions. Author

Review: This work bears some relationship to that of E. T. Jaynes on the maximum entropy formulation, although the work in this paper is much more specific. It is concerned with the expected value of a loss function wherein the loss function contains a random parameter. When little is known about the random parameter, what is the most pessimistic distribution that can be assigned? The paper solves this problem for certain kinds of information known about the parameter, e.g., the value of the median is known. The formulation of a problem in this manner is potentially important to reliability because very often most of the things one would like to know are in fact largely unknown. Very little of this kind of analysis has been done by reliability engineers, but it is a topic well worth pursuing. Very few references on this topic appear in the reliability or associated literature so that one will have to look to *information theory* literature in order to get a head start and not to begin the work from scratch. This paper can be considered introductory on the topic. The problems it does solve are not sophisticated but this beginning is important.

R69-14560 ASQC 824; 844; 851

THE PRINCIPLE OF HEREDITY IN THE THEORY OF RELIABILITY.

G. D. Kartashov and A. I. Perrote.

Engineering Cybernetics, vol. 6, 1968, p. 78–83. 4 refs.

A principle is formulated for the theory of reliability, determining the influence of the manufacturing process on the characteristic of the product. The application of this principle makes it possible to solve a number of general problems from the field of accelerated testing. Author

Review: This is an interesting paper. It is somewhat philosophic in nature and attempts to provide the basis for a theory. Many ideas when first stated appear very good and seem to make a valuable contribution to knowledge. Upon closer examination, it may be found that the statements are tautologies; that is, some of the concepts therein are really defined only by the statement itself. Thus if there is to be a contribution to knowledge, the idea must be expressed differently. When put in non-tautological form, it will usually have much less impact. This appears to be true for the basic idea in this paper. Essentially what the authors need to say is the following: Suppose it is possible to write formulas for all of the operating characteristics (performances, figures of merit, etc.) of a system. Suppose further that the effects of time and environmental factors, such as voltage and temperature, all appear explicitly so that the remaining factors which may be considered to characterize the structure of the system do not depend on anything except initially-selected values, that is, these parameters will be constants of a given system. Then the calculation of any reliability expressions would be much easier, including those for accelerated testing. If all this were true, much reliability effort would be reduced to a trivial exercise since all the needed data would be known or could be derived by relatively simple experiments. This is the *principle of heredity* when reduced to its simplest terms. Whether it is even possible ever to accomplish this situation is not obvious on its face, but it may be a useful direction in which to go. Much of the so-called physics of failure (reliability physics) efforts are in this direction. There is the old recipe for unicorn stew that begins "After catching the unicorn, then . . .".

R69-14561 ASQC 824; 838

RELIABILITY OF A SYSTEM WITH RESERVES.

N. M. Akulinichev.

Engineering Cybernetics, vol. 6, 1968, p. 99–103. 2 refs.

The reliability characteristics of a system with reserves with limited restoration are determined. A system considered consists of m operating and k reserve elements (cold reserve). At most, one failed element can be replaced at any given time. The failure of the system begins when the number of faulty elements becomes at least k + 1, after which the system is disconnected. The replacement of the failed element by a reserve element takes place instantaneously. The distribution function of the failure-free operating time of the system is determined and calculations are presented. The suggested method can be extended to cases of reserves of a very general kind where there are several groups of reserve elements. Author

Review: This paper considers a particular kind of system characterized as follows: (a) There is parallel redundancy. (b) The redundant elements are not operating, and while they are not operating, their hazard rate is zero. (c) When an operational element fails, a new one is perfectly switched in with zero down time. (d) When there are no new elements left to be switched in, the system fails. (e) The distribution of system restoration times is arbitrary except that the mean restoration time is bounded and known. (f) The elements themselves have exponential failure times. Several properties of the operating time and restoration time are derived. Not all of the mathematics was checked but it appears to be correct (there is a misprint in equation 1). The results contain integrals and sums which are not tractable unless the choice of restoration time distribution is fortuitous. It is doubtful that this particular problem has been solved in the American literature since there are many ways of stating this kind of problem. The results will be useful largely to other theorists since the equations are not in a form usable by design or reliability engineers.

R69-14562 ASQC 824

A GENERAL THEORY OF FATIGUE DAMAGE ACCUMULATION.

Arthur Sorensen, Jr. (Wisconsin University, College of Applied Science and Engineering, Milwaukee, Wis.).

American Society of Mechanical Engineers, Winter Annual Meeting and Energy Systems Exposition, New York, Dec. 1–5, 1968, Paper 68-WA/Met-6. 14 p. 34 refs.

Members, $0.75; nonmembers, $1.50. (A69-16149)

Development of a general linear theory of isotropic cumulative failure. This involves a phenomenological consideration of fatigue damage accumulation under very general conditions. To accomplish this, it is necessary to extend the basic notion of cycle-dependent behavior for a harmonic stress variation to more complicated situations. The mean and alternating components of a conventional waveform are given a suitable interpretation to account for irregular stress-time variations. The state of stress also receives proper consideration to allow for independent variation of each tensor element. The entire program is motivated by a desire to achieve complete generality, and the systematic development of the analytical model is predicated upon the experimental observations and theoretical proposals of previous investigators. This provides a firm logical-empirical basis to support the proposals made in the investigation. Author (IAA)

Review: This appears to be a good piece of work (with one exception as noted below). Linear cumulative damage is used. The author extends this concept in the following three independent but combinable ways. (1) The triaxial stresses are continually changing in an arbitrary fashion (assuming zero mean load). (2) There is a constant mean load (presumably this is adapted directly from the literature). (3) A method of calculating damage due to a complicated wave form is presented. The first two extensions by the author go smoothly; the last one concerning the method of decomposing an arbitrary stress into a mean and variable stress has several rough spots. For simplicity, this last extension is originally viewed as uniaxial stress and extended to triaxial stresses by the methods mentioned earlier. For the mean stress, the author uses an exponentially-weighted average, such that stresses occurring in the far past are given negligible weight; those occurring recently are given essentially unit weight. The most serious difficulty with the author's definition of mean stress (s) can be seen by a uniaxial load which varies between +P and −P with the change occurring abruptly. Assume that the cycle time remains the same but that the fraction of the cycle time during which the load is +P is a variable f such that $0 < f < 1$. It is generally conceded that no matter what the value of this variable, the accumulated fatigue damage will be the same (say for $0.1 < f < 0.9$). Yet the author's formula will give a mean stress under these circumstances which will vary almost from +P to −P and correspondingly affect the formulas for fatigue damage. This effect is the hazard accompanying the use of any integrating form for the mean value. The concept of the mean as described by the author is well defined, but its interpretation in a lay sense is tricky. Apparently, it is suitable only under conditions wherein the load is oscillating rapidly enough that the function is averaged over a great many such oscillations and thus the effect of the most recent oscillation is negligible on any variation in that mean. It is interesting to note that the author suggests a value for this parameter on the order of one radian per day (approximately 0.04 rad/hr). Those fatigue tests which are over in the course of a few hours would use a mean load equal to the mean of the entire spectrum of loads performed throughout the life which may have been 10^4–10^6 cycles. Perhaps the old-fashioned method of decomposing a spectrum which separates it into half cycles and uses as a mean the mid-range between the two extreme points is still reasonably satisfactory. Even if it is not, the obvious conflict with experimentally observed results is not present. But, regardless of the above criticisms, the author's efforts are a valuable attempt to extend fatigue models.

R69-14568 ASQC 824
SOME PROPERTIES OF THE RELIABILITY RESOURCE.
O. M. Namicheishvili and A. N. Lavrov.
(Akademiia Nauk SSSR, Izvestia, Technicheskaia Kibernetika, Mar.–Apr. 1968, p. 112–116. In Russian.).
Engineering Cybernetics, vol. 6, 1968, p. 104–108. 3 refs.
(A68-33565)

Analysis of some characteristics of the reliability of service life determined according to the formulas of Sediakin. It is shown that the arbitrary value of the time to failure is always distributed exponentially. IAA

Review: Even though this paper appeared in a respectable Russian journal, it deals trivially with a trivial matter. The principal reference for this paper and the source of the idea used in it was covered by R68-13819 (in it, the author discovered the hazard rate and cumulative hazard). Reliability resource is the name the authors give to the cumulative hazard ($-ln$ R). The authors derive the simple result (which could have been done by simple variable change) that the cumulative probability function for the cumulative hazard is also exponential. There is little in this paper to recommend it to either beginners or experts. It is not that any of the results are wrong; they are largely just trivial.

R69-14569 ASQC 824; 844
CAUSAL APPROACH TO RELIABILITY.
R. G. Stewart (Lockheed Palo Alto Lab., Palo Alto, Calif.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 91–99. 8 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Since failures are caused, there exist relationships between the physical time and stress dependence of the failure mechanisms, the circuit or system definition of failure, and reliability figures of merit and time-to-failure distributions. The results suggest that some currently used reliability procedures are incorrect and misleading, and in need of change. For example, system failure rate can be much larger than the sum of part failure rates since system gain can for some failure modes effectively amplify failure rate as well as signal. Author

Review: This paper is largely old material previously published by the author in his Reference 4 (see R67-13215). Part of the material near the end was previously published by the author in his Reference 8 (see R68-14072). The relatively new sections are: Advantages and Disadvantages (page 91), which incorporates some of the criticisms which have been made of his earlier paper; Stress Excursions (page 94); and Mapping of Variability by Kinetics (largely on page 96). The same comments in the earlier reviews still apply to this paper. Other than the paragraphs on Advantages and Disadvantages, the additions are largely further mathematical excursions which have the same value as the earlier ones. For purposes of review, it is convenient to divide this paper into three parts: (1) the mathematical explorations concerned with expressing device behavior in terms of device parameters; (2) the introduction of the reciprocal time to failure as a variable of interest; and (3) the discussions of the inadequacy of conventional statistics. The first of these—the mathematical explorations—are interesting and apparently the mathematics has been done correctly. The question that arises in this kind of mathematics is its utility. At present, we do not know enough about the devices we use to have these new kinds of relationships do us any good. Eventually, they may, but the mathematical excursions provide little new insight into the problem. The second item, the introduction of a new variable—the inverse of time to failure—is not unreasonable. The author finds some uses for it. The biggest difficulty is that he gives it a name that is unfortunately already over-worked, namely, failure rate. This is not the only difficulty. The choice of name implies a parameter of a distribution whereas this new quantity is itself a random variable. Perhaps the name *reciprocal life* could be associated with this variable since *reciprocal life* has not been preempted by anyone else in statistics. (That name will be used henceforth in this review.) The author calculates some distributions of *reciprocal life* given a particular distribution for time-to-failure and shows some interesting properties of the distributions of *reciprocal life* and time-to-failure for the same process. It may well be that engineers and statisticians will find a use for *reciprocal life* in their descriptions of devices and populations of devices. The reader should not let the misleading inconvenient name (failure rate) blind him to the fact that the variable itself may be very useful. The third phase of the paper, the denigration of some classical statistical concepts, is without foundation. As mentioned above, the term failure-rate has several meanings in the literature already and thus can be ambiguous. The paper confounds them with others such as reciprocal of mean-time-to-failure. The hazard rate is a quite useful term when it is understood. Contrary to an easy inference from the paper, it does not *always* increase near the end of the sample life. For example, the log-Normal distribution and some Weibull distributions have a hazard rate which goes to 0 as $t \rightarrow \infty$. There is some conceptual difficulty in the paper between the sample and the population. If the *population* has a finite life, then the hazard rate must become infinite as that bound is approached. The life of a sample will always be bounded, but the hazard rate is calculated for the population. If the hazard-rate-vs-time of the population is being estimated from a sample, one can expect wide fluctuations as the survivors become small in number (especially the last one). One of the best examples of the utility of the hazard rate is mortality tables. People in their twenties have a relatively low hazard rate is mortality tables. People in their twenties have a relatively low hazard rate (about 0.1%/year); that is, they are not very likely to die in the near future; while those who have lived to age 100 have a high hazard rate (about 40%/year) and are very likely to die soon. Those people who have done well by living long are characterized by a high hazard rate near the the end of their lives, but that does not detract from their feat of having attained a ripe old age. Of course, the hazard rate is not useful for many things and to assert that because of that fact it is not useful at all is wrong and misleading. Criticism of this portion of the text is difficult because of the non sequitur character of much of the text. The denigrations are almost like saying, "You should not grow roses in your garden because concrete blocks are much better for the foundation of your house." It is a difficult statement to argue with; the reviewer can only be bewildered, shrug his shoulders, and go on to other things.

R69-14571 ASQC 824; 540; 552; 822
HAZARD PLOT ANALYSIS OF INCOMPLETE FAILURE DATA.

Wayne Nelson (General Electric Research and Development Center, Schenectady, N.Y.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium Sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, The American Society for Nondestructive Testing, and The American Society for Quality Control. New York, IEEE, Inc., 1969, p. 391–403. 15 refs.
Avail: Available Under IEEE Catalog No. 69C 8-R; $8.00.

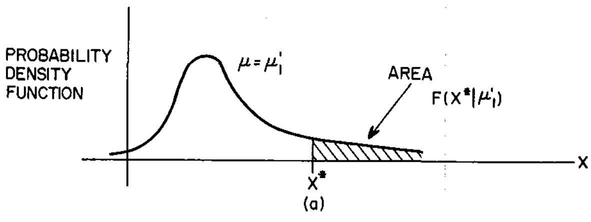
A simple graphical method is presented for obtaining reliability information from incomplete failure data consisting of times to failure for failed units and running times on unfailed units where the failure and running times are intermixed. It is typical of field data. The graphical method, called hazard plotting, is based on the instantaneous failure rate of a distribution of time to failure and, for that reason, provides direct information on the instantaneous failure rate. The hazard plotting method and some of its uses in reliability analyses of field data are presented and illustrated with examples based on real and simulated data. Theory underlying the hazard plotting method is described in an appendix. Hazard plotting papers are presented for the normal, lognormal, exponential, Weibull, and extreme value distributions. Author

Review: This paper covers the same material in approximately the same way as the paper covered by R69-14507. Some of the examples are different but the presentation is intended to accomplish the same purpose. If one has trouble following one of them, the other may give a slightly different perspective since much of the wording is not the same.

R69-14577 ASQC 824; 512; 851
RELIABILITY DEMONSTRATION TESTING CONSUMER'S RISK VS. CONFIDENCE LEVEL.
Marvin D. Genzer (Edo Corp. R/M Engineering, College Point, N.Y.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the *American Society for Nondestructive* Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 608–614. 6 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

In an open invitation for opinion and controversy from industry, the question is asked: Are confidence level and consumer's risk related in reliability demonstration tests? Three types of tests are used to illustrate the question: the fixed time test, sequential probability ratio test, and the constant confidence level test. Examples are given for each test type. In the epilogue an opinion is offered in answer to the question, and warning is made for contracts to be careful in specifying reliability. It is concluded that they should also specify whether the customer is interested in the reliability of a single piece of equipment, therefore the confidence level, or whether he is interested in the reliability of a lot of equipments based on a test of a relatively small sample, or consumer's risk. L.B.H.

Review: This paper presents some apparent paradoxes which often confront the reliability engineer who is not also a qualified statistician. As is the case with many paradoxes, they are not always easy to solve—even for the experts. There are at least two reasons for their existence: (a) phrases have been lifted from ordinary language and given very specific meanings when used in a specialized field, e.g. *confidence, independence* in statistics, *work* in physics; (b) not everyone is scrupulously careful in his use of specialized language, not only in his speech, but in the literature as well, e.g., *confidence* is 90%, instead of *confidence* is at least 90%. Basically, the author is contrasting *confidence* level and *consumer's risk*. Both are specialized statistical terms. *Confidence* level is concerned with estimating a value of a non-random unknown quantity from a set of data. *Consumer's risk* is concerned with error in testing an hypothesis (e.g., Is the following true or false? The population contains too many defectives). Thus, it is not necessary on their face that the two have any connection whatsoever; this in itself is a partial resolution of the paradoxes. But it is instructive to pursue the matters deeper than their face to see if there is some relationship —and there is. The remainder of this review is an explanation of the author's three example paradoxes. There are three introductory explanations. (1) The strict classical definition of *confidence* level is: *confidence* level is the fraction of times that an assertion about the value of a non-random unknown quantity is true. *Confidence* limit(s) is the assertion about the value of a non-random unknown quantity. For example, one could have 90% *confidence* that the true value of fraction defective of a lot of parts was less than 2%. (The 90% is a *confidence* level, the 2% is an upper *confidence* limit.) (2) A reasonable definition of *consumer's risk* is: for a given sampling plan, the *consumer's risk* is the fraction of times that lots of a given quality will be accepted. (This differs slightly from some textbook definitions in that this one is more general. But the generality will be useful later on.) (3) Exact *confidence* statements about discrete variables are difficult to make since the results of the test (test-statistics) are discrete numbers rather than continuous variables. With a discrete test-statistic and strict application of the theory, one cannot give an exact *confidence* limit and level. When one is specified exactly, only upper and lower bounds for the other (rather than an exact value) can be found. Unfortunately, this fact is ignored even in the "better" literature. The remaining discussion is limited to a continuous test-statistic, but it can be extended (tediously) to the discrete case. Presume (a) the sampling plan has a test-statistic x and a value of x, viz. x^*, such that the lot is accepted for $x < x^*$ and rejected otherwise. For example, x might be the average of four values of tensile strength, and x^* might be 30,000 psi. (b) There is a parameter μ such that $Pr\{x \quad x^* | \mu = \mu'\}$ is known for all values of μ'. (The vertical bar is read as ". . . given that . . .", Pr is read as ". . . the probability that . . ."; F is some known function.) (See Fig. 1.) F must be monotonic in μ' (for any F there is only one μ' and vice versa); otherwise life would get very complicated. If x has a Normal distribution, F will have the usual tabulated values for the right tail of the distribution and will be monotonically increasing with μ'. (c) $F(x^*| \mu')$ is an increasing function of μ'. This is for convenience, one could work out a relationship for a decreasing function.



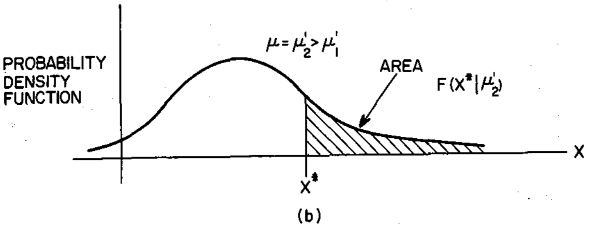


Fig. 1: Probability density curves of x, showing F(x*, μ'). (The entire curve need not be known--only the function F.)

With (a), (b), (c) in mind, one can construct the curve for Probability of Acceptance (A) of a lot vs. its value of μ'. This is is called the Operating Characteristic (OC) curve of the plan. (See Fig. 2.) Now, A is simply derived from F.

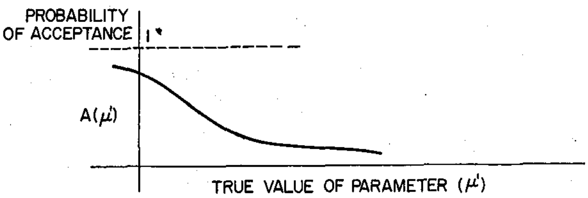


Fig. 2: OC Curve

$A(\mu') \equiv Pr\{x < x^* | \mu = \mu'\} = 1 - Pr\{x > x^* | \mu = \mu'\} = 1 - F(x^*|\mu')$. In our case, it will look like Fig. 1. The *consumer's risk* is the value of A for any value of μ'. Customarily the term is applied only when μ' is large and A consequently small. (The consumer does not count it much of a risk when μ' is so small—or so negative—that A is very close to 1). Thus the OC curve has been derived in terms of an arbitrary function. Now suppose the same sampling plan is used and we wish to make *confidence* statements. Let $x = x^*$, i.e., our test-statistic by coincidence is the critical value. What *confidence* statements can we make? To figure this out, we first make three comments: (1) The basic relationship in evaluating confidence is: $Pr\{\mu < \mu' | x = x^*\} = Pr\{x > x^* | \mu = \mu'\}$. (2) The first expression in (1) is what we mean by the *confidence* that $\mu < \mu'$; call it $C(\mu')$. (3) The second expression in (1) is just $F(x^*|\mu')$. Thus we have $C(\mu') = F(x^*|\mu')$, and from above, $A(\mu') = 1 - F(x^*|\mu')$. Obviously $C(\mu') + A(\mu') = 1$, regardless of the form of F. In words: suppose the test-statistic turns out to be the critical value. Pick any value of μ' (true mean strength) and find the *consumer's risk* (A) from the OC curve. Then the *confidence* that the true mean strength is less than μ' is 1–A. The *confidence* that it is more than μ' is A. Now if the test-statistic is different from the critical value, then the *confidence* will be different from 1–A. One must substitute the phrase ". . . is greater than . . ." or ". . . is less than . . ." in place of the ". . . is . . ." in "The *confidence* level is 1–A." Which is appropriate is not too difficult to figure out. This explains the example #1. The practice of imputing a *confidence* level interpretation to the OC curve has been extended to other plans than the type mentioned above. In particular, it has been extended to multiple sampling situations (e.g., sequential sampling). The validity of this imputation is not obvious, but no statement is made here about the imputation's being true or not. In multiple sampling, *confidence* level is a very tricky thing with which to deal. It will be best (until presented with contrary evidence) to presume that anyone using a *confidence* level in a sequential reliability test is speaking loosely and is referring obliquely to the OC curve. This finishes the discussion of example #2. When one uses single sampling statistics in a multiple sampling way, he is in trouble. It is rarely if ever a valid procedure and has led many people astray in the past, even in the published literature. The example #3 is of this type; the procedure may appear superficially to be valid, but it is very likely to be misinterpreted, even by its author. The author's epilogue, as does the main part of the article, contains some fact, some fiction, and some irrelevancies. The explanations, insofar as they exist, are given above. In short, for single sampling plans there is a known easily-demonstrable relationship between *consumer's risk* and *confidence*. For any other situation, the burden of proof is on the one who wishes to show the relationship.

R69-14582 ASQC 824; 541

National Aeronautics and Space Administration, Washington, D.C.

COMPUTERIZED ARRENIUS RELIABILITY EXTRAPOLATION TECHNIQUES

Charles R. Toye (Elec. Res. Center)

Dec. 1968 16 p refs

(Contract 125-25-04-09-10)

(NASA-TN-D-4902; N69-13368) Avail: CFSTI

Computerized mathematical techniques and algorithms useful in obtaining extrapolated component failure rates derived from the Arrhenius equation are presented. The mathematics of the Arrhenius equation is reviewed. A computer program for the calculation of an important constant in the equation is given, and a computerized extrapolation procedure is illustrated. Author

Review: As far as this paper goes, it is a very straightforward application of putting a straight line through two points. Since logarithms and reciprocals are involved in the variables, having a computer do the work is simpler than doing it by hand. It is what the program does not do that is more important than what it does do, however. The biggest difficulty is that it gives no measure of uncertainty in the extrapolated prediction. The results are generally extremely uncertain in any practical application of the Arrhenius formula to real devices (as opposed to laboratory measurements of reaction rates of very simple chemical systems). A more recent program and method of analysis which allows (but does not require) more than two points and which estimates the uncertainty in the extrapolated prediction is covered by R69-14527. Even though the author says that only two points are generally taken on the temperature curve, very few, if any, papers on reliability have ever recommended only two points. At a minimum, they recommend three and usually suggest that it is nice if you can have about five. The reason that the uncertainty is so important is that from realistic data the predicted time to failure at the use conditions can commonly have an uncertainty of a factor of 10,100, or more.

R69-14583 ASQC 824

Washington Univ., Seattle. Lab. of Statistical Research.

ON THE IMPORTANCE OF DIFFERENT COMPONENTS IN A MULTICOMPONENT SYSTEM

Z. W. Birnbaum

20 May 1968 24 p refs

(Contract Nonr-477(38))

(AD-670563; TR-54; N68-31265)

In a system whose functioning or failure depends on the functioning or failure of its components, some components may play a more important part than others. A quantitative definition of this notion of importance is proposed in the present paper for systems with coherent structures, assuming (1) that only the structure of the system is known, or (2) that also the reliabilities of all components are known. Some theoretical properties of the so defined concepts are discussed, and applications are presented to such problems as allocation of spare parts or appropriation of funds for improvement of component reliability. Author (TAB)

Review: This paper introduces an interesting notion about the relative *importance* of components in a system. Many people have probably had some feeling about this concept before but this paper appears to be the first to give this notion a quantitative measure. Some of the conclusions reached upon applying this quantitative concept are appealing. Some seem to contradict an intuition; e.g., the *importance* of every component is smallest both when n components are in series and when n components are in parallel. One might expect those elements in series to have a greater *importance* than ones in parallel. But regardless of intuition (which at best is only a guide), the concept does appear useful and can perhaps find its way into the engineering literature where designers and reliability engineers can make use of it. At present, the concept is couched in quite theoretical terms and is relatively inaccessible to engineers.

R69-14586 ASQC 824; 412; 831

Naval Postgraduate School, Monterey, Calif.

A METHOD FOR COMPUTING LOWER CONFIDENCE LIMITS ON SYSTEM RELIABILITY USING COMPONENT FAILURE DATA WITH UNEQUAL SAMPLE SIZES

Jack R. Borsting and W. Max Woods

Jun. 1968 28 p

(AD-672322; NPS-55Wo/Bg8061A; N68-34631)

A method is presented for constructing system reliability using component failure data when the sample sizes for testing on the component parts differ greatly. The procedure can be applied to weapons systems as easily as subsystems. No assumptions about failure distributions are made. The accuracy of the procedure was examined by computer simulations and in this manner the procedure has demonstrated high accuracy for cases of practical interest. Author (TAB)

Review: Finding confidence limits for the reliability of a series system when the elements have a binomial distribution is not a tractable problem. Therefore many attempts have been made to find approximate confidence limits; this paper is one of those efforts. (A preliminary paper on this topic by the same authors was covered by R67-13032. The paper covered by R69-14296, while of itself not too satisfactory, contains good references.) The procedures in the present paper seem reasonable and the results are easy to use. The reasoning in many of the steps in the derivation is not clear, but since the justification is empirical anyway, it makes little difference if one understands the authors' reasons or not. Whether this approximation would be suitable in a contractual situation is not clear but otherwise it can be used. Another paper on this topic is [1].

Reference: [1] Joseph Bram, "Confidence limits for system reliability," OEG Research Contribution No. 79, Center for Naval Analyses, Washington, D.C. 20350, Feb 68 (AD-666 650) (See review in this issue of RATR.)

R69-14587 ASQC 821

WHAT IS PROBABILITY?

Ralph A. Evans (Research Triangle Institute, Research Triangle Park, N.C.).

IEEE Transactions on Reliability, vol. R-18, Feb. 1969, p. 2.

The definition of probability theory, an integral part of reliability theory, is discussed from two distinct approaches. The opposing views are noted as (1) the relative-frequency, or objective and (2) the degree-of-belief, or subjective, definitions. The usefulness of each approach is considered. The mathematical theory of probability is found to be equally applicable in each case; but it is concluded that there is a practical difficulty in applying probability to degree-of-belief in that new information must convert former degree-of-belief to new degree-of-belief according to rigorous formulas (Bayes' theorem). L.B.H.

Review: The purpose of this one-page editorial appears to be to settle and clarify some underlying arguments between believers of Bayesian probability theory and the believers of "relative frequency" probability theory. The intentions are honorable and laudable but the result falls short of being a clear concise discussion of the pros and cons of either philosophy. The most important statement appears at the end of the editorial where the author warns those who use Bayes' theorem to be careful that they might be biased in their approach to applications. If the intention was to warn,the editorial succeeded; if it was to discuss the merits of each philosophy, it is a good beginning. Whatever the intent, theorists and others who apply probability theory should read this discussion—it is very worthwhile.

R69-14592 ASQC 821; 431

ANALYTIC JUSTIFICATION OF THE WSEIAC FORMULA.

Peter H. Fowler (TRW Systems, Redondo Beach, Calif.).

IEEE Transactions on Reliability, vol. R-18, Feb. 1969. p. 29. 4 refs

A tutorial description is given concerning the analytic validity of the Weapon System Effectiveness Industry Advisory Commttee (WSEIAC) method of system effectiveness assessment. Notes are presented to show that the method is correct within the inherent Markovian limitations. Definitions for computing the total system value are considered, and analytical examples are derived. It is concluded that the WSEIAC formula is justified for the special case and is extended to general reward systems. L.B.H.

Review: This is a very short derivation. The assumptions are stated clearly although briefly. The author is emphasizing the definition of the dependent variable (value). If you define it differently, as others have done, it is not unreasonable that you should get a different answer. The crux of the matter is: Which definition is "correct"? The difficulty in answering this question has its source in original verbal descriptions which are not precise enough. In this circumstance, one usually has to settle for (although not necessarily be satisfied with . . .) arguing that his explicit formulation is most useful, whereas the others are not. In his note the author is clearly giving a useful and correct definition (and consequent derivation). There is, of course, more to the entire WSEIAC package than this particular formula. It should not be inferred that the justification of this particular formula justifies the entire package.

R69-14593 ASQC 821; 822
GENERATING RANDOM VARIABLES HAVING A SPECIFIED FAILURE RATE FUNCTION.
Ernest M. Scheuer (RAND Corp., Santa Monica, Calif.).
IEEE Transactions on Reliability, vol. R-18, Feb. 1969, p. 30.

The relationship of failure rate function to reliability theory is discussed. It is noted that random variates need not always be drawn from the standard distributions used to describe lifetimes in simulations of reliability situations. Random variables may be generated from a distribution having any given failure rate function, since there is a distinct relation between the failure rate function and the survival probability function. Examples are presented to both standard and novel results. L.B.H.

Review: This note shows how two well-known facts can be combined to generate random variables having a specified hazard (failure) rate function. This method is not necessarily recommended for generating random variables from the standard distributions (exponential, Weibull, Normal, etc.), for which there are often more efficient techniques. A brief discussion of some of these techniques is found in *Handbook of Mathematical Functions*, NBS 55, Milton Abramowitz and Irene A. Stegun, Editors, 1967 (U. S. Government Printing Office), Chapter 26. However, the method in this note can be considered for situations where the distribution is not given directly, but implicitly through its hazard rate. Many programmers are undoubtedly already aware of the principles involved.

83 DESIGN

R69-14546 ASQC 830; 838
A SELF-HEALING CONTROL.
Bruce E. Briley (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).
Bell System Technical Journal, vol. 47, Dec. 1968, p. 2367–2378. 7 refs.
(A69-15457)

Description of an electronic computer self-repair technique which does not require system duplication. The properties demanded of control hardware to effect this end are identified and their practicality is considered. A prototype computer constructed to test the feasibility of this form of self-repair is described, and test results are discussed. Author (IAA)

Review: Terminology in the field of reliability is an interesting topic and is more important than we sometimes give it credit for; at least some of our thinking is restricted by the conceptual image of the words we think with. In this paper, the author is demonstrating yet another method for having a computer do its job when some portion of the hardware has failed. A very specific organization of the computer is necessary for the author's self-healing and he describes it well. The exactness and explicitness with which it is necessary to describe these new concepts for computer organization make the paper somewhat more difficult to study and understand—merely because one must constantly refer back to the definitions for some of the terms. The self-healing is a specific kind of self-repair which in turn is a particular kind of redundancy. The author states that self-healing is practicable; perhaps more accurately it could be stated that he has demonstrated that it can be done. Regardless of that, the author is certainly correct in characterizing it as a ". . . potentially useful variation of self-repair."

R69-14558 ASQC 831; 612
National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
AN ANNOTATED BIBLIOGRAPHY OF COMPUTER-AIDED CIRCUIT ANALYSIS AND DESIGN
Charles W. Meissner, Jr.
Washington 1968 44 p refs
(NASA-SP-7023; N68-19882) Avail: CFSTI

An annotated bibliography is presented on computer aided circuit analysis and design with emphasis on the application of computers to the analysis of electronic circuits. The bibliography presents a listing of authors and their works, and a chronology of the development of computer aided analysis. The bibliography covers the period from 1956 to 1966. B.S.D.

Review: The notations in this bibliobraphy increase its usefulness considerably. It covers the decade from 1956 to 1966 and apparently is a representative sampling of the papers rather than an attempt at a complete bibliography. For example, there appears to be only one paper on NET-1. The subject index is very meager; it contains only the most general topics. The paper will be of most value to those who are doing research in the area rather than to those who are trying to find a reference to an important computer-aided technique. This is especially true, of course, because of the cut-off date of 1966.

R69-14563 ASQC 838
MAJORITY VOTER DESIGN CONSIDERATIONS FOR A TMR COMPUTER.
Michael Ball and Fred Hardie (IBM Corp., Owego, N.Y.).
Computer Design, vol. 8, Apr. 1969, p. 100–104.

Two types of majority voters used in Triple Modular Redundancy (TMR) computer organizations, threshold sensing voting devices and logic decision voting devices, are examined. Each type was found to be workable, and the choice of using either one or the other is dependent on system requirements and trade-off decisions used in TMR computer design. Both types lend themselves to those applications which require the high reliability of a TMR computer organization destined to operate over a relatively short time period. When this time period is followed by a long term availability requirement, the switchable characteristics of the logic decision voter may be applicable, for it carries its own spares for either manual or automatic replacement of failed modules. Further studies are necessary to determine the cost effectiveness of the logic decision voter in a TMR computer organization. Reliability predictions show the realizable system improvements obtained by their use. Author

Review: This paper is the third by these authors which describes triple modular redundancy (TMR). The other two were covered by R68-14106 and R69-14490. This particular paper goes into the details of the voting and switching systems somewhat more than the others; much of the material overlaps. The discussion is good and informative. On the last page, however, it is not always explicit to what the authors are referring, especially in Figure 8: the horizontal axis there is unlabelled, it is the same as that in Figure 7; the top curve is the R_{TM} from p. 104; the middle curve is R_{TSM}; and the bottom curve is the R_{TM} from p. 103. Even though TMR is a good computer design technique for high reliability and has been successfully used (see, for example, [1] not everyone agrees that it ". . . shows the most promise." There is no discussion in this paper of how many logic steps in a module a given voter will handle (it will handle as many as you want). It is implicitly assumed that the voting circuitry has an unrealiability much less than that of the module upon which it acts. Further, it is apparently assumed that unreliability in the turnoff and error detection circuitries will not affect the reliability of the system. Regardless of the value judgments of the authors, the paper is a good description of the system and the challenges associated therewith.

Reference: [1] Ralph E. Kuehn, "Computer redundancy: Design, performance, and future," IEEE Transactions on Reliability, vol. R-18, Feb. 69, p. 3–11.

R69-14564 ASQC 838

GENERALIZED PARALLEL REDUNDANCY IN DIGITAL COMPUTERS.

Narsingh Deo (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.).

IEEE Transactions on Computers, vol. C-17, June 1968, p. 600.
5 refs.
Grant NAS 7-100.
(A68-36841)

Application of a general expression for the probability of failure of an n-fold redundant system. It is pointed out that triple modular redundancy becomes common when applications place a high premium on the reliability of the digital computer, as is the case when space computers are required to function for several years without any human intervention. As the weight, volume, and cost of electronic components decrease, 5-, 7- or 9-fold redundancies should be considered. IAA

Review: This note is a summary of part of a paper covered by R68-13743. In that review, it was pointed out that statistical independence of failures was a necessary requirement but only implicitly stated. Another implicit requirement brought out by the Comment [1] is that good/bad must be an adequate description of each element. The Comment and the Author's Reply accompanying it discuss the utility of the latter assumption. On triple redundancy, the exact formulas have been worked out wherein each element fails to either a 0 or 1 and the relative frequency is known. In the limit when this relative frequency is either 0 or 1, the answer of course must reduce to the present analysis wherein good/bad is considered a sufficient description. In the Author's Reply to the Comment, he did not show how his formula for taking into consideration failures at various levels was derived. Obviously, the answer would depend somewhat on what kind of a voter were used. If it were an analog voter, one could expect a certain kind of response; if it were a digital voter, a quite different one would undoubtedly occur. There have been few, if any, papers in the literature reporting on just how digital circuits have failed in the field and the relative frequencies with which they fail to 0's, 1's or something in between. There have however been *comments* to the effect that failing to a 0 or 1 is much more common than anything else. Furthermore, if the voter were digital, it would be forced to presume that its input was either 1 or 0. The author is correct in stating that his formula does give an upper bound on the probability of failure. Just as important as the kinds of behavior allowed in the derivation is the assumption of statistical independence of those failures. With the growth of integrated circuits, one could expect many such gates to be put near together on the same chip. If the environment is at all uncertain (and when isn't it?), then the probabilities of failures of the individual elements are no longer statistically independent. Then the probability of failure of the unit will be much greater than given by the formula in the text.

Reference: [1] Comment on "Generalized Parallel Redundancy in Digital Computers," by Paul H. Giroux and Author's Reply, IEEE Transactions on Computers, Vol. C-18, Jan. 69, p. 80.

R69-14588 ASQC 838

COMPUTER REDUNDANCY: DESIGN, PERFORMANCE, AND FAILURE.

Ralph E. Kuehn (IBM Corp., Electronic Systems Center, Owego, N.Y.)

IEEE Transactions on Reliability, vol. R-18 Feb. 1969, p. 3–11
15 refs.

The design problems, reliability prediction, field performance, and future applications of redundancy techniques to digital systems are considered. Triple Modular Redundancy (TMR) is discussed using the logic of a launch vehicle digital computer, whose self-correcting memory is also described. A Monte Carlo technique for predicting computer reliability is considered in a design engineering rather than a programmer approach. The unique means of indicating single-channel malfunctions, while continuing to mask these with respect to system operation, is introduced. Quad redundancy at the component part level is described, and the process of arriving at a quad redundancy implementation and circuit and design problems associated with it are considered. Future applications of TMR and quad redundancy in digital systems are speculated on and projected for military, space, and commercial usage. Author

Review: This paper is not as general as its title might imply but is nevertheless quite useful since it portrays two redundancy techniques actually being used by a computer manufacturer. The discussion is in general terms; for example, there is no indication of how many elements are grouped together with one voter in the triple modular redundancy. The kinds of considerations necessary before choosing a particular configuration are covered quite well. The discussion of quad redundancy is interesting in that while papers in this area were quite common several years ago, they have since disappeared from the literature. It was widely regarded as not being very practical. This paper shows that in a particular kind of situation it was useful. It should be emphasized that even though this paper describes successfully-operating computers, other manufacturers might have handled the same problem in a different way. This illustrates the fact that, especially where high reliability is concerned, the amount of engineering judgment (decision in the face of inadequate facts) is so high that it is often impossible to say that one approach is better than another for a particular system especially when one takes into account the different kinds of experience and facilities available to different manufacturers).

R69-14589 ASQC 830; 612; 844

FAULT ISOLATION IN CONVENTIONAL LINEAR SYSTEMS: A PROGRESS REPORT.

John H. Maenpaa, Carl J. Stehman, and Walter J. Stahl (Scully International Inc., Downers Grove, Ill.).

IEEE Transactions on Reliability, vol. R-18, Feb. 1969, p. 12–14.
2 refs
(Contract AF 33(615)13573.

A computer program is described which implements a previously suggested procedure for isolating faults in conventional linear systems. The technique is based on the analysis of network function responses at critically chosen test frequencies applied to the normal input-output terminals of the circuit under test. The feasibility of the diagnosis technique is discussed in terms of the experience with the computer program and some empirical studies which have been conducted. Example circuits are included which have been processed by the computer program. Problem areas related to both the basic theory of the technique and the computational limitations of implementation are defined. Solutions are proposed for some of these problems; others are merely defined for study by the circuit theorists. Author

Review: This paper is on the same topic as one by the same authors covered by R69-14504. The transistor circuit examples used in both papers are the same; the rest of the paper takes a somewhat different approach. The computer is used to prepare a fault dictionary rather than to isolate faults in an actual operating circuit. Test measurements are made at each of several frequencies and the results are compared with the usual operating behavior. If enough of these tests are made, the fault can be isolated completely. This paper points out that the computer program can get entirely out of hand if one is not careful, and shows how the authors have reduced the problem to a manageable size. The paper also goes on to show some of the other disadvantages of the method and the kinds of things that need to be done to improve it. Reliability engineers should be familiar with the methods described in this paper even though the methods are not always optimum for a given hardware problem.

R69-14590 ASQC 838

DISTRIBUTED REDUNDANCY IN TWO-LAYER THRESHOLD LOGIC NETWORKS.

John L. Youngblood (General Dynamics Corp., Ft. Worth, Tex.) and Arthur M. Breipohl (Oklahoma State University, School of Electrical Engineering, Stillwater, Okla.).

IEEE Transactions on Reliability, vol. R-18, Feb. 1969, p. 15–20. 10 refs.

A method is described which can be used to select redundant threshold logic units on the basis of system considerations rather than the duplication of existing units. This mathematical technique consists of iteratively selecting redundant threshold logic units for the first layer of a two-layer solution of simple problems, and it is shown that fewer units are required for single error correction than would be needed if existing units were duplicated. Author

Review: This paper is a publication based on a Ph.D. thesis by the senior author, and it suffers from a malady common to many such papers—obscureness of expression. This subject matter is not really very difficult, but in this paper it takes on a patina of great difficulty because of the authors' clumsy way of describing their notation. This contrasts with the great clarity with which the referenced papers describe *their* notation (and it is different notation, by the way). In addition, the examples are hardly examples, in the sense of clarifying this situation. The technique which is described is interesting and can be useful. It consists of adding redundant threshold logic units on the first level of logic so as to improve reliability in the presence of single first-level errors. Linear inequality constraints have been considered, so the method is claimed to be more valuable than others. Once the reader has made peace with the notation, the method is explained in the paper. The algorithm is useful if good results can be obtained by the use of a single rundundant threshold unit. For more than one, the authors state that "It is recognized that this is not necessarily an optimal approach; however, it has been used with limited success." The prospective user will need to be aware of this disclaimer. The Reader Aids pertaining to this article suggest that its results are useful to theoreticians, and that its purpose is to widen the state of the art. Both of these statements are true; the above comments show that it would be unattractive to a practitioner.

R69-14591 ASQC 838

RELIABILITY OF A SPECIAL CLASS OF REDUNDANT SYSTEMS.

Donald E. Anderson (Sperry Rand Corp., Univac Div., St. Paul, Minn.).

IEEE Transactions on Reliability, vol. 19, Feb. 1969, p. 21–28. 8 refs.

Equations are developed for predicting the reliability of a special class of redundant systems. Applicable systems include those which operate in a standby mode for a long period of time in anticipation of participation in a single mission. Manual repair is allowed in the standby mode but not in the mission mode. The analysis is also applicable to the single-mission case alone (no standby), where the reliability in this case is evaluated as a function of the reliability state at the start of the mission. The development employs the traditional approach using the concept of failure states and the attendant birth-and-death equations. Author

Review: This is a competent treatment of a particular kind of situation. The author is clear in his description of the system being analyzed and in the assumptions he makes (except that statistical independence of failures is implicit, not explicit). The assumptions are ones commonly made for mathematical tractability which is essential if the systems become at all complicated. The author's cautions to the user in his conclusions are worthwhile in that he brings out some eminently practical points. He especially cautions the user to be very careful of the system description when the unreliability is reduced by several orders of magnitude due to redundancy. Some elements of the system which are apparently redundant may not be so. This is also the reason why it is worthwhile explicitly stating the assumption of statistical independence of failure under the same conditions (drastic reduction of unreliability). Severe unpredictable environments can effectively eliminate redundancy.

84 METHODS OF RELIABILITY ANALYSIS

R69-14548 ASQC 844

British Aircraft Corp., Luton (England).

FATIGUE TEST RESULTS AND ANALYSIS OF 11 PISTON PROVOST WINGS TO DETERMINE THE EFFECT OF ORDER OF PROGRAMMED LOAD. FATIGUE TEST RESULTS AND ANALYSIS OF 4 PISTON PROVOST WINGS TESTED IN AN ASCENDING-DESCENDING ORDER OF LOADING

H. E. Parish
Mar. 1968 18 p refs
(Contracts KC/G/027/CB.5(a); KC/G/059/CB5(B))
(S&T-Memo-5/67; S&T-Memo-1/68; N68-30298; N68-30299)

Fatigue results of 11 wings programme-loaded in ascending order were compared with 41 wings tested in descending order. Results indicate a substantial reduction in the log mean life when testing in ascending order but negligible difference in variance. Comparison of these results with results from two other studies indicates that the magnitude of peak stress and shape of the spectrum applied, very much influences whether descending or ascending order of load gives the longer endurance. Results of fatigue tests on four wings program loaded in lo-hi-lo order are compared with similar tests performed in hi-lo and lo-hi orders reported previously. The results lie almost mid-way between the results for hi-lo and lo-hi tests. No significant difference is shown in either the variance or mean value since the results lie within the scatter of the previous tests. Author

Review: These reports describe full-scale fatigue tests on obsolete aircraft which have been retired from service. The wing structures presumably had accumulated some fatigue damage in service before being tested. The comparison of the results is based on the ordering of loads within a programmed cycle. The author compares his results with those of others, but this does not make their theoretical basis any clearer. In the low-high-low case, the results are not statistically significant, presumably because of the very small number in the sample rather than because there would actually have been no difference in the log-means if a great number had been tested. In any event, the test results are an important contribution to the body of data which is building up and which eventually can provide a basis for successful hypotheses about fatigue behavior. Fatigue, of course, is an important reliability factor not only in aircraft but in most other mechanical structures.

R69-14554 ASQC 844
PANEL DISCUSSION EXAMINES EVOLUTION OF THERMAL EVALUATION.
Jim McCarthy (ed.).
Insulation, Apr. 1968, p 36, 38–40.

The evolution of thermal evaluation is discussed, and several problems and accomplishments are noted. Large rotating apparatus, specialty transformers, D-C machines, turbine generators, and future trends in materials and systems are considered. It is concluded that (1) functional tests are more desirable than chemical classification; (2) thermal degradation is almost never the mechanism of failure in the field; (3) failure criteria, testing time, and compatibility need further work, (4) compatibility is not well understood or predicted; and (5) it is the application that is important. L.B.H.

Review: In the language of the reliability engineer, the panelists were discussing failure modes, physics of failure, and environmental effects. The difficulties involved in thermal evaluation of dielectrics for large machines are essentially those which most everyone has in trying to predict the field behavior of material by means of laboratory measurements. They are as follows: (1) The modes of failures in the laboratory are not necessarily the same as those in the field. (2) The laboratory environments do not reproduce well enough those seen in the field, especially combined environments. (3) Accelerated tests are needed to get good results inexpensively. (4) The failure modes which the tests are designed to find are not the only ones by which the equipment fails in the field. This condensation of the panel discussion is a good summary although, at least for the non-specialist, some of it is too condensed. Perhaps the most important question is that of how cumulative damage is calculated especially when not only the severity level of a damaging environment is changed but also the kind of environment is changed. For example, if a dielectric has been weakened by the application of reasonable voltages and temperatures for a long period of time, what has happened to its short-term dielectric strength, to its corona resistance, and to its mechanical strengths? The topic of the panel is yet another area wherein more interchange of ideas with reliability engineers would be helpful to both groups. An interesting point is that power engineers generally accept without question the Arrhenius behavior of dielectrics with respect to temperature whereas this relationship is often challenged by reliability engineers.

R69-14567 ASQC 844; 821
PREDICTION OF LOW-CYCLE FATIGUE LIFE OF SPECIMENS WITH FABRICATION FLAWS.
A. G. Pickett (Southwest Research Institute, San Antonio, Tex.).
(American Society of Mechanical Engineers, Petroleum Mechanical Engineering, and First Pressure Vessels and Piping Conference, Dallas, Sept. 22–26, 1968, Paper 68-PVP-15)
AME Transactions, Series B – Journal of Engineering for Industry, vol. 90, Nov. 1968 p. 620–626. 14 refs.
(A69-12997)

A modification of the notch stress procedure for fatigue-life analysis is presented. The importance of considering the mechanics of the specimen and the effects of the notch on specimen mechanics is illustrated by example. The procedure is applied to correlate the results of small-specimen tests with large weld-defect specimen tests. The significance of crack-initiation life and crack-propagation life and the dependence of these portions of total fatigue life on specimen geometry and loading are described. Author (IAA)

Review: Low-cycle fatigue is not a rare failure mechanism in aerospace hardware and many efforts are being made to understand and control it. This paper deals with the prediction of life when the part is known to contain a flaw. The discussion is good and scholarly; therefore understanding it is limited to those with previous experience in this field. The understanding requires not only practical knowledge in fatigue matters but theoretical understanding of such concepts as stress concentration factors and total plastic strain. The paper is a valuable addition to the literature on this topic and once a person is a valuable addition to the literature on this topic and once a person has gotten experience with applying this method, it can be expected to stand him in good stead.

R69-14572 ASQC 844
HOW MEANINGFUL ARE RELIABILITY PREDICTIONS?
R. E. Myers (Honeywell Inc., Aerospace Div., Minneapolis, Minn.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 412–416. 5 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

The role of reliability prediction is described and many pitfalls, which seem obvious but are usually ignored, are pointed out. The major premise is that many and practically inseparable variables impact on the actual reliability; therefore predictions are limited to somewhat gross approximations relating to measured past experience on equipments of an essentially similar nature. The similarity restriction extends to the type of procurement, the supplier's capabilities, and the in-use conditions. Author

Review: This paper is a reasonable discussion of the difficulties inherent in a reliability prediction. It is interesting to compare it with the papers by Codier and by Keene on pp. 383-390 and 404-411 in the same Proceedings. The former is convincing but not enlightening; the latter and this one are good solid discussions of the whys and why-nots of reliability prediction. (Reliability prediction is similar to accelerated testing in that they are something everyone does and will continue to do even though he cannot prove that the answers he gets thereby are always the right or best ones.) Under most conditions, one is lucky if a hazard rate prediction for reliability is within a factor of 2; more likely, it will be within a factor of 10. (Space vehicles tend to have lower hazard rates than calculated; airborne equipment tends to have higher hazard rates than calculated.) Virtually all of the author's points are excellent, but they tend to be reasons for emphasizing the uncertainty in the predictions—not for ceasing to use them. Further, he presumes that relative frequency is the only interpretation of probability, whereas degree-of-belief can also correspond to probability. One difficulty with field failure data that the author does not explore is that it may be falsified to cover an error on the part of the operator or be warped in some fashion because of the administrative system the users work under. The author suggests that failure data are self-invalidating because the same data initiate corrective action. That is only partly true: (a) the action may be to buy from another supplier—the original manufacturer's components will still be used by others, (b) the contemplated remedial action may not be worth it, (c) no one may pay much real attention to the failure reports or they may not take effective action—the world is far from perfect in this regard. But these controversial aspects of the paper do not detract from it; they only help the non-specialist put it in perspective. It is a worthwhile paper, especially for those whose faith in reliability numbers is unbounded.

R69-14573 ASQC 844

SPACECRAFT FAILURE RATES—WHERE ARE WE?

Abraham Leventhal (NASA, Goddard Space Flight Center, Greenbelt, MD.) Charles E. Bloomquist (Planning Research Corp., Los Angeles, Calif.) and Jerome A. Joseph (TRW Inc., Redondo Beach, Calif.).

In Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium Sponsored by the Institute of Electrical and Electronics Engineers, The Institute of Environmental Sciences, The American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc. 1969 p 444–452 11 refs

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

It is pointed out that the operational reliability of spacecraft equipment and component parts has undergone marked improvement, particularly in relation to the occurrence of so-called random failures. This phenomenon is documented and related to reliability program activities. The approach taken is to analyze the failure rate aspects of a particular program, Orbiting Geophysical Observatories (OGO), in detail, to examine the cost, schedule, and performance tradeoffs involved and then to place these results in context with results from more general surveys of spacecraft reliability. Discussion is made of the parts program, component and systems design review procedures, design modifications, prelaunch failure reporting, and feedback system. Based on analyses, charts for simplified preliminary reliability predictions for spacecraft subsystems, assemblies, and components are presented. Other conclusions based on the analyses are provided, including design, management, and cost implications involved. Author

Review: This is a documentary paper for those who are interested in the details of the OGO project and the kinds of failures and failure (hazard) rates which have been observed on these spacecraft. The paper is adequate for this purpose within the space limitations. References are given for more complete information. There are occasional editorial lapses such as saying ". . . the diodes and resistors were improved in reliability from 20% to 60%," with little explanation of what that means. These lapses do not in general interfere with the main purpose of the paper. Not only are component-part failure rates estimated, but the raw data are given and both assemblies and subsystems have their hazard rates estimated. In many cases, there were no failures so that the confidence range is extremely large. The term "random" failure is used with "random" in quotes. Its meaning is not entirely clear but apparently is that the cause of failure is unknown.

R69-14574 ASQC 844; 775; 851

IDEALIZED VERSUS OPERATIONAL RELIABILITY OF RF POWER TRANSISTORS AS DETERMINED BY INFRARED SCANNING TECHNIQUES.

E. B. Hakim, B. Reich, and G. Malinowski (U.S. Army Electronics Command, Electronic Components Lab., Ft. Monmouth, N.J.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc. 1969 p 543–548 5 refs

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Burn-out of power transistors is noted, and the application of infrared scanning techniques is discussed as a means of obtaining insight as to the mechanisms leading to failure. Data of experiments made on devices under pulsed dc operation are included. Results from the operational amplifiers are then compared with the pulsed data. Radio frequency operational data are presented at 30 MHz, and data of various load terminations are presented and analyzed. From these results, RF power transistors are rated to operate under nearly any load termination. Author

Review: The authors make the following very worthwhile observations: (1) Infrared scanning techniques can be extended to observe hot spot formation under RF operation. (2) The values of thermal resistance calculated from temperature measurements made at RF correlate as expected with pulsed dc measurements. (3) Present methods of specifying maximum operating levels based on some average value of thermal resistance are inadequate, largely ignoring hot spots. (4) At RF operation mismatching and amplifier detuning cause higher values of thermal resistance at fixed values of collector voltage. (5) For forward-biased second-breakdown conditions, ballasting emitter resistors are reconfirmed as effective in limiting the increase of hot spot thermal resistance with increasing collector voltage. The paper furnishes added evidence for the usefulness of infrared scanning methods as a tool for separating transistors which are prone to second breakdown from more resistant units (see R69-14055). The illustration contained in this paper is particularly impressive—two similarly rated RF transistors exhibited significantly different hot spot behavior to the infrared scanner and subsequent operation in an FM amplifier confirmed that the transistor with the less favorable hot spot thermal resistance performed more poorly in the amplifier. While the technical content of the paper is interesting and exciting, it is not communicated well. Ambiguous, unclear language is used throughout the paper. The reader must guess the meaning of too many poorly-worded sentences. When the reader knows what the authors intended to say, no major problem exists as in the following. "As late as 1959, the cause of burnout of many junction semiconductor devices was related to the phenomenon designated as second breakdown. Since that time more articles and papers have been prepared on this subject, with the possible exception of Large Scale Integration (LSI), and yet the basic mechanisms are not fully understood." However, when the reader does not know what the authors are thinking, communication slows or ceases. Two of the authors have described the infrared scan measurement in greater detail and with superior clarity in *IEEE Transactions on Electron Devices*, vol. ED-16, Feb 69, pp. 166–170.

R69-14575 ASQC 844; 433

SATURN 5 SYSTEM RELIABILITY ANALYSIS.

Richard A. Venditti and Randolph M. Sineath, Jr. (Boeing Co., Huntsville, Ala.).

In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and The American Society for Quality Control. New York, IEEE, Inc. 1969 p 567–571 6 refs

Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Systems analysis was performed to develop a detailed understanding of the behavior of the Saturn 5 launch vehicle in the prelaunch phase. The analysis consists of a large scale digital computer simulation model which analyzes and simulates the operation, checkout, and launch of the vehicle. This model accepts and analyzes system reliability data, maintainability data, and operating time constraints to determine the impact on Saturn V system availability. The failure rate methodology used involves the transition from predictive data to assessment data, which in turn combines failure rate predictions with field failure data through the use of Bayesian and classical techniques.

Review: This is a rather general paper on the methods used for reliability assessment. Two areas are treated in some detail, namely, (1) a table of hazard rate factors for environmental area vs. launch sequence phase, and (2) the Bayesian technique used for estimating the MTBF of elements. As is common with virtually all complicated situations, the constant hazard rate hypothesis is made, and descriptions of elements are restricted to good/bad. Even though the Bayesian method for MTBF estimation is given in more detail than most of the other subjects, the exact methodology is not described. Some local jargon is used for modifiers of MTBF, for example, *predicted MTBF* apparently means that number which is assigned before any operating data are received, *assessed MTBF* apparently is that which combines the originally predicted number with the operating experience. The formula given for the conversion is equivalent to the following hypotheses: exponential distribution of failure times, a prior distribution which converts the exponential prior into an exponential posterior, a prior operating time of four times the predicted MTBF, and four prior failures. The latter two assumptions presume the same degree of engineering confidence in every one of the reliability prior predictions. This method is not the only way in which the Bayesian techniques can be used, but it does have the advantage of tractability (a decided asset in complicated situations). This article will be useful largely to those who wish only an overview of the situation.

R69-14578 ASQC 844; 833

Honeywell, Inc., Minneapolis, Minn. Aerospace Div.

FLUIDIC RELIABILITY Final Report, 21 Dec. 1966–15 Jan. 1968

Harvey Ogren, Eugene Peterson, and Darroll Bengston

Jun. 1968 144 p refs

(Contract DAAJ02-67-C-0003)

(AD-674222; USAAVLABS-TR-68-36; Rept.-20810-FRI; N68-38424)

The objective of this contract was to develop quantitative information concerning the reliability and maintainability of hydraulic fluidic components and systems. This was accomplished by testing a feasibility-model hydraulic single-axis stability augmentation system (SAS) under conditions simulating actual flights of a UH-1B helicopter and, along with 15 of each type of component making up the SAS, life testing under environmental conditions of 0.5-g and 2.0-g vibration, temperature from −30F to +200F, and cycling of the component input signals. Also tested were 15 bistable amplifiers. The components were divided into environmental and nonenvironmental groups, with the environmental group divided into groups subject to 50-micron oil and 10-micron oil. This made up the 15 components, five in each of the three groups. The feasibility SAS and the components making up the SAS completed the testing with no failures. While the bistable amplifiers did not meet the failure limits, they still had enough gain to switch another like amplifier. The results of this program show that fluidic components and systems are very reliable. Since fluidic components appear to fail only in a wearout mode, more components should be tested for longer periods of time to determine their life and how they fail. Author (TAB)

Review: This report will give heart to those who wish to be assured that fluidic systems will be very reliable. The experimental results are encouraging and their interpretation is enthusiastic and optimistic. This is not to say that the conclusions do not follow from the data but rather that the data leave a great deal of room for subjective conclusions. Fluidic devices do appear to have great potential in many applications for effective performance and high reliability, but similar predictions have been made about other components in the past. For example, transistors were never supposed to wear out or have degradation failure modes, and field effect transistors were supposed to be very radiation-resistant. These predictions turned out to be completely out of line. Trade magazines have reported problems with fluidic systems and, at least on some kinds, contamination appears to be a difficulty. In electronic systems, one has to be concerned about the availability of the proper kinds of electricity; so in a fluidic system, one has to be concerned about the availability of the proper kind of fluid at the desired low level of contamination. The enthusiasts for fluidic systems will tend to minimize the difficulties and emphasize the opportunities, as is reasonable. They are the ones who will make fluidic systems an important part of our control technology. But, as with probably every new advance in history, there will be many difficulties associated with its practical wide-spread implementation. There will be poor manufacturing processes, tradeoffs, endeavors to make the units smaller and less expensive, until the probability of failure becomes important. The conclusion that the fluidic devices do not have an operating period during which the failure times have the exponential distribution, but rather have a catastrophic failure rate of zero until some wear-out time, can be said to be true of many electronic components as well, especially properly screened semiconductor devices. It does require many millions of device hours of testing to estimate these low hazard rates. Thus, the failure behavior of fluidic systems may not be as different from some electronic systems as is proposed.

R69-14584 ASQC 844
Southampton Univ. (England). Inst. of Sound and Vibration Research.
STUDIES OF FATIGUE UNDER SINUSOIDAL AND RANDOM LOADING CONDITIONS
T. R. G. Williams and C. J. Taylor
Wright-Patterson AFB, Ohio AF Mater. Lab. Jun. 1968 42 p refs
(Contract AF 61(052)-862)
(AD-675188; AFML-TR-68-187; N69-11173) Avail: CFSTI

A program involving age hardening aluminum alloy L73 was undertaken to evaluate the response of this material to sinusoidal and random loading. The random stress pattern applied was derived from a resonance system, and the distribution of stresses conformed to a Rayleigh distribution of peaks at a narrow band frequency around 90 cycles per second. A discontinuity was observed in the sinusoidal S/N curves of the material associated with a change in fracture characteristics. The random loading results showed that the discontinuity was an important factor in the formulation of fatigue prediction theory. The results of testing mild steel under sinusoidal conditions are also presented. Author (TAB)

Review: One of the more interesting aspects of this paper is the apparent discontinuity observed in the fatigue curve around 10^4 cycles for both an aluminum alloy and mild steel. This is not a discontinuity in slope but an actual discontinuity in the curve (a horizontal displacement) and is presumed due to a change in failure pattern. This kind of discontinuity is not often reported in the literature in this life range which is neither short life nor long life. In both cases, the result was obtained with conventional sinusoidal testing. In the random fatigue tests on the aluminum alloy, it is not clear that this discontinuity exists although at one load (giving a median life of around 3×10^4 cycles) the entire set of lives is longer than one would expect from the rest of the curve at loads both above and below that point. As is customary, Miner's law was found not to hold for the random loads and some phenomenological explanations are given. The paper is another bit of evidence for experimentalists and theorists in fatigue to ponder, but it will be of negligible value to design and reliability engineers in their day-to-day work.

R69-14585 ASQC 844
Naval Research Lab., Washington, D.C.
ADVANCES IN FRACTURE TOUGHNESS CHARACTERIZATION PROCEDURES AND IN QUANTITATIVE INTERPRETATIONS TO FRACTURE-SAFE DESIGN FOR STRUCTURAL STEELS
W. A. Pellini
3 Apr. 1968 88 p refs
(AD-669690; NRL-6713; N68-30114)

The state of knowledge of fracture-safe design for steels is examined in relation to the requirements for achieving practical solutions to general engineering problems. Analytical procedures evolved from fracture mechanics theory are demonstrated to provide for quantitative interpretations of engineering fracture toughness tests. It is thus possible to couple the procedural simplicity which is inherent to engineering tests with the analytical advantages of fracture mechanics theory. The coupling of these two approaches provides for practical advances in fracture-safe design which cover the totality of general engineering problems and requirements. The Charpy V test is shown to have applicability for use in the described fashion primarily in relation to the strength transition for high strength steels. The combined diagrams should serve the needs of both the materials and design fields. Author (TAB)

Review: This report is good, informative, and authoritative but is definitely not casual reading for those who need it most. In his preface, the author refers to some portions of the report as a simplified text on applied engineering fracture mechanics. This it is, but *simplified* is only in respect to the much more complicated books and articles to which one is often exposed. The average reliability or design engineer cannot learn the contents of this report by studying it himself. The report can, however, serve as an excellent text for a knowledgeable person who wishes to indoctrinate engineers who need to be acquainted with it. There are some technical terms and acronyms in it but, unfortunately, these are all a part of learning the subject. The reliability of aerospace and aerospace-related structures are vitally affected by the considerations in this report. All those engineers who are concerned with failures of mechanical things in their daily work are encouraged to find some means of effectively studying and learning the contents of this report.

85 DEMONSTRATION/MEASUREMENT

R69-14570 ASQC 851
RELIABILITY OF BEAM-LEAD SEALED-JUNCTION DEVICES.
D. S. Peck (Bell Telephone Labs., Allentown, Pa.).
In: Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Jan. 21–23, 1969. Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control. New York, IEEE, Inc., 1969, p. 191–201. 7 refs.
Avail: Available under IEEE Catalog no. 69 C 8-R; $8.00.

Reliability tests on several lots of developmental beam-lead sealed-junction transistors and bipolar integrated circuits are summarized. The test conditions include accelerated temperature and power, reverse bias at accelerated temperature, and accelerated humidity with reverse bias. Median life is described for both transistors and integrated circuits, and the failure mechanism is explained. Author

Review: This paper may be one of the most important papers of the conference. It is a performance report on beam-lead sealed-junction (BLSJ) devices fabricated by Bell Telephone Laboratories' highly-publicized beam-lead technology, including the recent sealed junction technique (silicon nitride over silicon oxide). The data given in the paper show that this combination performs well indeed in comparison with conventional planar silicon technology. In all tests the BLSJ devices equal or surpass the conventional devices in spite of the fact that they are not sealed in a hermetic enclosure as are the conventional devices. Defective BLSJ junction seals are easily screened by a short high-temperature test. The survivors are less affected by contamination and temperature and no more severely affected by humidity than conventional devices. The data are impressive; their presentation in the paper is convincing. Just how well other manufacturers can do with this technology is not discussed in this paper but is a question of vital importance to workers outside the Bell organization. It has been about four years since the introduction of beam lead, but nearly all the literature on the subject, particularly the reliability data such as contained in this paper, has been presented by Bell personnel. In a subsequent private communication the author has responded directly to this question. He cites the Dec. 9, 1968 issue of *Electronics* which, in a survey of semiconductor manufacturers, listed several manufacturers as already delivering beam-lead devices with "many others" to follow suit by mid-1969. The implication is that widespread acceptance and adoption of beam lead is well under way and the lack of non-Bell publications is not significant. Indeed the author cites the time lag between the first Bell publication of the diffused p-n junction and that of the first non-Bell publication (which was about four years) as evidence that such gaps are not unusual or unexpected. Independent inquiry confirms this opinion. Nearly all manufacturers are investigating beam lead in one stage or another. The overwhelming majority of those manufacturers canvassed were very optimistic and projected important roles for the BLSJ technology in their future product line. (This paper is abstracted in *Electronics*, vol. 42, no. 5, 3 Mar. 69, pp. 225, 227.)

R69-14581 ASQC 851; 814

THE TESTING DILEMMA–HOW MUCH IS ENOUGH?

George Flynn (ed.).

Electronic Products, vol. 11, Mar. 15, 1969, p. 32–34, 36, 38, 40, 42, 43.

Product reliability is considered from the testing standpoint, and various methods and philosophies of testing are discussed. The quantity of testing is analyzed; too much testing is considered to be money thrown away, but too little is costly in the long run. Murphy's Law is acknowledged as the source of some trouble and some solutions are suggested to overcome it. Computerized testing is examined and analyzed in respect to mechanical aspects of components. After a discussion on testing accuracy and available testing equipment, it is concluded that the reliability engineer is faced with many choices as to when to test and when not to test, with several cost and inspection factors to consider. L.B.H.

Review: This article discusses the topic of the title well enough. Unfortunately, it cannot answer the question that is posed but rather it offers questions that users should answer in order to determine how much testing they will need. The article will have its main value for those who are new to this field and consequently do not recognize all of the practical problems that testing vs. not-testing can produce. The questions raised are good ones. Most of them are directed toward electronic components, especially semiconductors. The use of the term "100% inspection" is usually ambiguous. What it often means is that any particular test is applied to 100% of the output, not that any particular component has 100% of its qualities tested, since the latter is in fact undefined. Therefore when it is stated that a particular manufacturer 100% tests his output, it is wise to find out for what particular characteristics he is testing all of his parts. Low-power semiconductor devices are usually the ones with which people are having the most trouble. Some consumers talk about fraction defectives of up to 20% in incoming material (and one has even quoted 50%), especially for commercial devices as opposed to those made to a "superspec." In summary, the article effectively says to evaluate your total costs as a function of the amount of testing and pick that amount of testing which minimizes total costs. One has to be careful in this case to include penalties for late delivery, etc., to be sure to take into account all good and bad things that can happen to the company because of the given amount of testing. Since this curve cannot be generated to any high degree of accuracy and since the minimum will probably be rather broad, much engineering judgment and guessing will go into the final answer.

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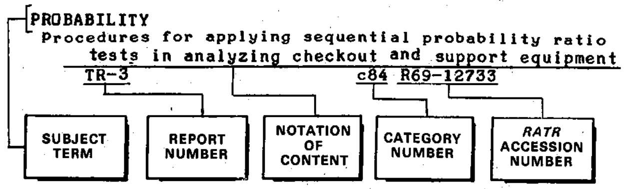

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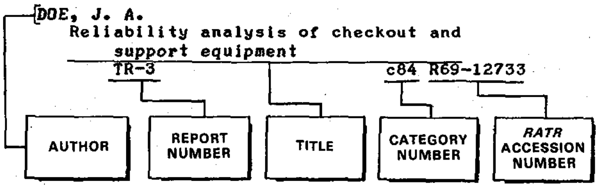

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SEPTEMBER 1969

Volume 9
Number 9

R69-14594—R69-14643

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

Label	Citation	Label
RATR ACCESSION NUMBER	R69-12733 ASQC 844; 413	ASQC CODES
	General Equipment Company, Banville, Calif.	CORPORATE SOURCE
TITLE	RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT	PUBLICATION DATE
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	*TAB* AND *STAR* ACCESSION NUMBERS
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	AVAILABILITY SOURCE

Label	Citation	Label
RATR ACCESSION NUMBER	R69-12739 ASQC 814	ASQC CODE
TITLE	SEMICONDUCTOR RELIABILITY.	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	AUTHOR AND AFFILIATION
JOURNAL REFERENCE	*Electric Journal*, vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	*IAA* ACCESSION NUMBER

Label	Citation	Label
RATR ACCESSION NUMBER	R69-12765 ASQC 773; 221; 823	ASQC CODES
TITLE	TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).	AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*	
	Available from Assoc. of Reliability Eng., New York: $1.00	AVAILABILITY AND PRICE
IAA ACCESSION NUMBER	(A69-12407)	

VOLUME 9 NUMBER 9

Reliability Abstracts and Technical Reviews

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September 1969

80 RELIABILITY

R69-14627 ASQC 802; 824; 837
Research Triangle Inst., Durham, N.C.
PRACTICAL RELIABILITY. VOLUME 1: PARAMETER VARIATIONS ANALYSIS
Washington NASA Jul. 1968 92 p refs
(Contract NASw-1448)
(NASA-CR-1126; N68-31478)

Concepts such as model, randomness, statistical ignorance, and statistical independence are explored and explained. The effects of variations of parameters can be evaluated by changing components in a physical model or by creating a conceptual/mathematical model of the system and then analyzing it. There are only a very few basic techniques for analysis of mathematical models and these are rather extensively treated. The uses to which these models and their analyses may be put are many and only a few of these are treated such as sensitivity and worst-case analyses, and calculation where extreme extrapolation is necessary. There is a brief discussion of the sources and uses of variations data both in purchased and in manufactured items. A series of appendices gives some mathematical details, thus saving constant reference to other books. Author

Review: The report is advanced as a tutorial exposition on the state-of-the-art of parameter variation analysis for the reader with at least the equivalent to a B.S. in engineering. It in fact assumes rather more, both a knowledge of at least elementary statistics and some acquaintance with reliability problems. But these minor quibbles can be set aside in view of the probable class of engineer for whom the report is written. It then proceeds to examine each of the stated topics with authority, wit and restraint. A major effort is made to (1) define rather precisely some of the terms subject to misuse and (2) set up a hierarchy of problems and solution methods. The practicing engineer is reminded that he is not alone, that aid in the form of statisticians and computer programmers is not only available but should be called in for complex analyses. And help is given in recognizing traps for the unwary engineer. The report is not without its drawbacks. The language in some critical areas is that of the mathematician rather than the engineer. The difference is sometimes subtle but none-the-less frustrating. Certain terms are used without adequate description or example for a tutorial text. For instance the exact meaning of "probability density function" and its relation to the discussion of randomness of the Normal (Gaussian) variable (page 4) leaves something to be desired. The inclusion of examples complex enough to show some of the interrelationships under discussion would have been most helpful. Some of the footnotes are trivial; e.g., vertical bars about an expression indicating absolute value, but the definition of hazard rate as the probability density function divided by the cumulative distribution function (pdf/cdf) is tucked away in footnote (c) of Appendix G. The report must be studied rather than skimmed. The material in the appendices should be considered as an integral part of the text for the novice rather than extended footnotes. The style is refreshing and many of the comments show an awareness of the viewpoint and problems of the practicing engineer. This is not a cookbook specifying step-by-step the procedures to be followed in parameter variation analysis. It can be a valuable text for the tyro trying to get his feet wet in a complex business and of perhaps even greater value to the engineer of some experience in obtaining greater perspective of his own work. Its style makes it more likely to be read than most such texts.

R69-14628 ASQC 802; 820
Research Triangle Inst., Durham, N.C.
PRACTICAL RELIABILITY. VOLUME 2: COMPUTATION
Washington NASA Aug. 1968 138 p refs
(Contract NASw-1448)
(NASA-CR-1127; N68-32760) Avail: CFSTI

This report places in perspective the role of autoadigital computations in design for reliability. It is intended for the design engineer, the systems engineer, and the test engineer as well as the reliability specialist. The degree of detail with which the various topics are treated is sufficient to enable the engineer not previously familiar with the subject to properly select and use the methods presented. The report first briefly describes the computer, how it is used, and some of the mathematical problem types that are amenable to computer solution. The orientation to reliability is then provided in a brief perspective of reliability tasks and the relation of the computer to them. Later sections treat specific reliability tasks and explore the mathematical methods related to them and how the computer is used to implement them. Some specific computer programs are identified and their uses illustrated by examples. Parameter variation analysis and reliability prediction are treated. The last section treats some recent developments in communicating with the computer which make it more suitable to engineering and reliability applications. Author

Review: The purpose of the report is to place in proper perspective the role of automatic digital computations in design and to enable the engineer, not previously familiar with the subject, to select and use the methods presented. This is a difficult objective to achieve, but those who have not forgotten everything they learned in a four-year engineering course and have not forgotten all of their mathematics and who know enough about mathematics to have the kind of problems discussed in this report will find that it fulfills its purpose. On the whole, the report is easy to read and is worthwhile. Specific comments on each chapter follow. Some of them reflect more a matter of opinion than fact and the reader will have to make his own judgments thereon. The comments tend to be negative because a report of this kind is usually presumed to be accurate unless specific discrepancies are point out.

I. INTRODUCTION

There are some good bits of philosophy in the Introduction, and it would be wise for most readers of the volume not to skip it. The word "model" is used often in the report but is not explained. It presumably refers to the abstraction of the system that a person has in his mind and to the defining equations for that abstraction plus the logical consequences of those equations.

II. FUNDAMENTALS OF DIGITAL COMPUTATION

1. This is the kind of information that one rarely admits to needing. The description of how a digital computer works is probably adequate for most people. The complete novice to digital computers may find it confusing although the examples help. There is some good philosophy in this chapter— nothing as trite as GIGO (garbage-in-garbage-out) but the reasoning behind that caricature is explained. 2. The detailed discussion of the problem types for which engineers use computer programs will be trite and repetitious for those who have kept up to date. Perhaps those whose mathematics is rusty will appreciate the detail. 3. The use of the adjective "closed form" for functions is one which misleads many people and is used in different ways. Roughly speaking, the criteria for a function's being in closed form are (a) it has a name, (b) it is well tabulated or its values are otherwise easily obtained, (c) its analytic properties are well known and well described. The Gaussian integral is an example of a function which is in closed form (except possibly for an adequate name) and which many people mistakenly think is not. In this paper, however, closed form apparently means "capable of being performed by direct addition or subtraction (this includes multiplication and division)" since these are the only operations that many digital computers directly perform. Another way of expressing the usage of "closed-form" in this text is that the function be a rational polynomial fraction. 4. There is a misprint in the second equation on page 14. 5. The discussion of least squares is perhaps good enough for the typical engineer who will use it and it has some good points. Those with overly rigorous and detailed scruples will wish that more had been said. 6. On page 19, the phrase "complex function" is used where "complicated function" is meant. 7. The later part of this chapter is devoted to uses of the computer for evaluating several kinds of processes. Perhaps a useful thing to be said is that if you do not find that part useful, skip it (never underestimate what an engineer can forget in ten years).

III. RELIABILITY AND THE COMPUTER—A PERSPECTIVE

1. The introduction to this chapter further limits the kind of material included in the report. Thus, we see that the title is descriptive in the sense that everything contained in the report is Computation but many things about Computation are not contained in the report. 2. The assertion that the actual number obtained in a reliability prediction is of little value (i.e., only relative numbers are important) is hotly contested by some people. There are those, for example, who claim accuracies of around $\pm$ 10% in estimating a failure rate, while others suggest that if one can come within a factor of 10, he is lucky. If one is designing equipment very similar to that for which the parts data are available, then the predictions can be quite close. Otherwise, they are much more uncertain. 3. One thing not mentioned is that one's first few experiences with digital computation may be traumatic—the results apparently not worth the effort and the costs completely out of hand. These experiences are not uncommon but are worthwhile going through in order to achieve the many benefits that familiarity with digital computation can give.

IV. PARAMETER VARIATION ANALYSIS

1. Worst-case analysis does not require that a function be expanded in a Taylor's series. 2. The suggestion that a subsystem need not be able to pass a worst-case analysis because it is very rare that one will get such a disconcerting arrangement of parameters is true in the strict sense. But in the practical sense of the real world of incomplete models, inadequate data, etc., one often likes the safety involved in having a subsystem pass a worst-cast analysis; it allows for unforeseen circumstances which all too frequently happen. 3. Unfortunately, the same symbol is used for both sensitivity and normalized sensitivity. It would have been less confusing to use a different symbol. The sensitivities are defined in terms of finite increments; often one uses the partial differential notation as the definition and the increments as approximations thereto. 4. As is common in statistical jargon, the word "normal" refers to the Gaussian distribution. It is not readily distinguishable by engineers from other uses of the word "normal;" e.g., perpendicular, usual. 5. It is not clear from the text that the propagation of variance formulas are strictly true only when the equation is linear or is adequately approximated by a linear function. In the linear case the mean of the function is the function of the means and the variance of the function is the weighted sum of the variances and covariances of the several variables. 6. Equation 4–10 is in error. The subscripts $\bar{x}$ should not themselves be subscripted but should be plain since the function is evaluated at the mean value of all the components of the $\bar{x}$, not just the one indicated. The nomenclature for that equation should be accordingly modified and the sentence immediately following should also be modified. Many of the paragraphs in this section are either wrong or not clear. For example, for the covariance term, it is said that ". . . simulates the true situation in which correlation between two input parameters can either increase or decrease the total performance variability." The term does not simulate anything. It is in fact the way things happen granted the model is accurate. In the next paragraph and elsewhere in this chapter, it is asserted that the propagation of variance method assumes all input parameter distributions are Normal. It is not necessary that any of them be Normal for the equations to hold. Linearity of the performance equation is all that is necessary. 7. Another bit of jargon not explained are the terms correlation and correlation coefficients. When writing for engineers, it is helpful to use the term *linear correlation*, since it more specifically describes the actual calculation and since the word correlation is used by engineers to describe any kind of relationship, even nonlinear ones. 8. The method for calculating the variance on page 36 is given in words. This is harder to understand than a formula. The discussion of convolution, especially the second half, is not clear, perhaps

again because it is given in words rather than a formula. 9. The statement is made that a discrete probability density function is simply a normalized histogram. This is an over-simplification and does not distinguish between the sample characteristics and the population characteristics. Often, one of the big problems is what happens out in the tails and a normalized histogram obtained from a small sample will not give that information accurately. A uniform distribution will very often be more pessimistic in the tails than the actual distribution (as mentioned in the text) but the reader should be cautioned that it need not be, especially for populations which are left over after other selections have been made from them. 10. The bibliographic technique is poor in many places. A librarian would be hard put to find many of the references. Some of them do not even have dates. 11. The word correlation sometimes appears to be used in its specialized statistical sense meaning linear correlation and at other times, in its lay sense which would be equivalent to statistical dependence. It is not always clear which is which nor is it clear in the PVA analysis that merely giving the coefficient of linear correlation is not necessarily sufficient to describe the relationships between two variables even if they are both Normal. A covariance matrix is a complete description for Normal variables only when they have a jointly Normal distribution. Thus, the program given in the text has limitations which are not stated explicitly enough. 12. The engineer should consult a professional statistician before attempting anything other than a very simple statistical analysis of his systems.

V. PART APPLICATION ANALYSIS
This is an extremely short chapter, less than one page. The reader is referred to Volume V, ". . . Part Applications Analyses in Some Detail." It is not obvious where in Volume V these analyses are explained. It would have been interesting as well as informative to have listed more details of some of the special-purpose programs, especially for non-electronic systems.

VI. FAILURE MODE AND EFFECTS ANALYSIS
As the text says, about the only way that computers help here is in tabulating and bookkeeping.

VII. RELIABILITY PREDICTION
The statement "One of the simplest roles of computers in reliability prediction is to use such an equation for estimating system probabilities. . . ," is too simple. This can be a very complicated, tedious computer programming situation especially for large aerospace systems where there are many degrees of mission success and many logical paths through the network.

VIII. TESTING
This chapter is complicated; an engineer will have to know pretty much what he wants to do in order to have this chapter tell him how to do it on a computer.

IX. TRENDS IN DIGITAL COMPUTATION
1. The difficulty not mentioned about problem-oriented languages is that the engineer may not be aware of the assumptions made in the program. That is, he may not know what model has been assumed for the behaviors of the elements of the system. This situation is an expansion of an engineer's not knowing what the letters in a formula really stand for and under what conditions the formula is applicable. 2. The seeming preference for time-sharing computers as opposed to the individual computer for on-line computation could change depending on the economics of hardware. 3. Future developments in computers seem limited only by the imagination and people's ability to pay for them. This latter point is neglected. There is considerable doubt in some circles as to whether many of the super input-output devices are economically feasible now and when they will become so.

X. APPENDICES
These programs apparently do not have checking features on the input data to be sure that they are in the proper ranges; so the system is not as foolproof as it might be. The reproductions of the programs are reasonably legible. Individual characters which are illegible can probably be deciphered without too much trouble from the balance of the statement. All in all, the report is practical and can help an engineer learn about digital computers and learn how to talk to programmers. It will not make a programmer (or numerical analyst) out of him. In a private communication the author has indicated that the computer programs listed in Appendices B and C have been revised. A potential user of these programs should contact Mr. J. R. Batts, Programmer, Statistics Research Division, Research Triangle Institute, for the most recent version of the program(s) desired.

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Research Triangle Inst., Durham, N.C.
PRACTICAL RELIABILITY. VOLUME 3: TESTING
Washington NASA Aug. 1968 298 p refs
(Contract NASw-1448)
(NASA-CR-1128; N68-32779) Avail: CFSTI

Testing is discussed from an engineering viewpoint. The subject is structured in terms of basic test types, basic problem types amenable to treatment by the basic test types, and applications of testing in hardware programs. The emphasis is on basic principles and practical problems in implementing them. Generally, the discussion emphasizes testing for reliability rather than reliability testing in the formal sense. Part I is devoted to concepts, definitions and general procedures. In particular, a section on test classifications considers the many ways of viewing tests and some of the prevalent confusion in terminology is resolved. Parts II and III collectively treat the basic test and problem types. The manner of separating these discussions into the two parts serves to highlight an important consideration in testing which is often overlooked, viz., whether or not aging is important. Part IV contains discussions on several subjects including nondestructive testing, environmental testing, and accelerated testing which are common to several or all of the basic test types. Part V surveys the major applications of testing in hardware programs and draws special attention to applications associated with reliability. An Apppendix contains discussions of the mathematical topics pertinent to testing.
Author

Review: This, the third in a series on "Practical Reliability," addresses itself well to the typical design engineer, and thus meets its objective stated in the "Foreword." It is written in an unencumbered form, in easily understood, down-to-earth language. In many respects this could be considered a handbook of testing, for in its 210 pages it covers basic test conditions, classification, planning (which enumerates various approaches) it goes into considerable depth on both non-aging and aging tests, and covers a variety of miscellaneous topics. In the latter, specific nondestructive tests are considered, including optical, radiography, thermal methods, liquid penetrants, magnetics, and ultrasonics. Programming for and analytical tools to appraise accelerated testing are also covered. In Part V, hardware program applications, feasibility, development, qualification, acceptance, in-process, special tests, and post-acceptance tests are each considered. There is also a section on reliability testing and screening. Finally, the appendix, consisting of 77 pages, provides mathematical and statistical techniques to aid in planning for test data and, subsequently, interpreting results. Each of these are tied in with the main body of the report. Of particular interest, the report provides an abundance of references, thus offering the reader a convenient index to the best that is available in key subject areas. It is doubtful that such a complete index is available elsewhere. In addition to providing the reader with the basic subject information within each area, the report challenges the reader, or perhaps cautions him against making typical test blunders. The only criticism of any note is that the report does not specifically address itself to the economics of testing. Since assessment or proof testing is such a vital part of today's design effort, the report is recommended as required reading for all design engineers, and a copy should be found in the library of all test laboratories.

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Research Triangle Inst., Durham, N.C.
PRACTICAL RELIABILITY. VOLUME 4: PREDICTION
C. A. Krohn et al Washington NASA Aug. 1968 168 p refs
(Contract NASw-1448)
(NASA-CR-1129; N68-31979) Avail: CFSTI

The features and techniques of reliability prediction are identified and brought together in this report. Part I is largely qualitative discussion concerned with introduction and perspective. Contents include discussion and opinions on the role of reliability prediction, on perspective features, e.g. program phase and hardware level, on the relation to other analyses, and on the problems. Part II is concerned with reliability measures or definitions concerning single items, including data sources. Part III is devoted to the reliability prediction techniques which are suitable for general use and to classical reliability models. This material is scattered throughout the references; the treatment here mainly identifies approaches and relates them, with reliance on the references. Included for multi-term models are logic, lifetime, environment and bound-crossing topics. The remaining Part IV is concerned with concepts related to the detailed treatment of failure modes without independence assumptions. This is food-for-thought material from the results of research on reliability prediction techniques. This material in Part IV, in general, is not suited for widespread application. The Appendix presents a ready reference on some basic probability laws and on various probability distributions. Author

Review: This report accomplishes its objectives of bringing together scattered material, presenting some material which is not in textbooks or handbooks, and identifying several points which have a tendency to be missed. In keeping with the fact that it is addressed to engineers, it deals with reliability prediction in the narrow sense, and does not include some of the more esoteric concepts which have appeared recently in the literature. It contains a lot of good practical advice for those who are concerned with reliability prediction; there is little, if any, bad advice. These two considerations are very important, and the fact that some of the more complex expressions for reliability and maintainability are not included is not really a detriment in any practical sense. The following are specific comments on the individual sections of the report. The philosophy expressed in Section 1 is good. In the discussion of accuracy of prediction, it is suggested that at best, one can be within a factor of 2 on hazard rate but no limits are given for the worst that one may do by using the rough-and-ready prediction techniques in, say, MIL Handbook 217. In Section 2 the word "independence" is used, as is common in statistics, to imply statistical independence. This can be different from *physical* independence. The emphasis in this section on subjective factors is good; no matter how much arithmetic and mathematics may be used, at some point or other in the analysis it must become quite subjective. In this section, the word "stress" is used in at least two different ways: (1) as it is used in mechanics, and (2) as it is often used in electronics. These are two quite different uses. The discussion of people in Section 3 is quite good. Near the end it is stated that probability and statistics have had a somewhat unsuccessful history of application in reliability, as compared to the history of successful application in such fields as agriculture, communications, economics, and information theory. The major reason cited for this is that many of the people who have been involved in reliability prediction have just been weak in the theory and practical applications of probability and statistics. Not denying this, it seems pertinent to add that other sources of difficulty are that (1) when reliabilities are high and samples are small, one rarely runs across an event of interest; and (2) when one does run across an event of interest, trying to apply cause and effect physical reasoning can be very difficult. The difficulties in getting good reliability data are well stated. These difficulties are not specific to the reliability field, but apply to the problem of getting any kind of good field data. The discussion of reliability measures in Section 4 is generally suitable for its intended purpose. The authors could have mentioned that the listing of states must be exhaustive and mutually exclusive if the formulas which they give are to apply. There is a particularly good note on page 21 which distinguishes the exponential failure law from randomness. This clarifies a misconception which is quite common in the reliability literature. The discussion of the bathtub curve is also quite good. The figure on page 25 which shows the difference between the hazard rate curve and the probability density curve (sometimes also referred to as a failure rate) is instructive. Many people have drawn these curves incorrectly. Section 4.4 on environment brings out some good points. Section 4.5 on Poisson processes seems a little more wordy than necessary, but it may be instructive for some people. The balance of Section 4 is on repairable items. It is very helpful to those who are trying to distinguish between various ways in which the exponential distribution might arise. Section 5 deals with the analysis of failures of the drift or degradation type, under the heading "Bound-crossing." This choice of terminology is not the best, since the principal users of the document are to be engineers. Also, "bound-crossing" has been the topic of some rather sophisticated mathematical-statistical research, but that is not really the topic considered in this section. Under distribution types in Section 5.1.3, the examples are not limiting, although it would be easy to read them that way. For example, one could take from the text the impression that the condition "positive and negative deviations of the same magnitude are equally likely" implies a Normal distribution, whereas in fact this condition implies simply a symmetrical distribution, of which the Normal is a good example but is certainly not the only example. At the end of Section 5.2, there is perhaps not enough emphasis on the difficulty of knowing the shape of a distribution far out in the tails, especially when one is attempting to fit the data with one of the more tractable distributions. In dealing with the stress-strength model (Section 5.3), there is often a lot of difficulty in trying to get the tail of the distribution for the strength margin. The introduction of a safety margin is a useful thing to do, although no reasonable values of safety margin are mentioned in the report. Approximately the last half of Section 5 needs to be followed very closely in order to understand what is being done. One gets the impression that the discussion is more complicated than is really necessary. Section 6 contains some information and advice on obtaining reliability index values for single items. Some additional points which could be mentioned in this connection are the following. The RADC Reliability Analysis Central has had severe budgetary curtailment, and therefore will be a somewhat limited source of reliability data. Also, it should be emphasized that even under the best of circumstances it is difficult to know what kind of face to put on reliability numbers for components or parts unless you were there when they were taken, or you personally know the man in charge and are convinced that he is competent. Similarly, there tends to be a wide disparity between what a manufacturer thinks his product will do and what a consumer will think that same product will do, even under circumstances where no dishonesty is involved. If field data are used as sources it must be remembered that in addition to a failure report being a description of what happened it is also in some cases used by the receiver as a basis of value judgment on the competence of the person making the report. Therefore there is a tendency to blame failures on the hardware even in cases in which they should be blamed on the human element. As an overall comment on Part II (Sections 4, 5, 6), it consists largely of the conventional elementary textbook approach, although some of the philosophy is very good. Some topics might well have received more emphasis; for example, the Weibull distribution for semiconductors, the various kinds of distributions asserted for metals in ultimate tensile strength; and there is virtually nothing on the subject of metal fatigue. Part III (Sections 7, 8, and 9) deals with approaches for developing reliability prediction equations for system reliability as functions of item reliabilities. These are conventional and classical approaches, which are suitable for practical applications. The presentation seems a little wordy in places, but this is not unreasonable in view of the tutorial purpose of the report. In Section 7 the author is careful to point out those places in which the assumption of statistical independence is necessary, rather than just presuming it all the way through. This feature will be helpful to the beginner. It would also have been helpful if the authors had distinguished between a simple equality and an identity (definition). Section 7.4 is a good discussion of cut and tie sets. In this section it is presumed that it is not difficult to get the cut and tie sets, whereas in a very complicated situation it may be quite difficult. In Section 7.5 the fact that E_i stands for the environment in the *ith* phase is not made explicit. Apart from these relatively minor points, Section 7 is quite good and brings out important points in techniques. The practical nature of doing some of the things is well handled. The assumption of statistical independence is emphasized, especially where redundancy is concerned, and important factors which may negate the assumption are brought out. All of this can be a help to the practicing engineer who wants to apply these techniques. The following are minor comments in connection with Section 8. In Section 8.1 it could have been noted that one can use average hazard rate over the mission time and, as long as the mission time stays fixed, these average hazard rates can be treated in many ways as if the behavior were exponential. There is a minor error in Equation 8-3 in that T_m should be raised to the *nth* power. The parallel configuration does not treat the most general case where k must operate out of n items. In Section 8.2, it is not made clear in the definition that the hazard rates of standby items are presumed to be zero while in the standby condition. This is very important, especially for high reliability missions. It can also be pointed out that standby redundancy is equivalent to some kinds of maintenance. Furthermore, all of the equations presume exponential behavior. On page 86 the criterion for failure is given as "If the rated stress is exceeded by S_0/s then system is assumed to fail." It is not clear whether this means "the rated stress on any one item causes the item to fail" or "the system fails when the average stress is greater than that," or perhaps something else. Also, it is not clear whether the reference is to the actual stress on the system or to some exceedance over an initial stress. The notation is a little confusing since S_0 is the load on the whole system whereas S_r is the rated stress for one element. While one can get the answers to these questions by working backwards from the equations, he should be able to interpret the equations from the word statements. In the discussion of prediction approaches for stress-strength problems (Section 9.2.1), it is assumed that the stresses and strength are each one-dimensional, whereas in practice they are often multi-component numbers. The formula on page 100 presumes statistical independence between stresses and strengths. However, it appears not inconceivable that some *measures* of stress are not independent of the *measure* of strength of the item. An impact test for impact strengths might be of this variety. Apart from these minor points, Section 9 is quite good and will be useful to engineers with an appropriate statistical background. This statistical background is essential since by its very nature this subject matter involves statistics and probability. Part IV (Sections 10 through 13) is intended to provide insight somewhat beyond the current conventional practices. From the standpoint of the practicing engineer for whom the report is intended, it does this quite well. Section 10 is a good discussion of catastrophic and degradation failures. Section 11 consists of a detailed example which will have to be followed in detail by those who wish to get the complete message from it. Section 12 on general model development is rather tedious to follow in places, but perhaps this is made necessary by the nature of the subject. Section 13 is a useful recapitulation of the major points made in Part IV. The five appendices are intended as a ready reference on some basic probability laws and on various probability distributions, and serve this purpose quite well. In the discussion of the central limit theorem in Appendix A.1 it could have been pointed out that the condition of approximate Normality is not really a single criterion, but it depends on how far out in the tail you want the distribution to be Normal. The further one goes out into the tails the more likely is the composite distribution to be not Normal. In the example on page 160, apparently all of the events are statistically independent, but this is stated at the *end* rather than at the beginning.

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(Contract NASw-1448)
(NASA-CR-1130; N68-31980) Avail: CFSTI

Parts reliability and associated problems are discussed. This includes those functions—selections, specification, verification, review processes, and data sources—which are involved in a successful parts program. Some of the costs associated with these functions are discussed and an attempt is made to define an ideal data bank. Author

Review: This, the fifth in a series of "Practical Reliability" reports, treats the subject of parts in layman's or near-layman's terms. It is organized well and in effect defines a parts function one might find in his own plant. It is divided into five sections, viz., Parts Selection, Specification, Verification, Review Process, and Parts Data Sources. Each section is treated in functional terms. Examples of typical situations are given, lending support to each section with some reference to MIL and other helpful sources of information. Perhaps the most beneficial information given by the report is the set of bibliographies upon which the report was based. The typical design engineer with but a few years of seasoning experience will find this report a rather lengthy re-statement of what he (or some satellite group within engineering) should be doing—given enough money and time. It might be considered required reading for the fledgling engineer but only to emphasize the detail required to make truly knowledgeable parts choices. The *Standardization* sub-section of the *Parts Selection* section gives no consideration to benefits derived from standardization in terms of reduced inventory cost and penalties of obsolescence (without standardization). In this and in other areas, the report has ignored the potential benefits of a parts program to manufacturing. The reader is thus cautioned to consider parts selection and control also in terms of its benefits to production—the real objective of any design undertaking. The report primarily addresses itself to engineering which is its greatest weakness aside from being too general to be of substantial practical value.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14599 ASQC 812
THE NEED TO TEACH RELIABILITY.
R. C. Winton.
Electronics and Power, Jan. 1969, p. 8–10. 1 ref.

Emphasis is placed on the need to teach reliability adequately in engineer and technician-engineer courses. A case is made for including in such courses the basic concepts of reliability, taught at a mainly nonmathematical level, and the ideas of operability and maintainability. Also included would be (1) definitions of reliability, and the relationship of probability to reliability; (2) reliability requirements for cost, specifications, design and production, installation and use, maintenance and repair; (3) system requirements in relation to specific component requirements; (4) ergonomic considerations, or the consideration of man in relation to work; and (5) the significance of failure reporting. L.B.H.

Review: Even though the title of this article refers to the teaching of reliability, it is a good qualitative summary of many aspects of reliability and associated fields. As such, it is a good introduction for managers and others who need a non-technical discussion. With regard to the teaching itself, there are at least two points of view. One is that reliability should be taught as an integral part of other courses (e.g., rotating machinery and electronic circuits), so that it does not seem to be a separate activity in itself. The other is that the discipline is so specialized that one needs distinct courses in it. Perhaps the biggest difficulty with either approach (or even an approach which combines both methods) is finding the time in any given curriculum to add the material. Usually, if something goes in, something else must come out. In most college courses, the instruction is not hardware-oriented but rather deals with some fairly simple-minded mathematical models which can be used to analyze roughly a great many situations. Reliability is essentially a hardware problem and unless hardware is being taught, it is difficult also to teach reliability, except in a very nebulous way. However, it is the author's point that technicians and engineers need to be taught some basic concepts of reliability—and he is right. This is not to say that the proponents of reliability education should not push for its inclusion in various curricula, nor that unless the job can be done superbly well it is not worth doing at all, but rather to point out the difficulties involved.

R69-14604 ASQC 815
RESISTORS VS. CAPACITORS—LET'S STANDARDIZE THE MILITARY ESTABLISHED RELIABILITY PROGRAMS.
Lowell Savage (Erie Technological Products, Inc., Quality Assurance and Reliability, Erie, Pa.).
Evaluation Engineering, vol. 8, Mar./Apr. 1969, p. 28–29.

Certain non-standardizations that exist between the resistor and capacitor programs of the military services are pointed out. It is noted that: (1) a higher cost structure exists for capacitors because of inequities in the specifications; (2) a longer delivery cycle exists for capacitors than for resistors because of these same inequities; and (3) it is questionable whether, in fact, lot reliability of resistors is assured before shipment, as is expected of all established reliability components. Further standardization inconsistencies are examined and improvements are recommended for specifications, testing, delivery cycles, and lot acceptance requirements. L.B.H.

Review: The author presents some important criticisms of the MIL Specs on Established Reliability resistors and capacitors. It is not intended to be a balanced discussion; that is, whatever rationale (if any) there was for creating the Specs as they were in the first place is not presented. The author, if allowed more space, could perhaps have said why he felt that resistor and capacitor specifications should be more alike. While they have "being electronic components" in common, they are quite different components. They are subject to different kinds of failure modes, so that a priori one could as well assert that the test programs should be different as assert that they should be the same. This is not to say that there are not reasons why these components should be treated the same; it is just that the author has not had the space to show why. This kind of criticism of the MIL Standards is very helpful, at least insofar as it falls into the hands of those who create new and revised ones.

R69-14606 ASQC 813; 835
SHP SHAPES UP.
Richard W. Kowaliw (Challenger Research, Inc., Rockville, Md.).
The Electronic Engineer, vol. 28, Apr. 1969, p. 71–75.

The Navy's Standard Hardware Program (SHP) for military electronic system reliability is described as a means of lowering costs and easing maintenance. Its goal is to develop a family of functional electronic plug-in modules which serve as the basis for complex electronic systems. Such a standardization program is said to provide considerable cost savings due to improved logistics, design direction, common documentation, testing standardization, smaller maintenance costs, decreased design time, and increased reliability. The basic SHP module configuration is described in some detail. A quality assurance program is discussed with emphasis on the three qualification phases of design qualification, production qualification, and acceptance testing. Standard and special modules are differentiated, and lists of vendors and of hardware using SHP modules are provided. L.B.H.

Review: This is an enthusiastic description of a good program. There are disadvantages to such a modular commonality program, but the discussion of them is given more in terms of psychological reactions than in terms of hardware difficulties. It can cause psychological problems with designers if nothing else and usually requires some design tradeoffs. Naturally, it is the Navy's point of view and one shared by a great many others that such tradeoffs are in fact beneficial: increased reliability, better logistic support, and lower costs are much better than the minor increases in performance, decreases in weight, etc. that could be obtained otherwise. The packaging is obviously somewhat limited by the state of the art. Suppose a particular function once uses a double-thickness-can and technology further advances so that a single-thickness-can might be used. But a new piece of gear cannot be designed using the single thickness one. If that happened, old spares on hand of the double thickness type could not be used. Obviously, the connectors must have a great deal of commonality, and improvements in geometry of connectors are then disallowed—one cannot go around using different kinds of connectors on functionally alike modules. Generally speaking, those involved in the reliability effort or life-cycle costing procedures are in favor of this kind of commonality because of what they consider to be the overall benefits of the plan. One will have to look elsewhere than this paper if he wishes to find a good detailed discussion of the disadvantages and required tradeoffs.

R69-14633 ASQC 816

FORMAL VENDOR RATING SYSTEMS LEAVE ME COLD.

Rollie Griep (Motorola Semiconductor Products, Inc., Phoenix, Ariz.).

Electro-Procurement, Nov. 1968, p. 44, 45

Formal vendor rating systems for the electronics industry are considered unnecessary; for a buyer's judgment is able to transform qualitative data into a meaningful rating system. Usual rating systems are dependent upon formulas or equations that do not allow for the subjective analysis of subtle buyer, supplier, or industrial considerations. It is concluded that vendor performance should be measured against himself and his prior performance, and not in relation to some arbitrary norm. L.B.H.

Review: The author of this short article appears to be quite negative about vendor rating systems and to condemn *all* such systems without qualification. Although this reviewer sympathizes with some of the points made in the article, it is difficult to accept the overall condemnation. The author refers to the "buyer" as a skilled professional individual. Unfortunately this is not true in all cases and the buyer may be "sold" by a skilled or glib salesman. This reviewer acknowledges the skill of some buyers but is unable to attest to the expertise of *all* buyers. The author's statement "How an equation can have a common denominator for all these (diverse suppliers) is beyond my comprehension" is acceptable in context, or otherwise if we assume that only *one* equation or model is used for diverse suppliers. This assumption cannot be tested for validity since the article does not elaborate on it. The article states that the electronics industry emphasizes ideas and concepts rather than production lines and hardware, and is thus "the most volatile industry in history". This philosophy may apply to the author's portion of the electronics business, but it is not totally satisfactory when other elements of the electronics industry are taken into consideration. The author's feeling that many qualitative attributes are not considered in vendor rating systems probably holds true for the systems with which he is familiar. But not *all* systems ignore these very important attributes describing the supplier. This article is very worthwhile reading for those who are concerned with vendor rating systems, as it does provide a philosophy to which many, but not all, procurement executives subscribe. Therefore specialists in reliability and quality control who are trying to "sell" a vendor rating system will be able to prepare satisfactory counter-arguments or provide substantiating facts to convince the skeptic that the proposed system does in fact take the qualitative attributes into account.

R69-14635 ASQC 817; 823; 844

HI-REL PERFORMANCE WITH MIL SPEC PARTS.

Dale Vander Linden (Honeywell, Inc., Ordnance Div., Hopkins, Minn.).

Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 1–14. Avail: $8.00.

High reliability which was achieved with Mil Spec parts on a weapon system production contract is discussed. An equation is derived whereby Reliability (R) = Reliability of Design (R_D) $\times$ Reliability of Fabrication (R_F) $\times$ Reliability of Components (R_C). Tasks found to be important contributors to the success of the program were found to be (1) supplier reliability, (2) pre-failure analysis, and (3) confidence testing. Within these major areas, further factors are considered: reliability surveys, special processing requirements, failure analysis and correction, vendor control, reliability training and motivation, reliability awareness, and in-house dissemination of failure information. Successful results of the procedures are noted. L.B.H.

Review: It is interesting to look at this paper from the point of view of "how to manufacture a product when you get a lot of junk from your suppliers." This is a much more blunt (and perhaps unfair) characterization of the situation than the author gives, but such caricatures are often helpful in bringing salient points into view. The procedures mentioned by the author are reasonable and were apparently effective. (He neglected to explain how he solved one of his *horrible example* problems.) Screening (inspecting/testing each and every part) is becoming more popular for high-reliability equipment, even for commercial uses. This is caused by the incoming fraction-defectives being so high that the manufacturer has little choice if he wishes to put out equipment that will work. The tradeoff of extensive screening performed by the author on Mil Spec parts vs. high reliability parts is largely one of economics. His claim that he gets Hi-Rel attributes at a much lower cost than that of Hi-Rel parts would seem to presage something for the future Hi-Rel parts. Those who are faced with similar problems and have not thought of this approach would do well to get what ideas they can from the paper; albeit, some of the comments and terms are very general and non-specific.

R69-14636 ASQC 817; 831; 838

REDUNDANCY, FAILURE DETECTION CAPABILITY AND SYSTEMS RELIABILITY-A TRADE-OFF.

Irwin Nathan (Xerox Corp., Webster, N.Y.)

Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 15–21. 4 refs.

Avail: $8.00.

Some realistic models of the reliability for maintained systems are presented. Some of the basic conceptual ground work is laid for a realistic appraisal of system reliability constrained by imperfect failure detection capability. A suitable methodology is developed and applied to a maintained system. The system reliability is then optimized within the constraints of (1) test thoroughness, (2) imperfect failure detection circuitry, (3) time-to-repair, (4) failure identification time, (5) weight, and (6) cost. The optimization technique is based upon the use of La Grange multipliers. Author

Review: The general ideas in this paper are good (and are rarely emphasized in the literature); viz., (a) detection and switching circuitry are often imperfect, (b) these imperfections ought to be considered in a reliability analysis, and (c) it is possible to make tradeoffs on the various parts. The details of Section 2 (review of author's earlier work) are difficult to understand because they must be followed very closely and because one must have the previous work in hand (author's Reference 1). The details in Reference 1 are hard to verify because (a) the word description of the events is not clear, (b) the actual events appear to be complements of the listed events, (c) some of the multiple events appear to be impossible; e.g., the state 1,3,4 appears to require that (i) there be no failure, (ii) the detector shows that there is a failure, (iii) the detector is not 'showing a failure when there is none', and (d) in the differential equations it is not clear why event 6 cannot change into event not-6 in the success equations. In Section 2 it is not clear whether failure indication is a part of Detection or Switching. Furthermore, P[A,S] is defined to be reliability and is later used to represent the original algebraic expression rather than reliability. The first example of Section 2 does not make sense since there appears to be Switching but no redundancy. If Switching is interpreted as Indication, instead, one can make sense of it. In the expression on p. 17, the approximate hazard rate is for unreliable detection and switching (the paper states that it is for reliable ones); also it is for short times only. Fortunately, one can get the good message from the paper without detailed attention to the examples. One should not presume that those examples demonstrate a particular conclusion without recreating anc reanalyzing the model carefully. The lack of clarity mentioned above is such that it may well be possible for the definitions, etc. to be restated in such a way that the equations (with the redefined parameters) portray correct relationships.

R69-14640 ASQC 813

DEVELOPMENT OF DOUGLAS COMMERCIAL AIRCRAFT RELIABILITY PROGRAMS.

D. L. Gilles (McDonnell Douglas Corp., Long Beach, Calif.). *Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968.* Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 59–77.

Avail: $8.00

Consideration is given to a hardware-oriented reliability program of a major aircraft company. Necessitated by the advent of the DC-9, the program stressed major simplification of systems; a priority for design decisions based on the effect of equipment failure on aircraft utilization; component selection and improvement based on extensive historical operating data from airline experience; and optimum redundancy arrangements arrived at through reliability logic diagrams and probability calculations. Further expansion of formal reliability design techniques and program controls has been implemented on the DC-10, including firm reliability guarantees on subsystems and components. Author

Review: This is a good paper. It is non-technical and thus suitable for managers and others who do not wish to be concerned about the details. The emphasis is on engineering for commercial reliability rather than producing statistical numbers; although those who are involved in carrying out the details of this program are undoubtedly vitally concerned with mathematical models and statistics. The approach of having a supplier guarantee a mean-time-between-unscheduled-removals, rather than telling him how to arrange his program, is appealing. This, of course, presumes that suppliers have enough sophistication to be able to do this with reasonable assurance. While stress is laid on having to avoid the lengthy evolutionary approach in making a particular piece of equipment reliable, the reliability program itself has been evolutionary in nature, so that the suppliers have had a chance to grow up with the program. An interesting emphasis in this reliability program is a pre-design review, conducted by the chief designer, for each subsystem so that everyone knows beforehand what the requirements for the job are and what kind of conflicting advice to ignore. Obviously to effect this kind of program requires many trained and knowledgeable people. Presumably this program is easily paying for itself.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14594 ASQC 824

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

CONCERNING THE RELIABILITY OF INFORMATION FROM NETWORKS OF REMOTE SYSTEMS HAVING DISPERSED UNITS

B. O. Kasimov 25 Jan. 1968 20 p Transl. into ENGLISH from Vychislitelnyi Tsentr., Tr. (Erevan), no. 3, 1965 p 33–47 (AD-671875); FTD-MT-24-389-67; N68-32378)

An information network is described having n + 1 dispersed units, any one of which may be the dispatcher, and containing an arbitrary number of reserve channels. The solution is carried out in two stages: (1) the choice of a measure of reliability for which two variant methods are given; (2) the choice of the dispatcher point in order to maximize the reliability of transmission from the point of view of connecting points of the network with the dispatcher. A graphical example is used throughout as an illustration. TAB

Review: The problem considered is one wherein many units are connected with a central unit which acts as a dispatcher. Presumably, three measures for reliability of a system are given and then the choice is made as to which of the units should be designated the central or dispatching one in order to maximize the reliability (which one?) of the system. Unfortunately, this is a machine translation and many of the terms are not clear in themselves. Other important terms appear in quotation marks which indicates that the word has some other meaning than the one ordinarily implied and thus renders the sentence virtually incomprehensible. As it is, about the only value that can be gotten from the paper is some insight into the nature of a problem that is worth formulating precisely and then solving.

R69-14596 ASQC 824

AMPLIFIER RELIABILITY TAKING PARAMETER SPREAD INTO ACCOUNT.

Yu. S. Rasshchepliaev and V. N. Fandienko. (*Electrosviaz'*, vol. 22, Feb. 1968, p. 1–9.)
Telecommunications and Radio Engineering, Part 1—Telecommunications, vol. 22, Feb. 1968, p. 1–7. 6 refs Translation.
(A68-44529)

Description of a method for estimating the reliability of amplifier circuits having local and general negative-feedback coupling and an arbitrary number of individual stages. The proposed method accounts for sudden failures and changes in the parameters of both the amplifier-network elements and the feedback-network elements. Specific cases consisting of a multistage amplifier without feedback, with local negative feedback, and with general negative feedback are considered. Equations are derived for the gain probability of transistorized amplifiers, and two examples illustrating the calculation of this probability are solved numerically. IAA

Review: This paper treats a straightforward problem in a simple, not unusual way. The expression for gain of several stages of an amplifier is written down; failure is considered to be either catastrophic or drift. The two are asserted to be statistically independent but this need not be done since drift failure is really conditional on no catastrophic failures having occurred. Since the general problem is completely intractable, the usual standard assumptions of Normality and small variations are made; the latter allows linearization via a Taylor series expansion about the mean values. The mean and variance are calculated. An estimate is made of the error involved in linearization. The gains of adjacent stages are said to be correlated but the correlation is not obviously indicated. Not all of the mathematics was checked since it is very tedious. The fact that it is probably accurate may be irrelevant since it would probably be easier to derive the formulas from scratch under these simple conditions than to check the authors' work. It should be noted that the formulas for the mean and variance are true regardless of Normality, assuming that the linearization is justified. This article is a good translation from a competent journal which may lend some stature to the paper. Two other papers on this topic by the first author were covered by R67-13276 and R68-14056. The former is reference 4 in the present paper.

R69-14598 ASQC 824; 844; 851

ON INTERSECTING FATIGUE CURVES.

I. V. Kudryavtsev, A. D. Chudnovskii, and L. A. Sosnovskii. (*Zavodskaya Laboratoriya*, vol. 34, Apr. 1968, p. 459–465.)
Industrial Laboratory, vol. 34, Apr. 1968, p. 553–559. 24 refs. Translation.

Investigation analyzes the way in which information regarding the comparative strength of test objects obtained from fatigue tests depends on the number of cycles on which the comparison is based. The establishment of such a relationship acquires special significance in connection with the so-called low-cyclic (or repeated static) tests, in which the base (the number of cycles employed in the tests) is sometimes limited, not out of a desire to stimulate the true working conditions, but in order to reduce the number of experiments and the time required for the tests. Experimental data relating to the effect of the mechanical properties, structural shapes, and technological and other factors on the behavior of materials subjected to alternating loads as a function of the number of cycles is considered. Author

Review: This translation deals with an important topic in accelerated testing. Specimens from two different groups, say A and B, may show that A is better than B at high severity levels of testing. Further experiments at low severity levels may show the reverse—that B is better than A. A complete test at all severity levels would show that the life curves cross at some point. The author discusses this phenomenon, in particular, for fatigue curves and discusses in good detail the many different kinds of treatments and situations under which it can occur. It is a good paper for those who have blithely assumed that they can run all of their fatigue comparisons at high loads. Those who are already familiar with the crossing of fatigue curves for different specimens will probably give the paper a casual reading at best. There are other difficulties with accelerated tests which are not mentioned here, such as changes in failure mode.

R69-14600 ASQC 824; 822

System Development Corp., Santa Monica, Calif.

A NEW METHOD OF ESTIMATING THE WEIBULL SHAPE PARAMETER

V. K. Murthy Wright-Patterson AFB, Ohio. ARL Apr. 1968 28 p refs
(Contract F33615-67-C-1865)
(AD-674063; ARL-68-0076; TM-80038; N68-38214) Avail: CFSTI

The method of random hazard functions is applied to the case of the Weibull distribution and the following results are obtained: It is well known that, in the case of a Weibull distribution with two parameters alpha and beta, there is no way of estimating and testing for the shape parameter beta without knowledge of the scale parameter alpha using the usual methods based on maximum likelihood. The method of random hazard functions is now used to obtain a consistent and asymptotically normal class of estimates for beta independent of any specification whatsoever on alpha. This result enables one to test for the randomness of the underlying failure phenomena under the Weibull set up. An illustrative example is given. Author (TAB)

Review: The Weibull distribution is an important one in reliability, and this paper is directed toward a new method of estimating the shape parameter. The emphasis is on reliability applications although of course the method has a wider use. Not all of the mathematics was checked, but the method appears quite proper. (In Equations 20 and 21 the value of R_N for the longest time appears to be 0 from the definition. Therefore, $Z_N(T_{max})$ is at best undefined.) The calculation of the statistic involves a semi-arbitrary constant and a window function. The influence of extreme choices of these on the estimate is not mentioned in the paper, nor is any idea given of how many data points must be available in order to get the asymptotic properties. This paper, like many others, is written in a form for the theorist. If it is to be used by reliability engineers, it must be presented in a form which they can readily use and understand. It would also help if there were some examples, perhaps with simulated Weibull data showing how this new estimator is better than others.

R69-14602 ASQC 824; 822

New York Univ., N.Y. Dept. of Industrial Engineering and Operations Research.

A COMPOUND WEIBULL DISTRIBUTION

Satya D. Dubey Jun. 1968 11 p refs
(AD-672662; NAVSO-P-1278)

From the fact that the scale parameter of the Weibull distribution has a gamma distribution, one may conclude that the compound Weibull distribution may describe many types of data better than the Weibull distribution. Author

Review: Trying to find suitable reliability distributions is a favorite pastime of reliability theorists. The Weibull distribution itself is used more often in the mechanical field where wear-out is predominant and sometimes in the electronics field where the hazard rate is decreasing. In this paper, the author has compounded two probability distributions and has picked them in such a fashion that the analysis is tractable. The results are appealing to theoreticians since they give alternate derivations for other distributions which are shown to be special cases of the present one. The hazard rate for this compound distribution is decreasing always for large enough times. Therefore this distribution is not suitable for wear-out problems (assuming that wear-out, by definition, is the condition of increasing hazard rate as time $\rightarrow \infty$). At shorter times, the behavior can be increasing or decreasing depending on values of the parameters. For reliability engineers other than theoretically inclined ones, the paper will have marginal interest. Their difficulties are usually concerned with not having enough data to show which distribution to use, rather than being unable to find a distribution which will fit some available extensive data.

R69-14607 ASQC 824

Boeing Scientific Research Labs., Seattle, Wash. Mathematics Research Lab.

ESTIMATION FOR A FAMILY OF LIFE DISTRIBUTIONS WITH APPLICATIONS TO FATIGUE

Sam C. Saunders (Washington Univ., Seattle) and Z. W. Birnbaum (Washington Univ., Seattle). Mar. 1968 32 p *Its* Math. Note 561

(AD-671968; DI-82-0724; N68-33391)

The estimation problem is studied for a new two-parameter family of life length distributions which has been previously derived from a model of fatigue crack growth. Maximum likelihood estimates of both parameters are obtained and iterative computing procedures are given and examined. A simple estimate of the median life is exhibited, shown to be consistent and then compared, favorably, with the maximum likelihood estimate. More importantly the asymptotic distribution of this estimate is shown to be within the same class of distributions as the observations themselves. This model, and these estimation procedures, are tried by fitting this distribution to several extensive sets of fatigue data and then some comparisons of practical significance are made. Author (TAB)

Review: In a previous paper (see R68-14149 and R69-14407), the authors derived a new family of life distributions which might be applicable to fatigue since it was based on a physical model having to do with the fatigue process. Briefly, that paper asserted that the distribution of times to failure is such that $\sqrt{t} - 1/\sqrt{t}$ (along with scale factors) has a Gaussian distribution. The derivation in this paper of methods of estimating the parameters of that distribution is a valuable addition to the first paper. This distribution is used to fit some actual fatigue data, although no tests for goodness-of-fit are given nor is the fit of this new distribution compared with that of some others such as the Weibull or log Normal. The authors assert that the fit is adequate, a most qualitative value judgment. In a private communication the first author has stated that he has a low opinion of tests for goodness-of-fit and that the fit was as good as any for this kind of distribution. He shares this opinion of goodness-of-fit tests with a great many other people. What is usually important, and this presumably is what he means by *adequate,* is that the fit be good enough for engineering purposes. It is obvious from the data points and curve that they do not match, but the mismatch is less severe than in some other trial fits to data points. One may wish to try out this distribution in fields other than fatigue; for example, in dielectric breakdown. Before the function can become of widespread use, its tables and properties will have to be distributed more ubiquitously. (In a private communication the first author has indicated that these are scheduled for the October 1969 issue of the Journal of Applied Probability).

R69-14608 ASQC 824

Washington Univ., Seattle. Lab. of Statistical Research.

ESTIMATION FOR A FAMILY OF LIFE DISTRIBUTIONS WITH APPLICATIONS TO FATIGUE

Z. W. Birnbaum and Sam C. Saunders (Boeing Sci. Res. Labs.) 28 May 1968 33 p refs

(Contract Nonr-477(38))

(AD-670565; TR-56; N68-31821)

The estimation problem is studied for a new two-parameter family of life length distributions which has been previously derived from a model of fatigue crack growth. Maximum likelihood estimates of both parameters are obtained and iterative computing procedures are given and examined. A simple estimate of the median life is exhibited, shown to be consistent and then compared, favorably, with the maximum likelihood estimate. More importantly, the asymptotic distribution of this estimate is shown to be within the same class of distributions as the observations themselves. This model and these estimation procedures are tried by fitting this distribution to several extensive sets of fatigue data and then some comparisons of practical significance are made. Author (TAB)

Review: This paper is a verbatim copy of Boeing Scientific Research Laboratories Document D1-82-0724 (AD-671 968) and is reviewed under that number. Neither document gives any reference to the fact that the same paper is published under another report number.

R69-14609 ASQC 824; 822

Rocketdyne, Canoga Park, Calif.

RESULTS ON STATISTICAL ESTIMATION AND HYPOTHESIS TESTING WITH APPLICATION TO THE WEIBULL AND EXTREME-VALUE DISTRIBUTIONS

Nancy R. Mann Wright-Patterson AFB, Ohio ARL Apr. 1968 77 p refs

(Contract AF 33(615)-2818)

(AD-672979; ARL-68-0068; N68-37644)

Statistical estimation and hypothesis testing results are presented in four parts. The first includes a discussion of exact three-order-statistic confidence bounds on reliable life for a Weibull model with progressive censoring; the second, a test for the hypothesis that two extreme-value scale parameters are equal. The final two sections deal with tables of (1) expected values, variances, and covariances of order statistics from the first asymptotic distribution of smallest (extreme values), for sample sizes 1 through 25, and (2) for obtaining exact lower confidence bounds on reliable life under Weibull assumptions. Author

Review: This report consists of four separate papers all having to do with the Weibull distribution and reliability. The first of these has been published in the *Journal of the American Statistical Association,* vol. 64, Mar. 69, p. 306–315 (see review in this issue of RATR). As mentioned in that review, the work is an interesting and important contribution to a non-widespread problem. Part II uses two order-statistics instead of the three in Part I, and can be a useful test where one wishes to check for the constancy of the shape parameter. Also in common with the first part, the solution requires numerical evaluation. Most reliability engineers will require some assistance in learning how to use these tables and being sure of their exact meanings. The equation analyzed per se is not the Weibull distribution but can be transformed to the two-parameter Weibull distribution by a simple change of variables. Part III involves the calculation of statistical tables for the use of theoreticians in their analyses. They are of no practical value to reliability engineers in their daily work. This is not to say that the Tables are not worthwhile, but merely to point them out to design and reliability engineers for whom the tables will be useful. Part IV deals with setting a lower confidence limit on a tolerance bound for the lifetimes at a given reliability. This is again a rather specialized problem (it is related to [1]). It is very similar to Part I except that the censoring occurs only once and at the end of the test.

Reference: [1] N. R. Mann and S. C. Saunders, "On Evaluation of Warranty Assurance When Life has a Weibull Distribution," Boeing Scientific Research Laboratories Document D1-82-0771, Oct 68.

R69-14610 ASQC 824; 822

EXACT THREE-ORDER-STATISTIC CONFIDENCE BOUNDS ON RELIABLE LIFE FOR A WEIBULL MODEL WITH PROGRESSIVE CENSORING.

Nancy R. Mann. (Rocketdyne, Canoga Park, Calif.).

Journal of the American Statistical Association, vol. 64, Mar. 1969, 305–315. 11 refs.

(Contract AF 33(615)-2818)

A progressive-censoring model arises from a life test of a sample of items in which one or more of the survivors may be removed from the test at the time of any failure. Such a model is often more realistic for actual failure data which must be analyzed by a statistician than one in which all survivors are assumed to be removed from test simultaneously. The situation is considered in which the underlying failure-time distribution for the population sampled is the two-parameter Weibull distribution. The reliable life for the population is defined to be the $100(1-R)$ percent point of the failure-time distribution, where R is a specified population survival proportion, or reliability. An exact confidence bound on reliable life based on three observed ordered failure times is derived for this progressive-censoring model. The criterion used for selecting the order numbers of the three failure times upon which the bound is based depends upon computed values of the power function of the test associated with the bound. A table from which lower bounds can be obtained is given for R equal to .95, confidence level .90, sample size equal to 2, 3, . . . , 6, and all possible censorings. Author

Review: This paper extends the properties of the Weibull distribution. It is essentially the same as Part I of Aerospace Reserach Laboratories Report ARL 68-0068 which is reviewed in this issue of RATR. The Weibull distribution is often used in reliability estimation (especially where it is presumed by the manufacturer to give results better for him than the exponential would). The mathematics was not checked in detail but appears to be competent. The results themselves will probably need interpretation to most reliability engineers. Thus competent statistical help should be requested by them before trying to apply the tables in this paper. The problem is a rather specialized one, but nevertheless one for which the results are useful.

R69-14611 ASQC 824; 413; 551

ON THE KOLMOGOROV-SMIRNOV TEST FOR THE EXPONENTIAL DISTRIBUTION WITH MEAN UNKNOWN.

Hubert W. Lilliefors (George Washington University, Washington, D.C.)

Journal of the American Statistical Association, vol. 64, Mar. 1969, p. 387–389, 6 refs.

The standard tables used for the Kolmogorov-Smirnov test are valid when testing whether a set of observations are from a completely specified continuous distribution. If one or more parameters must be estimated from the sample then the tables are no longer valid. A table is given for use with the Kolmogorov-Smirnov statistic for testing whether a set of observations is from an exponential population when the mean is not specified but must be estimated from the sample. The table is obtained from a Monte Carlo calculation. Author

Review: The table presented in this note enables the testing of a set of observations for exponentiality by means of the Kolmogorov-Smirnov statistic when the population mean must be estimated from the sample. Like the usual Kolmogorov-Smirnov test, this special test can be used with sample sizes which are too small for use with the chi-square test. Since testing for exponentiality is often of concern to the reliability analyst, he will find this paper of practical value. The presentation is concise, but adequate for the reader with good background in the fundamentals of statistics. Of course the method tests for *statistically significant* departures from the hypothesized exponentiality. Whether the departures have *engineering* significance is another matter.

R69-14613 ASQC 824; 431; 838

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

A COMPARATIVE ANALYSIS OF REDUNDANCY TO INCREASE THE RELIABILITY OF INFORMATION SYSTEMS

G. P. Beznosov et al 4 Apr. 1968 15 p refs Transl. into ENGLISH from Akad. Nauk. Tr. Sibirskoye Otd. Inst. Avtom. i Elektr. (USSR)

(AD-679506; FTD-HT-23-146-68; N69-17495) Avail: CFSTI

Various methods of using redundancy for enhancing reliability of information systems are analyzed and compared. The mean time between failures is adopted as a single criterion of system reliability. Assumptions are system operation and failures permit describing the system by a simple uniform Markov chain with a finite number of states. The system states are determined by possible combinations of faulty and sound elements. TAB

Review: The author wishes to compare various kinds of redundancy and he uses as the figure of merit *mean time to first failure.* While this is not necessarily the best figure of merit, it has the advantage of being one often used. Its main disadvantage is that often such systems are used for times that are short (compared to a characteristic failure time of one unit) and thus the early hazard rate is of more importance. The equations for parallel redundancy, both standby and active, are derived using Markov chains. There is no indication of how the equations for majority logic and threshold logic were obtained. Using numerical examples, the author claims that the effectiveness of each kind of redundancy is in the following order from best to worst: standby, active, threshold logic, and majority voting. These assume perfect switching where switching is necessary. Since there are no details of the calculations for the latter two, it is difficult to evaluate the worth of the paper. Those design and reliability engineers who are seriously concerned with this problem will wish to make their own calculations on specific circuitry using the figure of merit most appropriate to their own particular needs. (On page 1, the phrase should read "exponential law," not "experimential law.")

R69-14624 ASQC 821; 423; 612; 838

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

A COMPUTER PROGRAM FOR REVERSION OF THE CUMULATIVE BINOMIAL PROBABILITY DISTRIBUTION

Darl D. Bien Washington May 1968 13 p refs

(Contract 120-33-05-02-22)

(NASA-TM-X-1592; N68-24141) Avail: CFSTI

A technique for reversion of the cumulative binomial probability distribution and an efficient and rapid computer program using the technique are presented. Reversion of the binomial series is useful in calculating the element success probability in a specified parallel system with redundancy which will yield the specified system success probability (reliability). The program is not limited to reliability problems but can also be used in a variety of scientific and engineering problems involving the reversion of the binomial series. Author

Review: The purpose of this paper is to show how element success probability can be calculated for a parallel system with redundancy. This involves solving the cumulative binomial sum to find the parameter of the binomial distribution. Rather than listing tables for it, a computer program in FORTRAN IV is shown. The reproduction of the program from the computer print-out is quite good, certainly as good as most any of the reproductions ever are, and a programmer should have no difficulty interpreting it. The running time on the 7094 is apparently on the order of a second to make one calculation. This paper will be of value to those reliability engineers who are involved in this kind of calculation and they will undoubtedly find it valuable to add this as a subroutine to their present computer libraries.

R69-14625 ASQC 823

ON A GENERALIZED SAVAGE STATISTIC WITH APPLICATIONS TO LIFE TESTING.

A. P. Basu (University of Wisconsin, Madison).

Annals of Mathematical Statistics, vol. 39, 1968, p 1591–1604. 16 refs

Research supported by the Wisconsin Alumni Research Foundation.

The Savage statistic is defined as the asymptotically locally most powerful rank test under the Lehmann alternative which include, as special cases, the exponential and the Weibull distribution models used in life testing. From this viewpoint, the generalized Savage statistic is studied, based on only the first r ordered observations $r \leq N$. A definition of $S_r^{(N)}$, the generalized Savage statistic, is provided, and the exact and asymptotic distribution is given. A curtailed form of $S_r^{(N)}$, suitable for life testing problems, is discussed, and the $S_r^{(N)}$ test is compared with other life tests on the basis of their curtailed forms. A k-sample extension of the statistic is considered, and tables are included to facilitate its use. Author

Review: This is a good paper and the results are of practical importance to reliability engineers and to the statisticians who advise them. The mathematics was not checked in detail but it appears to be quite competent. The possibility of shortened tests with essentially the same discriminating ability is noteworthy. Reliability engineers who are conducting comparison tests should be especially aware of this possibility since it allows for appreciably less expensive and less time-consuming tests. The paper requires too much statistical sophistication for most reliability engineers. However, it should be feasible to put it in appropriate form and publish it where these reliability engineers are more likely to see it.

R69-14634 ASQC 820; 410; 551

California Univ., Berkeley. Operations Research Center.

SOME RECENT DEVELOPMENTS IN RELIABILITY THEORY

Richard E. Barlow

Jul. 1968 24 p refs

(Contract Nonr-3656(18); Grant NSF GK-1684)

(AD-675034; ORC-68-19; N69-12306) Avail: CFSTI

This is a survey of problems and recent developments in some selected areas of nonparametric reliability theory. The paper is divided into three parts: Models for Life Distributions, Tests of Hypotheses, and Estimation Procedures. Author (TAB)

Review: This report gives a very useful overview of recent work in the mathematical and statistical theory of reliability. The reader does need a basic knowledge of mathematical statistics, but for such a reader the exposition is quite clear and precise. There is an extensive bibliography (thirty references).

R69-14638 ASQC 824; 431

EVALUATION OF RELIABILITY AND AVAILABILITY MEASURES FOR LARGE, COMPLEX SYSTEMS.

G. Grippo (MITRE Corp., Bedford, Mass.).

Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 33–49. 12 refs

Avail: $8.00

Simplified methods are presented for evaluating the common measures of reliability and availability for large, complex systems. The approach enables the system analyst to introduce system operation or maintenance constraints (such as switching times, limited maintenance crews, etc.) without adding appreciably to the complexity of the solution. The underlying mathematical model is based upon a Markov process. Since each measure is derived using the same basic approach, algorithms are easily devised for obtaining computer-aided solutions. These algorithms are included, and are used to obtain transient and steady-state solutions to both reliability and availability problems. Also included are methods for deriving mean up time and mean down time for maintained systems and mission readiness reliability. Author

Review: The author shows a not-well-known method for integrating the differential equations that can result from a Markov process. This is done by considering the system not to be continuous in time but to exist only at discrete times. The author implies, however, that the method is good for transition probabilities that vary with time, whereas it is not. Processes, which if they were happening only by themselves would be Poisson, are the only kinds that can be considered. Since this method is not widely mentioned in the reliability literature, those reliability and design engineers who need this kind of information would be well advised to be familiar with the contents of this paper.

R69-14642 ASQC 824; 831

THE STATE VARIABLE APPROACH TO SYSTEM EFFECTIVENESS.

N. I. Heenan.

Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 91–98 refs. Contract F19628-68-C-0365

Avail: $8.00.

The concept of super states is used to reduce the general nxn transition rate matrix operator to tridiagonal form. This permits generalized vector expressions to be developed for mean time between failure, mean up time, and mean down time. These general expressions permit the complete solution to be obtained for a certain family of initial excitations of the various states. System effectiveness is interpreted as the output vector of the equations of state and is then given, except for a feed-through term, as the product of a capability matrix C and the steady state solution X. It is pointed out that X may be the fixed point probability vector or it may be the steady state solution to the driven system. Author

Review: This is a mathematical paper. It is not entirely clear how much generality is being allowed in the system state equations in order for the final answers to be true. Three of the references which present justification for the steps are yet to be published and are the author's own work. Consequently, the mathematics was not checked, but it appears to be competent per se. The paper will be of value largely to theoreticians since it involves the form in which results are expressed rather than the results themselves. Presumably, the system being finally considered is that in Section 4; viz., a redundant system with transitions possible only to adjacent states. The processes are apparently Markov ones, and the probability matrix is a constant. (The author describes a 2×2 tridiagonal matrix. It is difficult to see how a 2×2 matrix can be anything other than tridiagonal.) In a private communication the author has stated that under steady-state conditions (provided all states can be classified as good/bad), it is always possible to reduce the matrix to a 2×2.

83 DESIGN

R69-14603 ASQC 838

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

CALCULATING THE INFLUENCE OF REDISTRIBUTION OF LOADS WHEN EVALUATING THE RELIABILITY OF CIRCUITS WITH PARALLEL REDUNDANCY

A. M. Margulis 25 Apr. 1968 15 p refs Transl. into ENGLISH from Avtomat. Vychisl. Tekh. (Riga), no. 12, 1966, p 161–168 (AD-679539; FTD-MT-24-104-68; N69-18023) Avail: CFSTI

The paper discusses the problem of evaluating probability of failure-free work for the time T of a circuit of parallel redundancy, consisting of N elements which are joined in the series-parallel or paralleled-serial modes. Considered are: (a) the possibility of the output parameter of the circuit exceeding the limits if tolerance as a result of failure of $m(m < N)$ elements; (b) the influence of redistribution of loads on the failure rate of elements. Author (TAB)

Review: This short Russian translation deals with an important problem: (a) There are several identical components in a redundant configuration. (b) They may fail by opens or shorts. (c) They have exponential behavior. (d) The hazard rate is a function of the number of redundant components. (e) Failure is said to occur not at an opening or shorting of the redundant system but when the parameter value exceeds some tolerance limits. In reading this report, it will help to have an earlier paper by the same author covered by R69-14434 since some of the notation is explained there. As is typical of some of these translations, the typography and translation are both difficult to read so that some understanding of the problem and its solution is essential in order to get anything from the article; one has to fill in a few gaps himself. Nevertheless, the paper does treat a useful problem and, while all the mathematics was not checked, it appears to be competent.

84 METHODS OF RELIABILITY ANALYSIS

R69-14595 ASQC 844

FATIGUE RESISTANCE DURING COMPLEX STRESS-VARIATION CYCLES (REVIEW).

M. Ya. Filatov. (*Zavodskaya Laboratoriya*, vol. 34, Mar. 1968, p. 331–336.)

Industrial Laboratory, vol. 34, 1968, p. 397–402. 22 refs. Translation.

Comparison is made of previously published articles concerning the influence of the stress-variation pattern on material fatigue characteristics. Substantial differences in the cycle patterns reproduced are noted, along with the types of stressed states, the properties of the materials, the volume of the specimens, and the equipment used. Comparison and analysis of the results obtained were therefore hampered. It is assumed that further research will permit better-grounded determination of monoharmonic cycles that cause equivalent damage, a factor that can be utilized in calculating the fatigue strength of structures exposed to polyharmonic loads. L.B.H.

Review: This is more of an after-the-fact discussion of data than an organized review of the subject. In fact, the last sentence of the paper, "It must be assumed that further research in this area will permit better-grounded determination of monoharmonic cycles that cause equivalent damage, a factor that can be utilized in calculating the fatigue strength of structures exposed to polyharmonic loads" expresses well the feeling one gets when reading the paper. The discussion is all of how, given the data, one might explain them rather than trying to predict what would happen and seeing if it turns out that way. This after-the-fact approach helps little, since almost anyone can explain almost anything given that it has occurred. Terms such as hardening and softening are used to indicate the effect of fluctuations within the main *cycle*. (The term *cycle* is used in its mathematical sense of that waveshape which is repeated, rather than the waveshape between two successive zero crossings of the slope in the same direction.) The interpretation of the Gerber-Goodman diagrams is not the one usually given in the American literature. All in all, theorists may find the paper helpful in its collection of some raw data and brief discussion thereof. But the paper is in no sense a unified review of the topic.

R69-14601 ASQC 844

STRESS CORROSION CRACKING OF GOLD PLATED KOVAR TRANSISTOR LEADS.

Bernard Reich (U. S. Army Electronics Command, Electronic Components Labs., Fort Monmouth, N.J.).

Solid State Technology, vol. 12, Apr. 1969, p. 36–38.

Corrosive flux is cited as one of the prime causes of stress corrosion cracking of gold plated kovar leads. In the past, considerations of this problem have failed to stress this particular point citing primarily the stress and humidity conditions. It is indicated that gold thickness is not a critical parameter in this problem since data presented indicate that the absence of gold plating does not materially affect lead cracking or breaking in the presence of moisture and stress alone. Author

Review: Stress-corrosion cracking is a failure mode we are apparently becoming more adept at identifying. It occurs in the largest steel structures and this paper describes a case where it apparently occurred in a very small wire lead. As stated in previous reviews, stress-corrosion cracking is often extremely difficult to predict in advance. It is more often a failure mechanism one finds upon analysis of a failed part. In this particular instance, since ". . . possibly stress although the influence of the latter was not strongly evident,") stress may not have been a cause; it might not have been stress-corrosion cracking after all. Some of the pictures do not clearly show what has happened, especially those which are only about twice scale. Presumably, the stresses that were introduced in the test leads were the residual ones caused by bending. No attempt was made to compare them with residual stresses that were in the wires merely due to processing. The author suggests that the breaking is more attributable to the influence of corrosive soldering fluxes.

R69-14605 ASQC 845

FAILURE DATA FEEDBACK: THE RELIABILITY ANALYSIS CENTER.

George T. Jacobi and Harold A. Lauffenburger (IIT Research Institute, Reliability Analysis Center, Chicago, Ill.).

Evaluation Engineering, vol. 8, Mar./Apr. 1969, p. 42, 46–48, 68. 3 refs.

Overview is given of the functions of a reliability analysis center, which essentially performs a feedback function between source and user. The primary objectives of the center are (1) to upgrade systems reliability through centralized collection, analysis, and dissemination of reliability and experience information; and (2) to provide better understanding of the nature of failures in microcircuits, leading to improved designs and applications. A detailed accounting is presented of a study done by the center on monolithic integrated circuit failure modes. L.B.H.

Review: Almost since a great surge of interest in reliability in the 1950's, people have been saying we need more data on failures and we need somehow to coordinate all this information so that it need not be duplicated and so that it is readily available to those who need it. Organizations and acronyms for accomplishing this purpose have risen; some have fallen; some groups were stillborn; some have survived a remarkably long time. The Rome Air Development Center has been in the forefront of *physics of failure* activities for many years and it is natural that their efforts in organizing an information processing system on failures should involve the *physics of failure* approach. The Reliability Central which they organized has been severely restricted for lack of funds. This new program (which is what remains of the old Reliability Central) attempts to create a viable and vital information center. The description in the space available is obviously not complete but is sufficient for a reader to determine his depth of interest. Fortunately, one portion of the article tells how to get further information and how to use the system. The only vital piece of information missing is that regarding charges. Is it free? If there are charges, what is a typical one or what is a typical range? In a private communication the authors have stated that it is free, now, for appropriate DoD and NASA contractors, but that a modest fee is being planned for all such information centers within a year. Service can be obtained from the Center by calling either author at 312/225–9630 x 4539. Any such information center works under tremendous handicaps that are quite familiar to those who have tried either to create or to use such systems. Nevertheless, the present setup seems to be doing the best that can be done with the available information—to put it in as useful a form as possible for as many people as possible. The spectrum of potential users ranges from those who refuse to accept any information unless given the name of the man who actually ran the tests (if they think he is good, they will accept the results; if not, they will not) to those who take what they are given with the blind faith of the eternally hopeful. Regardless of where one fits in this spectrum, this effort should be given the greatest possible opportunity and encouragement to succeed.

R69-14614 ASQC 844

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

RELIABILITY OF MAGNETIC TAPE MEMORIES

A. A. Kilna 4 Apr. 1968 15 p refs Transl. into ENGLISH from Akad. Nauk Lit SSR, Tr. Ser. B. Fiz.-Mat., Khim, Geol. i Tekhn. Nauki (USSR), no. 3, 1966 p 191–200

(AD-679508; FTD-HT-23-148-68; N69-17761) Avail: CFSTI

By lumping together noise associated with magnetic tape quality, inherent noise of signal processing circuits, and noise caused by mechanical sources such as flutter and tape-head channel crosstalk, the author expresses the reliability of digital tape readers as a function of probabilities of misreading 0 and 1. Assuming that noise follows a normal distribution pattern, the author shows that the probability of tape reader failure is a function of discriminator-threshold-level discerning between 0 and 1, and that this probability has a minimum and maximum value. A probability of failure for reading a random code is derived. These results are used to evaluate the reliability of the BESM-2M computer tape memory system. A method for finding the actual distribution of signal and noise amplitudes in this system is presented. TAB

Review: This short paper does not discuss the physical basis of the mathematical model very extensively. What it amounts to is that the amplitudes of zeros and ones are each presumed to be *normally* distributed about their own means and that there is some overlap so that no matter where a single discriminator level is set, there will be errors. When the mean and variance of each distribution are known, one can calculate the discriminator level that gives minimum conflict and the author does so. Some of the author's word descriptions are incorrect, but his formulas are satisfactory. For example, he gives the familiar misinformation that the area common to two probability density functions gives the probability of failure. Of interest to computer designers may be some information on the signal and noise outputs for a particular Russian computer. The chance of incorrect reading appears to be out in the 10σ portion of the tail of the *normal* distribution. If this is so, one certainly cannot calculate probabilities, at least within a factor of a 100 to 10,000, since even though the distributions may be *normal* in their central regions, there is no guarantee as to what they are like even for 5σ out in the tails, much less 10σ.

R69-14615 ASQC 844

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

APPLICATION OF A METHOD OF ESTIMATING HIGH TEMPERATURE LOW CYCLE FATIGUE BEHAVIOR OF MATERIALS

G. R. Halford and S. S. Manson Washington 1967 26 p refs

Presented at the Natl. Metal Congr. sponsored by the Am. Soc. for Metals, Cleveland, 19 Oct. 1967 Reprinted

(NASA-TM-X-52357; N67-39653) Avail: CFSTI

Further study is made of a recently proposed method whereby tensile and stress-rupture properties may be used to estimate low-cycle, strain fatigue behavior in the creep range. The method is based primarily on the equation of universal slopes previously developed for predicting room-temperature fatigue and stress-rupture. Fatigue life estimates are presented and compared with a large quantity of fatigue data for nickel-base alloys, high-and low-alloy steels, stainless steels, and aluminum-base alloys tested under laboratory conditions over a wide range of temperatures and cycling frequencies. Author

Review: The results of an investigation to evaluate a method of estimating high-temperature low-cycle fatigue behavior of materials are presented. Since elevated-temperature testing is time-consuming, expensive, and complex (because of effects induced by elevated temperature: oxidation, transformations, etc.), such a method for estimating the performance of materials is most useful. The method is based on certain assumptions and on elevated-temperature tensile and stress-rupture properties. It is not, therefore, entirely rigorous, but it is useful as a means of obtaining quick approximate answers for initial design and materials selection. It does not, however, eliminate the need for a more refined life estimate based on experimental evaluation of the low-cycle fatigue behavior of a material at elevated temperature. Design, test, and materials engineers will find the paper useful. The tabulation of elevated temperature properties could be useful to certain engineers. The paper is well documented with references.

R69-14616 ASQC 844; 782

CORROSION FATIGUE AND STRESS-CORROSION CRACKING IN AQUEOUS ENVIRONMENTS.

D. E. Piper, S. H. Smith, and R. V. Carter (Boeing Co., Commercial Airplane Div., Renton, Wash.). *(American Society for Metals, National Metal Congress, Chicago, Oct. 31–Nov. 3, 1966.)*

Metals Engineering Quarterly, vol. 8, Aug. 1968, p. 50–63. 10 refs.

(A68-39115)

Study of means of increasing the crack-propagation resistance in aqueous environments of high-strength alloys susceptible to stress-corrosion cracking (SCC) and to rapid corrosion fatigue. A quantitative measure of corrosion fatigue and SCC characteristics was required to provide a positive system of fracture control. This was obtained through fracture mechanics methods on several important titanium alloys. Specific heat-treatment conditions were then selected to increase SCC resistance in these alloys. The fatigue-crack growth rate of the titanium alloys tested was accelerated by increasing the material thickness and by placing it either in distilled water or in a 3.5% NaCl solution. These alloys were then ranked according to crack growth rate. IAA

Review: The authors state that the primary objective for their work was to determine how to increase crack-propagation resistance of high-strength alloys that are susceptible to stress-corrosion cracking and rapid corrosion fatigue. They further state that the secondary objective of their work was to learn how to use alloys in structures that require a fail-safe design when the material cannot be made totally immune to stress-corrosion cracking or rapid corrosion fatigue. Essentially, the evaluation of crack-propagation resistance was based on the following four types of testing: (1) plane stress and plane strain fracture toughness, (2) plane stress and plane strain stress-corrosion cracking, (3) corrosion fatigue, and (4) tensile properties. The materials evaluated were commercial titanium plate and sheet gage alloys, with steel and aluminum alloys for comparison. Fracture properties were based on linear elastic fracture mechanics. The results of the investigations indicate that certain titanium alloys are particularly susceptible to stress-corrosion cracking. This susceptibility is influenced by composition, heat-treat condition, and section thickness. The paper is well written and thoroughly documented with references and graphical and tabular data. Engineers involved with materials, design, and tests will find the paper useful.

R69-14617 ASQC 844

Advisory Group for Aerospace Research and Development, Paris (France).

RESIDUAL STRENGTH IN THE PRESENCE OF FATIGUE CRACKS

Paul Kuhn (NASA. Langley Res. Center) 1967 89 p refs

Presented at the Struct. and Mater. Panel of AGARD, Sect. 1-4, Turin, 17 Apr. 1967 and Sect. 5-7, Ottawa, Can., 25 Sep. 1967

(AGARD-ADVISORY-11; N68-23762) Avail: CFSTI

Results of a survey are presented which included visits to aeronautical organizations and firms. The purpose was to review the existing state of knowledge with respect to: (1) the residual strength of material specimens containing fatigue crack failure initiation of known proportions; and (2) the residual strength of typical structures using various types of materials. Rather than presenting a comprehensive summary, the report concentrates on the presentation and critical analysis of calculation methods useful to the structural engineer. Specially covered are methods for simple sheet specimens and the effects of thickness on sheet and plate with through-cracks and part-through cracks. K.W.

Review: The concept of residual strength—the strength of a material in the presence of a defect—is important to various branches of engineering, and the techniques for applying knowledge on this subject to design are reasonably clear-cut when the overall objective is to avoid catastrophic failure. In the absence of a catastrophic failure, however, the problem becomes less well defined because of economic considerations; e.g., the cost of testing to obtain failure criteria cannot be justified in the absence of catastrophic failure. This document is a comprehensive report of the results of a survey to determine the state of knowledge concerning the residual strength of materials which contain fatigue cracks. Essentially the author presents and critiques various methods for analyzing and calculating residual strength. As such, the report is quite lengthy, but it is well done and thoroughly documented with references and graphical and tabular data. The report should be a useful reference for structural design engineers, material engineers, and test engineers who are concerned with residual strength of materials in the presence of fatigue cracks. The report, because of its length and subject matter, must be studied in detail, rather than just read. The mathematics of the report was not checked in detail but appears to be competent.

R69-14618 ASQC 844

National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.

RESIDUAL STRENGTH IN THE PRESENCE OF FATIGUE CRACKS, PARTS 1 AND 2

Paul Kuhn (NASA. Langley Res. Center) Washington 17 Apr. 1967 75 p refs Presented at the Struct. and Mater. Panel of AGARD, Turin, 17 Apr. 1967

(NASA-TM-X-59836; N68-27351; N68-27409) Avail: CFSTI

A survey of engineering practices was conducted in aeronautical organizations and firms in order to assess the current state of knowledge concerning the residual strength of: (1) material specimens containing fatigue crack failure initiation of known proportions; and (2) typical structures using various types of materials. Critically examined are calculation methods useful to the structural design engineer for determining the strength of simple sheet specimens. Included are methods for notch and crack strength analyses as well as the methods of Critchlow, Christensen–Denke, Welbourne, McEvily–Illg–Hardrath, Griffith–Irwin, Broek, the comparison plots, and the log–log plot. The application of these methods to such materials as high-strength steels, titanium aloys, ceramics, and aluminum alloys is considered. The effects of sheet and plate thickness on cracks extending through the metal are reviewed. Fracture mechanics and the validity of test measurements are briefly discussed, and it is felt that the problem of obtaining valid data exists for aluminum and titanium alloys and steels. It is considered that thickness may be a more important factor for notch strength than metallurgical differences. The problems associated with surface cracks and the analysis of a complex structure containing cracks are also mentioned. N.E.N.

Review: This two-part report is largely the same as the author's NATO AGARD Advisory Report 1,1 (see review in this issue of RATR), which is a more polished presentation of the material.

R69-14619 ASQC 844

Aeronautical Research Labs., Melbourne (Australia).

THE EFFECT OF DEPTH OF MACHINING CUT ON THE FATIGUE PROPERTIES OF UNNOTCHED ALUMINUM ALLOY SPECIMENS

J. M. Finney, J. Y. Mann, and R. Simpson Dec. 1967 15 p refs

(ARL/SM-322; N68-33146) Avail: CFSTI

Residual stress measurements and rotating cantilever fatigue tests have been made on unnotched specimens of 2024-T4 and D.T.D. 683/3 extruded aluminum alloys machined from bar stock in either two or a series of four or five cuts. The cuts ranged from 0.346 inch to 0.004 inch in depth. It was found that the depth of cut caused no significant differences in the fatigue behaviour of either alloy. Author

Review: This is a short, well-documented report describing the result of an investigation to (a) measure internal stresses in both 2024-T4 and D.T.D. 683/3 extruded aluminum alloys after lathe turning with cuts of different depth, and (b) compare fatigue properties of unnotched specimens from the two alloys after machining to size with two cuts or a series of cuts. The work demonstrates that for the machining and polishing conditions evaluated, little or no residual stresses or work hardening effects were detected. These results are of considerable practical importance because of the implied reduced costs and machining time associated with the manufacture of fatigue specimens. The results should not, however, be extrapolated to other materials. The report is editorially well done, but it is not a reference paper.

R69-14620 ASQC 844

TECHNIQUES FOR EVALUATING RELIABILITY OF FLUIDIC SYSTEMS.

A. R. Adler (General Electric Co., Research and Development Center, Reliability Branch, Schenectady, N.Y.).

Hydraulics and Pneumatics, vol. 21, May 1968, p 105–109.

(A68-30799)

Description of a factorial test, based on statistical techniques, using pressure, temperature, and contamination as the three factors influencing reliability in fluidic devices. The testing device is a five-stage register consisting of a stack of 15 digital elements and a five-bit capacity. A second testing device with 15 flip-flop type elements is described. IAA

Review: Many papers take the point of view that fluidic systems are virtually 100% reliable and thus those papers are quite unrealistic. This paper, rather, takes the points of view that (1) fluidic devices have a great deal of promise for high reliability, and (2) it is worthwhile investigating the failure modes and mechanisms to see how real devices and systems need to be improved to achieve this promised reliability. The approach appears to be realistic and the results of the experiments are both interesting and informative. The listing of failure modes and mechanisms is in itself worthwhile. Thus those who are seriously considering using fluidic devices should be aware of the contents of this paper. In a private communication the author has stated ". . . that a somewhat more comprehensive version of this material appears in the April 1969 issue of *Fluidics Feedback*, published by the British Hydromechanics Research Association, Cranfield, Bedford, England, under the title "Reliability Techniques Applied to Fluidic Devices". Individuals seeking more detailed information on specific test results might wish to refer to this paper."

R69-14621 ASQC 844

PROGRESS IN RESEARCH ON CYCLE-DEPENDENT FATIGUE.

Trevor Broom (Central Electricity Generating Board, Research Laboratories, Materials Div., Leatherhead, Surrey, England).

Materials Science and Engineering, vol. 3, Sept. 1968, p. 138–144. 74 refs.

(A69-10133)

Review of the present state of knowledge on cycle-dependent fatigue of metals. The fatigue hardening and softening of metals

is described in terms of the crystal structure and stress amplitude. Special attention is given to the evolution of a mat and high-stress cell structure, as well as spreading of the Luders bands at the fatigue limit. The mechanism of the crack initiation and its growth is discussed including the formation of the hill-and-valley structures, strain localization on the grain boundary, and local hardening within the grains. The fatigue at elevated temperatures where the diffusion-dependent effects unambiguously appear is shortly reviewed.
IAA

Review: Fatigue is one of the more important mechanical failure modes, and it is often aggravated by other effects such as corrosion. This paper is designed for those who wish to become aware of the problems in fatigue theory and the areas of current research. For example, designers and reliability engineers who wish to have more than a surface acquaintance with the subject will find this paper both easy to read and informative. The value of the paper is considerably enhanced by the 74 references for further reading on the topics. As the author says, there is not space enough to cover all subjects (for example, low-cycle fatigue is not considered), but this gives the paper the distinct advantage of being short and easy to read. The amount of technical jargon is kept to a minimum so that non-specialists (including even managers) can read it profitably. Reliability engineers, especially those coming from an electrical engineering background, are urged to read this or similar papers and gain depth in mechanical failure mechanisms.

R69-14622 ASQC 844
FATIGUE-LIFE ESTABLISHMENT AND DETECTION.
David James (British Aircraft Corp. (Operating), Ltd., London, England). *Society of Automotive Engineers, Air Transportation Meeting, New York, Apr. 29–May 2, 1968, Paper.* 14 p.
(SAE Paper 680342; A68-31355) Avail: Members, $0.75; nonmembers, $1.00.

Indication of the need for continuing surveillance against fatigue defects and failures in aircraft components, emphasizing the limitations of the current procedures for establishing the fatigue life and for the detection of fatigue defects. The fatigue-producing environment is discussed, as well as the significance of structural response to dynamic forces and the relationship of these forces to continuous turbulence and other sources of energy. The scatter of fatigue behavior in structures under known loading conditions and its influence on the choice of inspection procedures is discussed, and the main methods of nondestructive testing for fatigue defects are outlined. IAA

Review: This paper is on an important topic and discusses it well for those who are otherwise informed enough to be able to read the paper. In its early parts, some mathematical sophistication is required, and it is generally presumed that the reader understands what fatigue is. The discussion of nondestructive testing methods likewise presumes some general familiarity with the area but does provide a useful survey for those who have this background. There is an extensive discussion of X-ray, and ultrasonics receives quite a bit of space. (It is mentioned that ". . . The dangers inherent in the use of ultrasonic equipment by unskilled personnel cannot be stressed too highly . . . ." but these dangers are not listed in the report.) The discussion of the difficulties involved in calculating the fatigue life is also good—especially for those who have some earlier background. In short, a reasonable number of people can profit from this paper. They are the partially, but inadequately, informed (informed enough to be able to understand the language and the basic concepts but not experienced enough to be completely familiar with the details).

R69-14623 ASQC 844
National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
VARIOUS MODES OF WEAR AND THEIR CONTROLLING FACTORS
Edmond E. Bisson Washington 1968 33 p refs To be presented at 71st Ann. Meeting of the ASTM, San Francisco, 23–28 Jun. 1968
(NASA-TM-X-52426; N68-21232) Avail: CFSTI

As an understanding of the basic mechanisms of wear permits alleviation of the causes, the various modes of wear are identified. These are: (1) Adhesive wear involves adhesive forces which form cold welds at the contacting asperities. During relative motion, shear takes place at the welds, with the shear strength influenced by contamination. (2) Abrasive wear involves damage to soft surfaces by a hard surface, and is affected by hardness, work hardening, crystallite orientation, and elastic modulus of the contacting surfaces. (3) Corrosive wear involves reaction of the surfaces with the atmosphere. (4) Surface fatigue occurs by local pitting or flaking. Fretting is defined as a combination of adhesive, corrosive, and abrasive wear. The influence of crystal structure on friction and wear is discussed, and comparisons are drawn between hexagonal and cubic structures as well as between single crystal and polycrystalline materials. It is pointed out that all modes of wear lead to loss of dimensional tolerances, high operating costs, and excessive expense for replacements. M.G.J.

Review: Mechanical wear of metals occurs in virtually all machines where there is nominal metal-to-metal contact. Alleviating this wear is an important part of good design. This paper can give a good understanding to design and reliability engineers of the various mechanisms of wear (it does not give cookbook procedures on how to prevent wear in any particular circumstance). The understanding is important and those designers and reliability engineers who are not familiar with this subject are well advised to read this paper. It uses a negligible amount of jargon yet explains the concepts clearly. It is also rather short (a virtue in itself) and contains many references for further reading.

R69-14626 ASQC 844
Motorola, Inc., Scottsdale, Ariz. Government Electronics Div.
MICROMINIATURE HIGH LEVEL MULTICODER Final Report
25 Nov. 1966 44 p
(Contract NAS9-4468; Proj. 3114)
(NASA-CR-92434; N69-14700) Avail: CFSTI

A reliability analysis is presented for the microminiature high level multicoder, with failure rates computed for both 80° and 160°F which is the maximum operating temperature of the equipment. Specification levels, worst performance at any temperature, and typical performance at room temperature (80°F) are given. The results indicate total electrical compliance at all temperatures. The multicoders meet both size and weight requirements and also performed satisfactorily during the following qualification tests: electromagnetic interference and susceptibility, temperature, altitude, shock, vibration, and acceleration. Because of a sealing problem, compliance during humidity and salt fog was not demonstrated. Author

Review: This report was not released for public distribution until over two years after it was written. Nevertheless it is instructive as an example of the kinds of reliability analyses people actually perform when requested to do so by an arm of the government. The hazard (failure) rate analysis uses multiplying factors on the hazard rate for screening, etc. and the hazard rates are added to get an overall figure. That number is inverted to get the MTBF. The tables used as sources for the hazard rates are the conventional type (e.g., there is no mention of a manufacturer). The conclusions and recommendations at the end of the report apparently follow from tests which are not reported explicitly in the paper but again they are typical of the kinds that are made. An appendix to part I gives the curves and methods for arriving at the hazard rate calculation. Those who are new to this kind of analysis should remember that the number of significant figures in the answer is merely a reflection of the additions performed, without any rounding off to account for significance in the final answer. The MTBF figures are, however, apparently rounded off to reflect an appropriate number of significant figures. Such answers are typically good to about ±20% at best (for equipment virtually identical to those upon which the hazard rates are based) and to within a factor of 10 to 100 for ballpark calculations. There is a difference between the way some papers in the literature say such analyses ought to be performed in order to be more accurate (e.g., one should not presume a constant hazard) and the way people actually do them. Very often the quality of the data is such that one cannot justify a more complex hypothesis than a constant hazard rate. Besides, there is the usual conservative circle wherein the customer wants only constant hazard rates because that is what he is used to getting and is all he understands; the manufacturer gives only constant hazard rates because that is what the customer is demanding and all he can reasonably supply.

R69-14632 ASQC 844

RANDOM LOAD SPECTRUM TEST TO DETERMINE DURABILITY OF STRUCTURAL COMPONENTS OF AUTOMOTIVE VEHICLES.

Henry R. Jaeckel (Ford Motor Co., Dearborn, Mich.) and S. Roy Swanson (MTS Systems Corp., Minneapolis, Minn.). *7th Congres International des Techniques de. l'Automobile, Barcelona, May 19–25, 1968, Paper.* Congress sponsored by the Fédération internationale des sociétés d'Ingenieurs des Techniques de l'Automobile. 12 p refs.
(Paper 3-02)

A rational approach to random load spectrum tests is presented, whereby the character of the service conditions is the base for an analogous random process readily obtainable in the laboratory. The spectrum test consists of a series of random vibrations at various levels of intensity, whereby the series of Root Mean Square (RMS) levels itself is randomized in sequence. The random vibration may be frequency-filtered to simulate the dynamics (i.e., the power spectral density profile) of the vehicle component. Each RMS level is in itself a stationary Gaussian random process, which can be statistically analyzed. Almost any field service load distribution can be duplicated statistically in the laboratory by means of randomizing or by selection of specific RMS levels. Acquisition of field load data may be simplified in the future, since only statistical values of load levels and samples of continuous recordings will be required. A test program utilizing this new technique is described in detail. Author

Review: This is an enthusiastic description of random load–spectrum fatigue testing as it concerns automotive problems. No disadvantages are mentioned. It appears to be presumed that this method will adequately simulate everyone's use of an automobile with respect to structural fatigue. Actually, there is little question that random fatigue tests simulate many kinds of actual operating conditions better than do constant-load tests and that the development of the theory and practice of random fatigue testing is an important step forward. It is possible, however, that sine-wave testing with random amplitudes will give as close approximation to service conditions as is necessary. It is also possible, for reasons not yet known, that the "idealized" model for behavior presented in the paper will be found to be inadequate. Thus if the paper is read for what it is (a highly enthusiastic account of an important development), it can be helpful. In addition, aerospace reliability and design engineers will find in it specific material of value. The following are examples of minor difficulties in the paper: (1) The second half of the definition for RMS is incorrect. RMS is the standard deviation only when the mean is zero. (2) Apparently, the life span of the part is being equated to the mean life, and yet most components are being presumed to fail beyond that time. The Bussa paper, which is referred to as a precursor of this one, was covered by R69-14408.

R69-14637 ASQC 844

SOME LESSONS IN RELIABILITY ASSURANCE OF VENDORED COMPONENTS OF SUBSYSTEMS IN A COMMERCIAL PRODUCT.

David B. Christian (Xerox Corp., Webster, N.Y.).
Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 23–31.
Avail: $8.00

Discussion is presented of some important lessons that are essential in vendor reliability assurance. There are three major reasons for failure: poor design, design mis-application, and manufacturing process variations. The percentage of each type is dependent upon the product phase, but some generalization may be made. Consideration is given to the laws of failure, which related the causes of failure to physical stress. It is concluded that stress is measureable and can be assessed. The contractor can perform qualification tests that evaluate the probability of design and manufacturing variation weaknesses. Examples are given to demonstrate the points made. Author

Review: This paper discusses reliability from an over-simplified point of view. Some examples of the difficulties are the following: (1) The section on distributions is misleading if not incorrect in places. (2) The two quotations, "The first three laws state that the occurrence of failure is measurable and predictable," ". . . degrade reliability in a manner that cannot be predicted" are self-contradictory. (3) Law number 2, that as the stress on a component increases, individual differences will cause greater variations in life, is simply not always true. Metallic fatigue is an excellent example of the contradiction. This is not to say that the paper does not make some good points; it does—but they are so intermixed with misleading and incorrect points that the beginner is well advised not to look here for information. Those who know enough to recognize those difficulties in the paper do not need to read it.

R69-14641 ASQC 844

FAILURE MECHANISMS IN PLASTIC ENCAPSULATED MICROCIRCUITS.

A. L. Tamburrino and V. C. Kapfer (Rome Air Development Center, Reliability Physics Section, Griffis AFB, N.Y.).
Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 79–89. 7 refs.
Avail: $8.00

Some tests are discussed which might be useful as qualification or screen tests for DIP microcircuits. The tests were conducted to partially fill the need for reliability information on plastic encapsulated integrated circuits in the face of quite limited and variable reporting of data from industry. The intent was to stress these devices sufficiently to produce realistic failures which indicate fundamental weaknesses in design, materials or construction, or failures due to variations or imperfections which might be screenable. Test samples are described in some detail, and requirements for additional efforts are included. Author

Review: The topic is most timely and controversial, both of which make for interesting reading. The paper is a good presentation of an apparently well conceived and well carried out set of experiments. The results confirm the suspicions of the military (and probably some industrial users) that regardless of the advances being made in plastic encapsulation, moisture may be a problem (not only may be, but undoubtedly will be). The good introductory discussion contrasts the points of view of the manufacturer and the user. This paper is written by a user (the authors are with the military); it is a good statement of that side and a realistic discussion of the difficulties. A useful paper which discusses both sides (although more qualitatively) is [1].

Reference: [1] "Plastic IC's demand new physical," by Lawrence Curran, *Electronics*, vol. 42, 12 May 69, p. 147–153.

R69-14643 ASQC 844; 838; 871
THE REQUIREMENT FOR MAINTAINABLE ELECTRONICS ON LONG DURATION MANNED SPACE MISSIONS.
Michael L. Johnson (Radio Corp. of America, Aerospace Systems Div., Burlington, Mass.).
Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Mocroelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 99–104. 3 refs.
Avail: $8.00

Evidence and a physical line of reasoning are presented to support the view that electronics systems need not be maintainable on long duration space missions. An examination of the causes of failure are said to indicate that long duration missions can be undertaken without resorting to maintenance. It is noted that failures are not random occurrences in piece parts, but rather the manifestation of defects introduced at all levels of fabrication and assembly. Accordingly, mission reliability is a function of the number of defects allowed to fly, and can be improved by screening at all levels of assembly. Pre-launch maintainability is required for high mission reliability and flight maintainability offers some significant advantages. However, it is concluded that much needs to be done to explore the disadvantages in general environmental terms and in specific cases before final decisions can be made. L.B.H.

Review: The basic premise of this paper, namely, to challenge the methods used for analyzing reliability, is a good one since it is one of the ways that progress is made. The relationship between redundancy and maintenance explained by the author is well thought out. The actual arguments used against conventional reliability prediction are difficult to assess because there is no single commonly-accepted such method. There are ballpark techniques such as those advocated in the RADC Reliability Notebook but their deficiencies are also conventionally recognized (at least by their authors, and many others). The classification of much modern electronics into good parts and defective parts is appealing but needs analysis in depth. For example, it can be asserted that any part fails due to a defect (by definition of a defect). The severity of a defect could be measured by the time it takes a failure to occur. Furthermore, it is not a simple matter of screening defects. In the first place, the less severe defects are usually more difficult to find and in any event, testing is not perfect. Perhaps the most telling argument that the author has is that many of the failures in our spacecraft are of the horrible-hardware foolish-failure variety and ordinarily are not included in parts failure rates. This is often because the system is not the sum of parts-as-defined but contains additional "non-parts" which are presumed to have zero failure-rate or fraction defective (such as some interconnections, wiring, etc.). An argument against redundancy and maintenance that the author has not used is that the calculations ordinarily presume (a) zero hazard rate of the spares, (b) maintenance will not damage anything, and (c) the environmental profile is not a random variable. Thus, in general, the author's message is good and the paper is acceptable as a first run through on this message. As the author points out, many of the details need sharpening.

85 DEMONSTRATION/MEASUREMENT

R69-14597 ASQC 851; 844
Army Electronics Command, Fort Monmouth, N.J. Electronic Components Lab.
ESTABLISHING A RELIABILITY PROFILE FOR NEW REED SWITCH RELAYS.
William J. Fontana Reprinted from Proc. of the Eng. Seminar on Elec. Contract Phenomena, Nov. 1967 p 195–229 refs
(AD-670981; ECOM-2978)

Consideration is given to a developmental program which leads to the design rationalization and reliability characterization of a miniature dry reed switch capsule which performs a true transfer function without the use of auxiliary biasing magnets. The electromagnetic and packaging design principle employed and other electromagnetic armature type relays are discussed. A comprehensive life test program to establish the functional relationships between reliable life expectancy and the usage variables of load current, ambient temperature, and electromagnetic drive is described. Appropriate mathematical functions are derived, and families of curves from which estimates of mean life and reliability can be made are presented. Their applicability to the prediction of life performance under a variety of circuit conditions and the effects of circuit tradeoff on reliability are discussed and examples of typical performance given. Author

Review: Of interest to reliability engineers is the description of the extensive life tests performed on these relays at a variety of severity levels. The tests used classical statistical design (although the paper did not say what the design was intended to optimize). The life data were presumed to fit a Weibull distribution (although no comments were made about the goodness of the fit). The Weibull parameters were estimated apparently by constructing the *least squares* straight line through the data on Weibull paper. This procedure leaves something to be desired since one would ordinarily not weight all of the points equally (they are correlated and the least squares analysis presumes uncorrelated points). The use of order statistics is a good and convenient way of estimating the parameters of the line. For example, see the publications of Moore and Harter, some of which have been reviewed in RATR. The failure criteria are given in detail. The 2V drop for excessive contact resistance seems rather high and it is not clear whether contact-miss as defined in (a) is permanent or transient. But overall, the paper does give reliability engineers a good picture of the scope of an extensive life testing experiment and what can be done in a practical way to derive data therefrom. Even though one might quibble about certain details, the accuracy of the overall results would probably not be affected by changing any of them.

R69-14612 ASQC 851; 844

Northrop Corp., Hawthorne, Calif. Norair Div.

DEVELOPMENT OF AN ACCELERATED STRESS-CORROSION TEST FOR FERROUS AND NICKEL ALLOYS Final Summary Report, Mar. 1966–Mar. 1968

A. H. Freedman and L. H. Stone Apr. 1968 90 p refs
(Contract NAS8-20333)
(NASA-CR-98120; NOR-68-58; N69-10638) Avail: CFSTI

A simple, accelerated, laboratory test for evaluating the stress corrosion susceptibility of a ferrous or nickel-base alloy has been developed. Single-edge-notched and fatigue-cracked specimens are tension loaded in a NaCl solution (200gm/liter distilled water), and the threshold stress intensity for stress corrosion (K_{ISCC}) is determined. Identical specimens were tension loaded in racks exposed at the seacoast, and their K_{ISCC} values were measured to act as standards for evaluating the accelerated test. The accelerated test requires a maximum test time of 1000 hours. Test times are one to three orders of magnitude shorter than those required for similar specimens in a seacoast environment. The acceleration of test time is produced by the aggressive corrodent, the presence of a crack, and the plane-strain loading conditions. Twenty of the twenty-three combinations of material, heat treatment, and welding conditions that were tested showed good-to-excellent agreement between the K_{ISCC} values obtained in seacoast and in accelerated tests. Author

Review: Accelerated corrosion tests by themselves are notoriously easy to devise and difficult to interpret. Stress-corrosion tests may be somewhat different although these accelerated tests are for the purpose of determining the behavior in a specific environment, namely the sea coast, rather than stress-corrosion susceptibility in general. The use of fracture mechanics in setting up and analyzing the test appears to be very worthwhile and probably contributes to the utility of the accelerated tests. The use of some processed elements (e.g., welded) further increases the utility of these tests since, as the author points out, few metals are used in their original condition. Before using the results, one should read large sections of the report to be sure he understands the limitations which have been imposed on them by the author. If this is done, this report can be of immediate assistance to design and reliability engineers.

R69-14639 ASQC 851; 835; 844

A TECHNIQUE TO EVALUATE POTENTIAL RELIABILITY PROBLEMS OF LSI ARRAYS.

Allan G. Riker, G. A. Christensen, and R. L. Thurston (Motorola, Inc., Semiconductor Products Div., Integrated Circuits Center, Mesa, Ariz.).

Proceedings of the 1969 Spring Seminar on Reliability, Maintainability – Parts, Microelectronics, Systems, Boston, Apr. 24, 1968. Seminar sponsored by the Institute of Electrical and Electronics Engineers, Boston Section. IEEE, Inc., 1969, p. 51–57. Avail: $8.00.

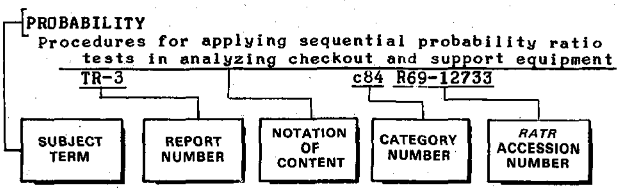
Consideration is given to (1) a description of potential reliability exposure areas of Large Scale Integration (LSI) complex arrays, (2) a method of evaluating LSI arrays, and (3) some specific evaluations of structures representative of LSI arrays. The potential reliability exposure areas of LSI arrays, different from those found in conventional integrated circuits, are noted to arise from the nature of the upper layers of glass and metal necessary for the circuit connections. The new method of evaluating critical processes involves selecting stressing structures contained in test pattern sites from actual LSI wafers. The evaluations have proven valuable in the investigation of electromigration phenomena, and additional work has shown that such potential failure modes can be reduced to insignificant levels by proper design of metallization and selection of compatible process sequences. L.B.H.

Review: As the authors point out, there is as yet no industry-accepted definition of LSI, and it is not the function of this review to dispute the one used by the authors. In essence, the devices with which the authors are concerned are those whose topography is so complex that they cannot be tested by the usual means for ordinary semiconductor devices and simple integrated circuits. The LSI circuit is considered to be a collection of subsystems with the system divided in such a way that each subsystem can be fabricated and tested separately. This paper then describes tests on those subsystems. Virtually all of the tests are accelerated tests; their interpretation is largely qualitative but nevertheless satisfactory. There are two kinds of things which can go wrong in these predictions: (1) interaction effects between the subsystems can be severe; (2) the qualitative models being used for extrapolating the results of accelerated tests can be appreciably in error. With all of the cumulated experience in fabricating silicon devices and with the field experience in using them, one would hope that these two possibilities are very small. The users of LSI devices can no longer be concerned with simply buying a black box which is either good or bad, but they must become more aware of what is inside of it and the kinds of things that can go wrong with it. This paper will be of valuable assistance to reliability and design engineers who are so concerned.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 9

Typical Subject Index Listing



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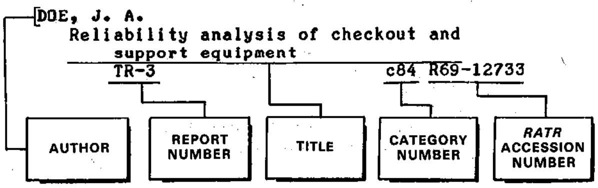
Typical Personal Author Index Listing



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Reliability Abstracts and Technical Reviews

OCTOBER 1969

Volume 9
Number 10

R69-14644—R69-14706

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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EXAMPLES OF CITATIONS IN *RATR*

RATR **ACCESSION NUMBER**	R69-12733 ASQC 844; 413	**ASQC CODES**
TITLE	General Equipment Company, Banville, Calif.	**CORPORATE SOURCE**
	RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT	**PUBLICATION DATE**
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	***TAB*** **AND** ***STAR*** **ACCESSION NUMBERS**
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	**AVAILABILITY SOURCE**

RATR **ACCESSION NUMBER**	R69-12739 ASQC 814	**ASQC CODE**
TITLE	**SEMICONDUCTOR RELIABILITY.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	**AUTHOR AND AFFILIATION**
JOURNAL REFERENCE	*Electric Journal*, vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	***IAA*** **ACCESSION NUMBER**

RATR **ACCESSION NUMBER**	R69-12765 ASQC 773; 221; 823	**ASQC CODES**
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).	**AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*	
	Available from Assoc. of Reliability Eng., New York: $1.00	**AVAILABILITY AND PRICE**
IAA **ACCESSION NUMBER**	(A69-12407)	

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80 RELIABILITY

R69-14656 ASQC 802
Scripta Technica; Inc., Washington, D.C.
BASIC PRINCIPLES, METHODS, AND OBJECTIVES OF RELIABILITY OPERATIONS [GRUNDLAGEN, METHODEN UND ZIELE DER ZUVERLAESSIGKEITSARBEIT]
H. Gross Washington NASA Apr. 1968 16 p refs Transl. Into ENGLISH From Jahrb. Wiss. Ges. Luft- und Raumfahrt (Cologne), 1966 p 369–377
(Contract NASw-1964)
(NASA-TT-F-11545; N68-22348) Avail: CFSTI

A description is given of a number of theoretical and experimental research methods associated with engineering reliability. A general outline of the basic concepts of reliability operations is presented, followed by a discussion of the various problems that may be successfully attacked by these methods. Author

Review: This is an adequate report although there is some mathematics in it that will not be understandable to some of the beginners to whom this report is addressed, for example the part on Markov chains. Even though the report is nominally addressed to both the engineering and statistical aspects of reliability, the approach is generally a statistical one in which testing provides inputs to the mathematical models. There is little emphasis on such things as safety margins (without probability), design reviews, management techniques for high reliability, accelerated testing, and feedback of field experience. There are occasional editorial errors, but if the report is read qualitatively it can be of some value to the beginner. The equations are perhaps better off skipped for this purpose although they are generally accurate. More authoritative texts for the mathematics such as the recent one by Shooman (see R69-14176) are recommended for those who wish to be introduced to that subject. There is little need for one to go out of his way to find a copy of this report.

R69-14662 ASQC 802
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
RELIABILITY OF THE MANUFACTURE OF ELECTRONIC COMPUTING MACHINES.
P. P. Mesyatsev 27 Apr. 1967 241 p refs Transl. into ENGLISH of "Nadezhnost' Proizvodstva Elektronno-Vychislitel'nykh Mashin" Moscow, Gosgeoltekhizdat. p 1–216
(AD-662213; FTD-MT-65-514; N68-15650)

The book deals with the theory and method of engineering and calculating the exactness, reliability, and effectiveness of electronic computing machines, when manufacturing them. The book is intended for technical engineers, who are connected with the designing of electronic equipment. TAB

Review: This book is only the most elementary treatment of the reliability problem. The material has appeared in the American literature many times. It is a translation of only particular sections of the book rather than the entire book. The main value of this translation will be for those whose work involves having a knowledge of the Russian work on reliability. Below, each chapter is reviewed in more detail. Chapter 1 is an elementary discussion of what a digital computer does and what the effects of various ambient conditions are. The remarks are brief but accurate and are intended to show that computers must be designed with the same care for untoward ambient effects as are other electronic equipments. The remainder of the chapter shows the main subdivisions of digital computers and the types of circuitry within those units. Some of the illustrations use tubes, others use semiconductors. The discussions are adequate. The how and why of computer manufacture is summarized. The discussion is suitable for someone with a knowledge of electronics and the manufacture of electronic gear but who is not familiar with digital computers. In Chapter 2 the probability of failure is asserted to be a better measure of reliability of a computer than is mean-time-between-failures. There follows the usual elementary introduction to probability theory. Several concepts are introduced and the usual mistake of equating random failures with catastrophic failures is made. Other concepts such as redundancy and maintainability are introduced. Statistical independence is only implicitly presumed in the formulas and it is asserted that the Poisson and exponential laws hold for electronic equipment. No consideration is given to other laws. Presumed practical formulas for hazard rates of vacuum tubes and other things are given. The idea of a Normal distribution of parameters is introduced and it is implied that there are no others. Aging is asserted to always decrease the reliability whereas this may not be so. Calculations and expressions for various kinds of series/parallel redundant networks are given. Statistical independence and exponential behavior are always assumed. Some simple not unreasonable cost formulas are introduced to show that the benefits of redundancy are not free. The causes of failures are broken down into conventional categories such as poor design, poor production, poor operators. A bathtub curve is introduced along with the usual explanation. Various mathematical models are introduced presumably to show practical applications of calculations for reliability involving defects and maintenance. They are reasonable but not stated in the way these things ordinarily are in American texts. In general, this chapter presents its limited material satisfactorily. Chapter 3 discusses the kinds of things that affect the production of equipment and thus influence reliability. In general, considerable use is made of mathematical models rather than detailed engineering considerations. The mathematical models are usually quite general and do not really say anything. Chapter 4 is essentially a sensitivity analysis using conventional measures. Some practical examples are given. Usually a Normal distribution is assumed for everything. The sources of parameter uncertainty are mentioned along with extensive use of mathematical models. In general, the use of specific narrow-purpose equations is overdone. In chapter 5 the costs of production, of improving the reliability, of removing defects, and of inspection are expressed with simple crude mathematical models. These are both interesting and important although in any specific situation, one will undoubtedly have to develop his own mathematical model. Various kinds of tradeoffs are discussed for improving the reliability, decreasing cost and weight, etc. Chapters 6 and 7 deal with management techniques in both manufacture and use of the digital computers. They are adequate for their purpose.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14648 ASQC 810; 433; 824; 844
RISK ASSESSMENT IN COMPLEX UNATTENDED AEROSPACE SYSTEMS.
Anthony M. Smith.
In: Seminar on Failure Analysis, 1968, Philadelphia, May 21, 1968. Seminar Sponsored by IEEE Philadelphia Section and Reliability Group p 11–21. 5 refs.

Discussion is presented on the primary question of successful mission performance, or management assessment of program risk as it relates to the achievement of spacecraft mission objectives. Two specific questions are considered for unattended spacecraft systems: (1) Why is management appraisal of risk such a vital element in the achievement of mission success? and (2) How is this appraisal accomplished; i.e., what techniques are used? Techniques, along with several case histories, for providing continuous management appraisal of risk are given and are found to have proven themselves credible risk assessment tools. L.B.H.

Review: This paper is exactly the same as that presented by the author at the 1967 Reliability and Maintainability Conference. It was reviewed under R68-13798. No mention is made in the paper of the fact that it was presented previously.

R69-14660 ASQC 817; 835; 871
THE LSI TRADEOFFS
George Sideris
Space/Aeronautics, vol. 51, Mar. 1969, p. 66–75.
(A69-24530)

Discussion of the tenfold increase in avionics reliability and maintainability promised by large-scale integration (LSI). LSI could make self-test, self-repair, and throwaway maintenance a rule, not an exception. It is pointed out that LSI will require some changes in outlook in order to reduce life-cycle costs. IAA

Review: For the systems designer and reliability engineer, this is a good article on LSI. The majority of the article is devoted to reliability and allied problems, including tradeoffs with maintainability, cost, etc. This is definitely not one of those highly enthusiastic articles that predicts an aircraft full of LSI in a few short months. It does show how a changing technology can radically change tradeoffs. Throwaway maintenance on a large scale is becoming possible (it should be remembered that there has always been throwaway maintenance on some scale). Some kinds of redundancy hold large promise for mitigating the effects of faulty elements both initially and during their life. Those who have not kept up to date on the systems implications of LSI technology (as opposed to LSI possibilities per se) would do well to read this article.

R69-14675 ASQC 817; 824; 830
Aerospace Corp., El Segundo, Calif. Technical Operations.
ECONOMICS OF RELIABILITY IMPROVEMENT FOR SPACE LAUNCH VEHICLES
Herbert Hecht Jun. 1968 205 p refs
(Contract F04695-67-C-0158)
(AD-675988; TR-0158(9990)-1; SAMSO-TR-68-340; N69-12189)
Avail: CFSTI

Present methods for planning reliability improvement of launch vehicles are reviewed. A theoretical criterion for optimum allocation of resources for reliability improvement exists that requires equal marginal failure reduction for all elements to be improved. This is of little practical value because suitable expressions for failure reduction as a function of resource expenditure are not available for all elements of the launch vehicle. A key finding is that a good practical approximation for the marginal failure reduction is the failure/value ratio which can be computed from available information. This permits a criterion previously only of theoretical importance to be used in a practical situation. Author (TAB)

Review: This report is a doctoral thesis, and is somewhat detailed and lengthy as is customary for such a document. The ideas expressed in it are good and the author's criterion for selection of elements to be improved (the failure/value ratio) appears to be very reasonable. He has a good discussion of the problem of statistical independence for redundancy calculations (in a spacecraft the probability of failure may actually be much more than would be the case if statistical independence were true). The statistical dependence arises very often because both elements can be equally aggravated by the same *stress*. The uncertainty in the existence of such large common *stresses* is often a cause for statistical dependence. The author also has good comments on the problem of how exact the calculations need to be in relation to the exactness of the model. In general, one need not be overly concerned about the exactness of some calculations because the basic uncertainties in the models are so large. His use of the term *unbiased* is not clear. In several places, especially on page 54, it is not obvious whether he is speaking of a personal bias or a statistical bias. On page 5, it can be noted that reliability estimates need not be statistically unbiased. Statistical unbiasedness is merely one characteristic that a statistical estimate can have. Also if an estimate has it, a nonlinear function of it will not. For example, if the hazard rate is statistically unbiased, the reliability will be statistically biased. In most of the usual statistical estimates, the statistical bias is not large compared to the uncertainty in that estimate anyway. The author makes use of many engineering judgments in the course of his dissertation. They appear reasonable although in other situations, other people might make different ones. Most of the space is taken up first for describing the inadequacies of traditional methods of decision making for this problem and later for examples and discussion of the proposed criterion. Justifiably, no attempt has been made to provide elaborate rigor for the criterion, largely because the uncertainties involved in the data for its application tend to be as bad as or worse than the inexactness of the criterion. All in all, this is a good paper and those reliability engineers and managers concerned with this topic should be familiar with the contents of it. One who is already familiar with some of the discussion can omit much of it and concentrate on the explanation of the criterion.

R69-14683 ASQC 815; 342

ARE MIL SPECS OBSOLETE?

Robert L. Cooley (Burton Research Labs., Culver City, Calif.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 29–32.

Avail: $13.00

A discussion is presented concerning the current state of federal and military specifications. Included are the problems of component control and of industry's supposed inability to change or update particular specifications. One successful solution to the latter problem is described—the formation and work of a Military Standards and Specifications Committee, comprised of jobber, prime contractor, and government representatives, which proposed to upgrade military and federal plating and finishing specifications and to define a set of practical standards. This cooperation of government and industry, it is concluded, proves that specifications need not become obsolete. L.B.H.

Review: Congratulations to the author and the organization for which he speaks—the National Association of Metal Finishers (NAMF). The article is more historical than technical, yet it serves an excellent purpose, viz., to encourage others who feel that military specifications are outmoded to do something: (a) organize, (b) act collectively, (c) develop and define purposes, (d) make it known and personally follow the action closely with integrity, honesty and unbiased contributions. The author is very critical of military specifications and of certain organizations in DoD, yet if the reader is willing to continue reading he will find that the author justifies his early remarks, offers solutions and in fact chronicles the action which apparently is going to be successful. He would have made more points and possibly more friends had he included a list of specifications to which the NAMF and its subcommittees had contributed. Some references would have been helpful to the reader not fully familiar with terms like certification, JAN standards, etc. However, the chronology is useful and valuable and should encourage "small" companies to feel that they really can "tell" the customer that his specifications can be improved.

R69-14685 ASQC 817

COST EFFECTIVENESS ANALYSIS: A CASE STUDY APPROACH.

Ben. S. Blanchard (General Dynamics, Electronics Div., Rochester, N.Y.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 229–238. 3 refs.

Avail: $13.00

The underlying principles of cost effectiveness are analyzed and their applications throughout industry are found to be inconsistent and in some cases inadequate. One specific area of concern, related to the selection and acquisition of DOD/military systems where a consistent approach is needed, is examined. An approach applicable to any such system is described, including (1) the concept of cost effectiveness, (2) applications of basic cost effectiveness principles, and (3) an analytical model plus case study illustrating the multitude and variety of elements which must be considered in a cost effectiveness evaluation. Author

Review: This is an extremely terse summary of cost effectiveness. The case study is not presented in much detail. The reader who is not at least familiar with the ins and outs of the procedures will have difficulty understanding them from the text. Those who will benefit the most are those who have had some introduction to and experience in the subject but wish another opportunity to go over the methods. The beginner can, however, learn something about the enormous complexity and detail that are required for a good cost effectiveness analysis from the information contained in this paper and can acquire some of the required generalities. Within the space limitations, it is difficult to see how the author could fulfill his intent. There is little discussion of uncertainty in predicted values and the points on the final figure appear to lie on a smooth curve of cost versus system effectiveness. One would not ordinarily expect this to happen. In this connection, the author in a private communication has commented as follows. ". . . the points are discrete and the curve is not supposed to be continuous. A production error resulted in a solid line (in lieu of dotted line) curve."

R69-14687 ASQC 817; 353

SCREENING OPTIMIZATION AT VARIOUS INDENTURE LEVELS.

Chris Biagini and Ben F. Clemons (General Dynamics, Electronics Div., Rochester, N.Y.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 293–304. refs.

Avail: $13.00

Some of the basic economic considerations of screening are discussed, and techniques are considered for selecting screening approaches which do not require the impact on reliability to be known. Two basic techniques are described, the first based on physics of failure and the second on cost and defect data. The two can be combined, using the physics of failure approach to establish a list of effective screens and the defect and cost data to select from this list those screens which are most cost effective. Author

Review: This is a good paper for those who are concerned about the cost effectiveness of screening. Unfortunately, some of the assumptions are implicit; for example, it appears to be assumed that the screening test rejects no good units and, perhaps, that it catches all bad units. It also presumes that good/bad is a suitable classification for units. Nevertheless, the article is instructive, easily read, and can help reliability engineers make sure that they have considered everything that they should. The examples are clear and easily followed. (The page numbers on 294 and 295 are apparently interchanged.) This is a paper that you can understand without having to know all about the subject to begin with. (An earlier paper by the same authors dealing with a cost-reliability model for screening optimization and related estimation problems was covered by R68-14118.)

R69-14690 ASQC 814; 633

PRODUCT RELIABILITY: THE CRITICAL PROFIT AND LOSS RESOURCE IN THE CHANGING ENVIRONMENT OF CONSUMERISM.

Henry C. Monroe (American Standard Corp., Plumbing and Heating Div., New York, N.Y.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference Sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 507–512.

Avail: $13.00

Consumer satisfaction is discussed in relation to its impact on product reliability and industry quality control and profit. Advice is offered for the supplier in dealing with the consumer forces: rediscover the significance of the consumer and concentrate on commercial product reliability; analyze the complete anatomy of the degradation of reliability; and concentrate on cost effectiveness. Commercial product reliability is assessed as the most critical resource management has, and one which must be used wisely.

L.B.H.

Review: This article is *must* reading for reliability specialists working in military, industrial, or commercial product lines. Although it is directed to the non-military endeavors of the economy, those supplying the military establishment should read, understand, and act on its admonishments. This is particularly true at the present time, as the military agencies are concentrating on "Life Cycle Costing" which is equivalent to "Total Cost of Ownership." The author, in this general article, points out that returns, rejects, warranty repairs and guarantee payments for products not performing acceptably do in fact subtract from profit and thus cost the manufacturer money over and above the cost of inspectors, quality and reliability engineers. "Consumerism" is a new term, but in general it means that we in Reliability and Quality Control had better look at the product the way the customer sees it—does it do the job satisfactorily? The author does not discuss probability, reliability, specified or unspecified conditions, but he succeeds in demonstrating that "the customer is (still) *King*". The cost of quality is not only salaries and unrationalized returns, but includes many items which accounting does not record on balance sheets. Whoever your customer, read this article, as it puts in perspective many thoughts some of us have had for years.

R69-14691 ASQC 813; 864

A RELIABILITY PROGRAM FOR WIRING DEVICES.

Guy A. Goethner (Harvey Hubbell, Inc., Bridgeport, Conn.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 517–524. 7 refs.

Avail: $13.00

Background requirements are discussed and environmental tests are developed for wiring devices. Examples are presented for reliability test programs for switches and for the Ground Fault Circuit Interrupter (GFCI). Six regulatory organizations that influence the performance of electrical wiring devices through their codes and standards activities are described. A failure rate analysis is developed for ac switches and a reliability program for the GFCI. Environmental conditions are discussed for use at test sites and an evaluation program is described for the effects of air pollution, temperature, humidity, sunlight, and precipitation on the GFCI.

Author

Review: If one ignores the brief scrimmage with statistics, this paper can provide an insight into the reliability activities of the wiring device industry. Of the five organizations described which have an effect on the quality of wiring devices, only the Military Standards directly represent a user and the USASI does in part represent the user. It is rare, as evidenced in the aerospace industry, that reliability efforts are extremely effective without considerable user pressure. Not only must the pressure be there, but in the case of government agencies there must be considerable technical assistance as well. No mention is made in the paper of the company organization for reliability; rather the emphasis is on testing. The extreme difficulties of accelerating environmental tests are brought out and appropriately so. Many of these accelerated tests must be interpreted qualitatively and in an engineering sense, that is, they are used only to uncover potential failure modes. The statistical exercise in the paper leaves much to be desired, as the following examples show. (1) There was no reason why cycles had to be converted to time. A hazard rate presented in terms of per cycle is quite as acceptable in the electronics business as is one in units of time. (2) The exponential distribution has been presumed for life. One would expect, especially with the lives of the switches being so close together, that some kind of wearout distribution would have been much more appropriate, perhaps a Weibull or a Normal distribution. (3) Part of the discussion reads as if an accept/reject test is being described but apparently it is not. (4) The author does not distinguish between true parameter values and point estimates thereof. His reliability function uses the point estimate of the hazard rate rather than the true value and thus his conclusions are inaccurate. (5) If a Normal distribution is presumed for the switch lives, the estimated mean is 115 k cycles. The estimated standard deviation is 18 k cycles (there are two degrees of freedom). It is easily seen that this would vastly change the table of the reliabilities on page 521. The discussion about the hazard rate of the ground fault circuit interrupter uses far too many significant figures. The estimate of hazard rate was developed from MIL-HDBK-217A; such an estimate is ordinarily regarded as a ballpark estimate—which means that if it were within a factor of two, one would be very lucky. The number of significant figures in the paper presumes that it would be within 0.1% or closer. Perhaps the major concern of aerospace engineers when reading papers such as this is that they have not sufficiently well explained reliability activities to other industries. It is encouraging to know that these other industries are using reliability techniques and are concerned about the reliability of their products.

R69-14701 ASQC 810; 830

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

RELIABILITY

Seymour C. Himmel *In its* Selected Technol. for the Elec. Power Ind. 1968 p 139–156

(N69-12579) Avail: CFSTI

The NASA-developed methodology for improving and maintaining the reliability and quality of hardware is outlined, and an analogy is pointed out in the NASA reliability requirements and those of the electric power industry. The methodology encompasses design and test criteria as part of reliability engineering and such functions of quality control as specifications, process control, inspection, acceptance testing at all levels, closed-loop failure analysis, a corrective-action system, and stock control. K.W.

Review: This is a good introductory paper with regard to reliability. It does not make the mistake so many do of trying to introduce reliability mathematics which is often poorly explained and incorrectly applied and which the beginner cannot remember anyway. Rather, this paper does a good job of presenting the engineering and management skills that are required in order that the end product possess the desired reliability. It shows the difficulties involved in their application and the kinds of details to which one must pay attention in order to avoid pitfalls. This is a good article for a beginner or manager to read in order to have a better speaking acquaintance with the subject. He need have no fear that some details are wrong and that he must not remember them.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14644 ASQC 824

Joint Publications Research Service, Washington, D.C.

CALCULATION OF THE LOWER FIDUCIAL LIMIT FOR THE PROBABILITY OF TROUBLE-FREE OPERATION OF COMPLEX SYSTEMS, PART I

Yu. K. Belyayev, T. N. Dugina, and Ye. V. Chepurin *In its* Tech. Cybernetics, no. 2, 1967 11 Jul. 1967 p. 75–86 refs

(N67-35288)

A description of the algorithm is given for calculation of the lower fiducial bound of the probability of trouble-free operation of a system with respect to results from testing its components. The algorithm is intended for application in the situation of insufficient data on the reliability of the elements where the numbers of breakdowns recorded during tests run on the elements are small. The class of systems for which the proposed algorithm is applicable includes the systems of the series-parallel-series type with a loaded reserve. The statement of the problem, a short description of the concept on which construction of the algorithm is based are given, and also the results of numerical calculations obtained using a computer are presented. Author

Review: This paper gives a reference to a new method for calculating the lower confidence limit of the reliability of a redundant system which is made up of exponential elements. The algorithm is described in a continuation of this paper (see N67-35812, which is also reviewed in this issue of RATR). The principle of solution is to evaluate the system at the edges and nodes of a hypersurface in n-dimensional space (n is the number of different kinds of elements in the system). This procedure would be impossible even for the best computers when n is 10 or more. The problem is reducible to manageable proportions when the test results for many of the elements are the same, that is, several groups have the same number of failures. The authors' method uses this fact to enormously simplify the algorithm. An example comparing the results of this algorithm with four others shows that it gives a much higher lower bound for the confidence limit and thus is presumably better. The other four methods are not described too well but apparently those techniques which are more recently available in the American literature are not compared with this one. This method is different from those generally shown in the American literature. There, attempts are made to find an approximate distribution of the system hazard rate; that distribution is used for setting confidence limits. The new technique is one with which theorists should be familiar. Of course it cannot do anything about the usual situation wherein for a reasonable number of tests on the subsystem, the confidence bound tends to be very low merely because of the small number of failures. It should be emphasized that this technique is good even in the presence of redundancy, whereas the American methods generally have been developed only for series systems.

R69-14645 ASQC 824

Joint Publications Research Service, Washington, D.C.

CALCULATION OF THE LOWER FIDUCIAL BOUND FOR THE PROBABILITY OF FAILFREE OPERATION OF COMPLEX SYSTEMS, PART II

Yu. K. Belyayev, T. N. Dugina, and Ye. V. Chepurin *In its* Tech Cybernetics, no. 3, 1967 21 Aug. 1967 p 102–118 refs

(N67-35812)

The general methods of construction of fiducial sets and theorems are presented. Based on these data, the search algorithm for the minimum nonlinear function in a truncated rectangle is constructed. Author

Review: This article is a continuation of N67-35288 which is also reviewed in this issue of RATR; it provides the mathematical justification of the algorithm and more details of the algorithm. It is for theorists only; the material would be of no interest to reliability engineers or designers. Not all of the mathematics was checked but it appears to be competent. No general criteria are given for deciding when the algorithm will be successful. The algorithm is given in a rather general form, certainly not specific enough for a programmer to write a program for a computer. He will require the assistance of a competent theoretician. This algorithm is a valuable addition to the literature on finding confidence bounds for the reliability of systems. Those interested only in the general aspects of the problem should refer to the earlier work (Part I). This paper (Part II) also appears in *Engineering Cybernetics*, No. 3, 1967, p. 67–77.)

R69-14658 ASQC 823

Pennsylvania Univ., Philadelphia. Dept. of Statistics and Operations Research.

PROBABILISTIC MODELS OF DECREASING FAILURE RATE PROCESSES

John M. Cozzolino Repr. from Naval Res. Logistic Quart., v. 15, no. 3, Sep. 1968 p 361–374 refs Sponsored by Sylvania Applied Res. Lab.

(Contracts Nonr-1841(87); NR-042-230)

(NAVSO-P-1278)

The infant mortality effect observed in the statistical treatment of reliability consists of a decreasing with age of the conditional probability of equipment failure (failure rate). One widely applicable explanatory hypothesis is that of population heterogeneity. This is developed as a basis for several specific models of decreasing failure rate processes. Since, in the case of repairable devices, decreasing failure rate is often observed after the occurrence of failure and repair, consideration is extended to include repair in an explicit way. This union of failure and repair models is a fruitful one in view of the interaction between the two processes and gives a complete picture of the life of the device in terms of a stochastic process, usually with nonindependent interfailure times. Four models, of particular significance due to their plausibility, mathematical tractability, and frugality of parameterization, are presented. Author

Review: The paper presents an interesting discussion of four models for failure processes which lead to decreasing failure rates. The mathematical difficulty of the paper varies considerably from section to section; not all of the derivations were checked in detail. However, a good summary of the work is given and an extensive list of references (twelve) is supplied.

R69-14659 ASQC 820; 431; 615
Washington Univ., Seattle. School of Business Administration.
OPTIMAL RENEWAL POLICIES FOR COMPLEX SYSTEMS
Roger C. Vergin Repr. from Naval Res. Logistics Quart., v. 15, no. 4, Dec. 1968 p 523–534 refs Sponsored by Ford Found.
(NAVSO-P-1278)

Two dynamic programming replacement models for industrial equipment are presented. The first is used to determine the optimal replacement policy for multi-component equipment; the second, to determine the optimal replacement policy for a multi-machine system which uses one replacement crew to service several machines. In addition, an approach is suggested for developing an efficient replacement policy for a multi-component, multi-machine system. Author

Review: An interesting application of dynamic programming to finding optimal renewal policies is presented in this paper. The exposition is quite clear and two numerical examples help clarify the technique. The limitations of the procedure are fairly well pointed out. In general the paper may be recommended as good reading for the practitioner interested in optimal or near-optimal renewal policies for complex systems.

R69-14663 ASQC 824; 814; 831
National Aeronautics and Space Administration. Marshal Space Flight Center, Huntsville, Ala.
METHODS OF ESTIMATING THE ECONOMIC EFFECTIVENESS OF INCREASED RELIABILITY OF RADIOELECTRONIC SYSTEMS
V. G. Krivoruchenko and L. B. Sul'povar Redstone Arsenal, Ala. Redstone Sci. Infor. Center 18 Apr. 1968 21 p refs Transl. into ENGLISH from Standarty i Kachestvo (USSR), v. 8, 1966 p 49–54 Prepared for Army Missile Command
(NASA-TM-X-61022; RSIC-785; N68-29890) Avail: CFSTI

Cost calculation methods of projected radio electronic systems used for automation and control of production processes are described. Two methods of improving the reliability (improving the quality of the components and optimal reservation) are given, and their economic expediency is determined. Author

Review: The mathematical models for calculating costs are unsophisticated but not unreasonable. There are occasional misprints which cause the reader needless extra attention. The two symbols $l\eta$ should be ln for natural logarithm. The A_o in the middle of page 3 should be A_c. The Ai should be A_i. The capital A's are cumulative hazard functions and some of the calculations could be simplified if that were realized. The formulas could also have been simplified somewhat by using the cumulative hazard function in place of (1-P)/P in the cost formula on page 2. These two functions are reasonably close (certainly much closer than the model is accurate) especially for high reliabilities. The increased cost due to more reliable components and due to redundancy is calculated. Some reliability allocation is apparently contemplated and the cost of repairs and failures are considered. A minimum cost for the system vs. hazard rates is then calculated. As mentioned above, the mathematical models are elementary but straightforward. The translation itself is better than many but still uses language awkward enough so that beginners in the field will not find the paper profitable to read. Those who are familiar with these kinds of models will probably not find any new ones here, but may wish to read the paper to find out what other people are doing.

R69-14670 ASQC 824
ON MAXIMUM LIKELIHOOD ESTIMATES OF HALF-LIFE.
William J. McBride (Varian Associates, Palo Alto, Calif.).
(Institute of Electrical and Electronics Engineers, Annual Conference on Nuclear and Space Radiation Effects, University of Montana, Jul. 15–18, 1968.) IEEE Transactions on Nuclear Science, vol. NS-15, Dec. 1968, p. 350–351. 4 refs.
Army-Supported research.

A maximum likelihood estimate of half-life is obtained by considering the observed times of disintegration as a random sample from a truncated exponential continuous probability density function. The result is identical to that obtained by considering the individual disintegrations as discrete independent events which follow the laws of probability. Author

Review: This is a correct derivation of an irrelevant result. Even though the derivation is explicitly for radioactive decay, it obviously applies to any situation for estimating the parameter of the negative exponential distribution. The difficulty faced by the author is that he is confusing truncation of the distribution of the parent population with censoring of the sample data. For example, the author is not seriously proposing that the item began decaying at time T_1 and then absolutely stopped decaying at time T_2. He is referring instead to the period of observation. The correct maximum likelihood derivation for the exponential parameter shows that under almost any conditions of censoring, the maximum likelihood estimate of the constant hazard rate is the usual one. One of the ways to point out the difficulty faced by the author is to calculate the hazard rate which, for radioactive decay, is presumed to be a constant. It is not a constant for his function; thus this derivation, and any of the author's references which are based on the same principle as his derivation, should be disregarded as being in error. (Of course, if one did actually have the kind of distribution of the parent population wherein all were dead in a finite time and the density function were negative exponential over the region, the answer might be useful. But in this case, the answer one gets depends on the starting time as well as the stopping time, as it is fairly easy to show.)

R69-14672 ASQC 825; 817
OPTIMUM ALLOCATION OF STAND-BY SYSTEMS
M. N. Bhattacharyya (University of Queensland, St. Lucia, Brisbane, Australia).
Operations Research, vol. 17, Mar.–Apr. 1969, p. 337–343. refs.

With a view to ascertaining the optimum number of standby systems, a derivation is presented for the expected cost function for operating *n* independent systems for a time period of length *t*, with *s* spare systems available. Author

Review: This is a theoretical paper which calculates (a) probability of a certain number of failures under parallel redundancy, (b) expected downtime (assuming no repair up through time t), and (c) expected unused time for spares (called expected waiting time in the paper). The author then uses these results to generate a very simple linear expected-cost function. Independent Poisson behavior is presumed for each element. The results in this form appear to be new and can be of use to theorists who wish to generate their own cost functions or perhaps they will be used in some other way. The largest difficulty with any paper such as this is finding it when you need it. The mathematics was not all checked but appears to be competent.

R69-14676 ASQC 824; 831; 844
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
PATTERNS OF FAILURES
I. B. Gertsbakh and Kh. B. Korsonskii May 1968 167 p refs
Transl. into ENGLISH from the RUSSIAN
(AD-682237; FTD-MT-24-391-67; N69-21504) Avail: CFSTI

The book presents mathematical models of failures according to their various causes. The laws of time distribution of failure-free operation are obtained. With the help of the method of moments and the method of separating the normal distribution parameters into three groups for processing experimental data, procedures for evaluating systems parameters are established. The book is intended for persons dealing with the application of the probability theory to reliability problems. TAB

Review: This is a collection of failure models and the mathematics used to describe them. It is a good book. There seems to be nothing like it in the American literature. It deserves a better translation than the machine translation it now has. Minor bits of editing would also improve it. As is typical of this kind of translation, the equations are extremely difficult to decipher. If these defects could be overcome, it could well serve as intermediate training and reference material for reliability engineers.

R69-14677 ASQC 824
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
LEAST-SQUARES CONDITIONAL ESTIMATION OF THE LOCATION PARAMETER OF WEIBULL POPULATIONS
William J. Herman (M.S. Thesis) Jun. 1968 954 p refs
(AD-684696; GAW/MATH/68-1; N69-28836) Avail: CFSTI

The method of least-squares is used to develop linear, unbiased, conditional estimators for the location and scale parameters of the Weibull probability density function with known shape parameter. Tables are provided for computing estimators from 1 order statistics selected from the m smallest values of a sample of size n. A method is presented for computing simultaneous estimators directly from the conditional-estimators. The tables include sample sizes from 2 to 13 for eleven values of shape parameter—0.5(0.25)2.0(0.5)4.0. TAB

Review: This is yet another of the theses on estimating parameters of distributions which are useful in reliability work. The discussion of the principles involved is informative but a familiarity with matrix methods is essential for understanding it. The tables themselves of course can be used without any knowledge of the methods used to derive them. In general, it will be necessary to read the text for explanations of using the tables. In particular, this is so if one wishes to estimate simultaneously the location and scale parameters. The shape parameter must be known in advance and be one of those values for which the tables are formulated. In most cases in practice, one will wish to make the simultaneous estimation of the location and shape parameters because he will not know either of them. In fact, the chances are he will be guessing at the shape parameter itself since it will not be known a priori. What is needed now is in up-to-date listing of all of the tables that are available in the series. This would be most helpful to reliability engineers since these sets of tables are quite valuable.

R69-14679 ASQC 824
Boeing Scientific Research Labs., Seattle, Wash. Mathematics Research Lab.
COHERENT LIFE FUNCTIONS
J. D. Esary and A. W. Marshall Apr. 1969 13 p refs *Its* Mathematical Note no. 596
(D1-82-0833)

The life function of a system expresses the life length of the system in terms of the life lengths of its components. The application of life functions to reliability problems is illustrated. The principal results are two characterizations of the life functions of coherent systems, which are used to obtain a number of properties for such systems. Author

Review: This report presents basic research on the fundamentals of reliability theory. Although "higher mathematics" is not used, it is, from a reliability viewpoint, quite abstract and will require considerable mathematical maturity to follow the proofs given. The ideas presented are quite interesting and we can look forward to further research and applications on the topics introduced here.

R69-14680 ASQC 824
California Univ., Berkeley. Operations Research Center.
A SYSTEM DEBUGGING MODEL
Richard E. Barlow, Frank Proschan (Boeing Sci. Labs., Seattle, Wash.), and Ernest M. Scheuer (RAND Corp., Santa Monica, Calif.) Apr. 1969 19 p refs
Contract (Nonr-3656(18))
(ORC-69-6)

The debugging of a new complex system during the initial period of its total life is described. During this period failures and errors are corrected as they occur, with resulting improvement in subsequent performance of the system. One mathematical idealization of this process leads to the assumption that system failure rate is decreasing with time. In practice, the debugging phase is considered completed when the failure rate reaches an equilibrium or constant value. Models are formulated for this phenomenom. Maximum likelihood estimates are obtained for relevant failure rate functions and for the end of the debugging period. A conservative upper confidence bound on the stable failure rate is obtained. Author

Review: The latest chapter in a very fruitful area of research associated with these authors (and others) is presented in this report. The flavor of this particular report is rather practical with several numerical examples being given. Many of the mathematical proofs mimic earlier ones to such an extent that they are not included. Although the estimation procedures given are maximum likelihood and are shown to have good limiting properties (as the sample size tends to infinity), one wonders a bit about their behavior for samples of small and moderate size.

R69-14681 ASQC 824

California Univ., Berkeley. Operations Research Center.

ASYMPTOTIC PROPERTIES OF ISOTONIC ESTIMATORS FOR THE GENERALIZED FAILURE RATE FUNCTION. PART 1: STRONG CONSISTENCY

Richard E. Barlow and Willem R. Van Zwet (Centraal Reken-Inst., Der Rijksuniversiteit Te Leiden, The Netherlands) Mar. 1969 25 p refs

(Contracts (Nonr-3656(18); Grant GK-1684)

(ORC-69-5)

A general class of isotonized fixed and random window estimators are proposed and studied. By appropriate choice of the window size, the maximum likelihood estimators are improved asymptotically. Strong consistency is proved for isotonic window estimators generalizing and simplifying previous proofs. Strong consistency is proved for a class of isotonic estimators when the basic estimator is strongly consistent. Author

Review: This is a highly mathematical paper and will appeal only to those versed in the appropriate technical methods of statistics and probability theory. Several interesting asymptotic results are established and one hopes that some guide as to which estimator is "best" for fixed (moderate) sample sizes may be forthcoming through future research.

R69-14682 ASQC 824

California Univ., Berkeley. Operations Research Center.

ASYMPTOTIC PROPERTIES OF ISOTONIC ESTIMATORS FOR THE GENERALIZED FAILURE RATE FUNCTION. PART 2: ASYMPTOTIC DISTRIBUTIONS

Richard E. Barlow and Willem R. van Zwet (Central Reken-Inst. Der Rijksuniversiteit Te Leiden The Netherlands) Apr. 1969 29 p refs

(Contract Nonr-3656(18); Grant GK-1684)

(ORC-69-10)

A general class of isotonized fixed and random window estimators are proposed and studied. These include maximum likelihood estimators previously studied. By appropriate choice of the window size, the maximum likelihood estimator is improved asymptotically. For wide windows the isotonic estimators are shown to have, asymptotically, normal distributions. This is not true for the maximum likelihood estimators. Author

Review: As with Part I of this report (see ORC 69-5 also reviewed in this issue of RATR), the mathematical ability needed for its comprehension is considerable. Two rather distinct estimation procedures are considered—those based on "wide windows" and those based on "narrow windows." The results for the first case are quite useful in that they involve limiting Normal distributions. However, the limiting distributions for the second case involve solutions of the "heat equation" and are thus not too tractable.

R69-14695 ASQC 824

INFORMATION AND SAMPLING FROM THE EXPONENTIAL DISTRIBUTION.

G. M. El-Sayyad (King Saud Univ., Riyadh, Saudi Arabia). *Technometrics,* vol. 11, Feb. 1969, p. 41–45. 8 refs.

Methods of sampling an exponential population in order to obtain a prescribed accuracy in the determination of the unknown parameter are discussed. The concept of information due to Shannon is used and it leads to well known schemes. Author

Review: The exponential distribution has long held a preferred position in reliability because of its tractability, its being a one-parameter distribution (the data generally are so sparse that more complicated hypotheses cannot be justified). Therefore an article is worthwhile when it expands our understanding of sampling from populations which are represented by the exponential distribution. This paper is decidedly for the theorists; the practicing reliability engineer and designer will get little from it. The person who wishes to use this work as a base upon which to build should be aware of its limitations; for example, the conjugate family of priors is used and complete ignorance is represented by the uniform distribution. The introduction of $\phi(\theta)$ about which information can be evaluated is logically equivalent to choosing a different state for initial ignorance. The results themselves are useful since they show particular sets of assumptions to which sampling plans are logically equivalent. This kind of knowledge often helps us make up our minds on just what kinds of sampling plans we wish to use, since we can appreciate more of their logical implications. E. T. Jaynes, in his work on maximum entropy formulations, has considered similar problems but from a slightly different point of view.

R69-14696 ASQC 824; 224; 412

SEQUENTIAL RELIABILITY ASSURANCE IN FINITE LOTS.

K. T. Wallenius (Clemson Univ., S.C.)

Technometrics, vol. 11, Feb. 1969, p. 61–74. 11 refs.

Sequential stopping rules are developed which assure fixed length lower confidence limits on lot reliability when inspection is of the rectifying type. Several models of production processes are defined and analyzed, including (1) a nonparametric model, (2) parametric models, and (3) parametric models with prior distributions. Author

Review: This is a highly theoretical paper. It analyzes a particular model of a portion of a reliability assurance program and is an extension of previous work by the same author. He uses "successive minimization" for selecting the stopping boundaries for a class of sequential rectifying inspecting plans. These plans guarantee lower confidence bounds on the outgoing quality of finite lots. There is an error in this paper in that S_d is defined as "the event $\tilde{n} = n_d$." In the previous paper, S_d is defined as "the event that sampling stops at (n_d, d)." These two conditions are not equivalent; so both cannot be necessary and sufficient for the same result. If the new definition is used, then the proof of Theorem 2 is not valid. If the old definition is used, the proof of the theorem is valid. The present paper extends the earlier work in the following two directions. (1) It gives alternate methods for constructing the stopping boundaries for the non-parametric model. (2) It introduces two new models to "explain" the variation of lot quality. It is doubtful whether the second extension adds much to the practical utility of this type of rectifying inspection plan because of the difficulty of knowing the prior distribution well enough. As is usual in such papers, the human aspects of sampling in the rest of the sampling/inspection system are assumed to be perfect. As a practical matter, these assumptions are rarely true and are often false enough so that it does not pay to refine a sampling procedure too far. (The identical paper appears as Technical Report No. 1, Department of Mathematics, Clemson University, Clemson, S. C. and also as Technical Report No. 135, Department of Statistics, Stanford University, Stanford, California, 1968; AD 669 791.)

R69-14698 ASQC 824

RAND Corp., Santa Monica, Calif.

CONSTRAINED MAXIMUM LIKELIHOOD ESTIMATION OF N STOCHASTICALLY ORDERED DISTRIBUTIONS

A. M. Geoffrion Jul. 1968 43 p refs

(Contract F44620-67-C-0045)

(AD-672954; RM-5683-PR)

The problem is considered of determining step function maximum likelihood estimates for *n* stochastically ordered distributions, subject to the constraint that the estimates themselves must also be stochastically ordered. This problem arises, for example, in the context of reliability growth. A new analytical method is presented, based on the Kuhn-Tucker optimality conditions for the concave program. For N = 2, the method yields the closed form solution, and for N $\geq$ 3, the method yields an efficient computational algorithm. The algorithm involves solving a short sequence of essentially unconstrained sub-problems with many fewer variables. Computational experience is presented showing that large problems can be solved in reasonable time with good accuracy, especially when compared with the performance of a general nonlinear programming algorithm applied directly to the concave program. The results should interest those concerned with solving large structured nonlinear programs, since the reduction strategy used is of quite general applicability. Author

Review: This Memorandum is part of the continuing work of The RAND Corporation in reliability assessment. For related earlier work see, for example, the report covered by R67-13101. The present report includes, in addition to the mathematical development of the method, a section on computational experience. It will thus be of interest to statisticians and also test engineers concerned with reliability growth. A companion Memorandum by S. P. Azen (RM-5536-PR, Jul. 68, AD-672956) documents the computer code which implements the computational approach devised in this report.

R69-14699 ASQC 824; 412; 413; 422

Wisconsin Univ., Madison. Mathematics Research Center.

HYPOTHESIS TESTING AND CONFIDENCE INTERVALS FOR PRODUCTS AND QUOTIENTS OF POISSON PARAMETERS WITH APPLICATIONS TO RELIABILITY

Bernard Harris Aug. 1968 17 p refs

(Contract DA-31-124-ARO(D)-462)

(AD-679925; MRC-TSR-923; N69-17361) Avail: CFSTI

Confidence intervals and tests of hypotheses for the parameter theta =(lambda sub 1)(lambda sub 2) . . . (lambda sub k sub 1)/(mu sub 1)(mu sub 2) . . . (mu sub k sub 2) are obtained, where lambda sub i, mu sub i are Poisson parameters. This problem is of importance in reliability analysis. Author (TAB)

Review: Confidence intervals and tests of hypotheses are obtained for the parameter $\theta = \lambda_1\lambda_2 \ldots \lambda_{k_1}/\mu_1\mu_2 \ldots \mu_{k_2}$, where λ_i, μ_j, i = 1, 2, . . . , k_1, j = 1, 2, . . . , k_2 are each Poisson parameters. The mathematical development is concise and the underlying assumptions are clearly stated. The applications to reliability promised in the title are accomplished by using the procedures described in the paper as approximate techniques for analyzing binomial data. This introduces the additional assumption that the binomial parameters considered are such that the Poisson approximation to the binomial is satisfactory. The author does not elaborate on this, and even in the section on applications, the orientation is strictly mathematical. Thus the paper will be of interest to other theoreticians rather than to practicing reliability analysts. The following statement on p. 11: "In reliability analysis a mechanism may fail if and only if each of k components fail" is presented without qualification as though it were a general truth. If the author wished, as implied, to give a concrete illustration, he should have specified the type of system to which this statement applies.

R69-14702 ASQC 821

Southern Methodist Univ., Dallas, Tex. Dept. of Statistics.

APPROXIMATIONS TO LARGE PROBABILITIES OF ALL SUCCESSES FOR GENERAL CASE AND SOME OPERATIONS RESEARCH IMPLICATIONS

John E. Walsh and G. J. Kelleher 20 Feb. 1969 8 p ref

(Contract N00014-68-A-0515)

(AD-684427; TR-25)

Situations are considered in which an overall effort is successful only when the efforts (or events) of a sequence are all successful. Often the principal interest is in cases where overall success has a large probability. An approximate value, and sharp upper and lower bounds, are developed for the probability that all events are successes. This is done for various levels of generality, including a form of complete generality. The results are useful when the probability of all successes is at least .8; then the approximate value is near both bounds. Optimum allotment of resources is considered to obtain a stated high probability of all success. Author

Review: The formulas in this paper are upper and lower bounds for the product of n numbers (which are between 0 and 1) when it is known that (a) r out of the n numbers (0 < r < n) are not greater than the arithmetic mean of the numbers, and (b) this arithmetic mean is known, and (c) the mean is reasonably close to one. The details were not checked, but the formula appears reasonable. Very often, in the situation where the arithmetic mean is very close to unity, one is interested not in the product of these probabilities, but in 1 minus the product (the probability of failure rather than the probability of success). Even for this situation, the ratio of "1 minus lower bound" to "1 minus upper bound" is still reasonably close to one under the stated conditions. The authors give some illustrations of situations wherein their formula is useful. Obviously, it is not useful whenever one does not wish to include the arithmetic mean in the formula. The author in a private communication has indicated that this paper has been published in the *Journal of the Operations Research Society of Japan*, vol. 17, 1969, pp. 114–118.

R69-14704 ASQC 824; 431; 872

Research Analysis Corp., McLean, Va.

A RENEWAL THEORETIC APPROACH TO THE ESTIMATION OF FUTURE DEMAND FOR REPLACEMENT PARTS

Richard M. Soland Reprinted from Operations Res., v. 16, no. 1, Jan.–Feb. 1968 p 36–51 refs

(RAC-TP-261)

A renewal theoretic approach is presented for the determination of the probability distribution of the demand for replacement parts in a specified future time interval. Ordinary, modified, and equilibrium renewal processes are discussed as models for physical processes in which parts are replaced as they fail. Some results from renewal theory are stated and then used to estimate the demand for replacement parts under a number of different conditions. Practical difficulties and ways to circumvent them are discussed, and an illustrative example is included. Author

Review: This paper is useful for the following reasons. (1) It gives a very brief summary of some of the pertinent results of renewal theory for calculating the number of spares. (2) It shows how this theory is used in actual situations. (3) Appropriate cautions are given for circumstances wherein the theory as developed will not hold. A later publication by the same author [1] summarizes the above theory and gives extensive tables for two reliability functions. The Weibull distribution, so popular in reliability theory, is used for some of the tables and the gamma distribution for the rest. Even though it is doubtful that the necessary assumptions will be fulfilled in any specific case, the theory and tables can be used to get an idea of the number of spares required. In particular, by appropriately choosing various parameters, one can run a sort of sensitivity analysis to get an idea of the range of numbers that might be expected in practice. Within its stated limitations, it is a good paper.

Reference: [1] Soland, Richard M., "Renewal functions for Gamma and Weibull distributions with increasing hazard rate," *Research Analysis Corporation Technical Paper* RAC-TP-329, Aug 68 (AD-675 424).

83 DESIGN

R69-14646 ASQC 830; 844; 851
ACHIEVING DESIGN RELIABILITY THROUGH FAILURE ANALYSIS.
J. J. Bussolini, (Grumman Aircraft Engineering Corp., Bethpage, N.Y.).
In: Seminar on Failure Analysis, 1968, Philadelphia, May 21, 1968. Seminar sponsored by IEEE Philadelphia Section and Reliability Group. p. 1–5.

Failure analysis alone has no effect on the attainment of design reliability. It is only when an effective failure analysis program is coupled with a well planned operation or test program and followed by a coordinated analysis and design feedback effort that its true value is derived in terms of cost effective reliability achievement. When properly applied, test and failure analysis efforts have increased reliability as much as ten to one over the course of a developmental cycle. Some of the statistics that tend to justify these conclusions are presented. Author

Review: The message of this paper is that failure analysis is a waste of time unless the results of that analysis can influence the way the equipment is made; the sooner in the life cycle the tests which result in these failures are performed, the more effective this knowledge will be. The message is a good one. Those who are not yet convinced can read the paper where the message is repeated and illustrated several times. For those who are already convinced, there is no need to read the paper.

R69-14661 ASQC 835
PLASTIC IC'S DEMAND NEW PHYSICAL.
Lawrence Curran ed.
Electronics, vol. 42, May 12, 1969, p 147–153.

The potential of plastic-packaged high reliability integrated circuits (IC) for military use is discussed with representative comments of both buyers and sellers. Varying environmental conditions, particularly moisture, are considered as a significant problem area and associated plastic IC research and evaluation testing is debated. Various checks are suggested to screen plastics for military applications, but their value is in dispute. It is concluded that, although many problems remain to be solved, there is improvement in IC qualification and in vendor attitude. L.B.H.

Review: This is a good article. It presents the arguments on both sides of the plastic encapsulation controversy and shows what each side is trying to do and how they are trying to do it. The article is as fair as any can be under the circumstances. This subject is of intense current interest and it is good to see a survey article in addition to those put out by one side or the other. A recent one by RADC authors is [1]. The problem of accelerated testing is the most important one and moisture in particular is the damaging environment. The big question to be decided is, "Does increasing the humidity and temperature accelerate the test reasonably, or does it introduce an entirely new failure mode?" The user of course has the final responsibility for deciding whether the plastic encapsulation is good enough and the manufacturers are almost in the position of interested kibitzers (they have important and useful things to say, but theirs is not the final responsibility).

Reference: [1] "Failure mechanisms in plastic encapsulated microcircuits," by A. L. Tamburrino and V. C. Kapfer, Proceedings of the 1969 Spring Seminar on Reliability, Maintainability, Reliability Chapter, Boston Section, IEEE, Apr 69, pp. 79–89.

R69-14664 ASQC 838
ESTIMATING THE OPTIMUM POSITION FOR RESTORING ORGANS IN NON-CASCADED REDUNDANT NETWORKS.
C. S. Repton (University of Birmingham, Dept. of Electronic and Electrical Engineering, Birmingham, England).
Microelectronics and Reliability, vol. 8, Feb. 1969, p. 23–31 7 refs

The design of redundant circuits which use separate error-correcting elements, or restoring organs, is discussed for networks with an arbitrary configuration. A search procedure, which can be implemented on a digital computer, is described. This technique can be used to indicate the most effective sites for the restoring organs so that the reliability of the network can be maximized for a given number of error-correcting circuits. Author

Review: This is a theoretical paper and is sufficiently terse so that the details are understandable only to a theorist who is quite familiar with the problem. There are no proofs that the algorithms are correct, although there is no reason to presume that they are not. Presumably, the symbol ${}^{m}C_{n+1}$ is the binomial coefficient for m things taken n+1 at a time. Apparently, it is a constant for any complete set of calculations; that is, the m and n are not functions of anything but are constants for an entire problem (in which case it is not clear why the coefficient is not factored out). The technique is worth analyzing by theorists, first of all to see that it does what it is intended to do and second as a practical approach to some kinds of problems. (An earlier paper by the same author dealing with cascaded redundant networks was covered by R68-13880.)

R69-14667 ASQC 830; 844
STATIC INVERTERS IMPROVE CONTROL RELIABILITY.
Robert W. Rosko (Public Service Electric and Gas Co., Electric Engineering Dept., Newark, N.J.).
Western Electric Show and Convention, Aug. 20–23, 1968, Paper. 15 p.

Various types of static inverters and inverter systems are described which have been developed to meet the critical requirements of power applications of a public utility company system. Performance of the inverter systems, problems encountered, and their solutions are reviewed. Author

Review: This paper is largely a case history which shows the outlines of the development processes through which the static inverters had to go before they were reliable. After they were debugged, the downtime has been less than 0.1%, which is considered good. The bugs in the design show the kinds of detail to which one must pay attention if he wishes to avoid such things. Management will usually have to decide how important it is that the unit work the first time. Then a decision can be made whether it will be cheaper to build and debug the units, or to analyze them on paper and try to debug them that way. Some of the failure causes were such simple things as inrush load current's being different from steady-state load current. The written paper will be of interest largely to designers and users of static inverters.

R69-14678 ASQC 831; 838
A METHODICAL APPROACH TO ANALYZING AND SYNTHESIZING A SELF-REPAIRING COMPUTER.
Douglas C. Dorrough (Louisiana State Univ., Dept. of Philosophy and Computer Science, Baton Rouge, La.).
IEEE Transactions on Computers, vol. C-18, Jan. 1969, p. 22–42. 120 refs. Research sponsored by McDonnell Douglas Corp.
(A69-25941)

Solution of problems of computer reliability by the development and methodical employment of a comprehensive systems-effectiveness measure. It is considered that no method exists for determining which self-repair techniques, taken singularly or in combination, provide the greatest improvement in reliability; which methods are optimum for initiating fault diagnosis and self-repair by redundancy and replacement; what constitutes a closed set of self-repair techniques and what theory can be formulated to demonstrate the completeness of the set; and the effect of self-repair on the total system relative to design, maintenance, availability, etc. IAA

Review: This is an excellent paper. The material, intended for both theorists and designers, is very clearly and thoroughly presented. The system the author uses of dividing and redividing the work into sub-heads makes it easy to return to the paper to find a given topic. The technique of relegating the example to an appendix makes the body of the paper more concise. The bibliography is outstandingly good. The techniques described by the author for achieving self-repair, and the use of his measure of system effectiveness are very valuable. On the whole, this is a well-written and well-organized paper, useful as a tool and a reference.

R69-14686 ASQC 831; 832; 843; 853; 400; 523; 551; 612
INFORMALYTICS.
Harold R. Leuba (Defense Dept., Washington, D.C.).
In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p 277–281. 2 refs
Avail: $13.00

Informalytics, a coined word referring to the use of information theory as an analytic tool to evaluate data, is described. The technique itself is discussed, as well as the data requirements necessary to use it and a summary of the results of one application of it. Informalytics includes the application of information and uncertainty measures as techniques for assessing correlation, dependence, and structure, and it also includes the statistics necessary to evaluate the likelihood implications of any particular observations. It is concluded that the value of informalytics lies in its ability to measure the relative impact of selected variables upon a stated criterion; that is, to measure the size of a problem. L.B.H.

Review: This is a good, interesting article. It is not a rigorous derivation of an analytic technique but is rather an explanation of one. The rigorous derivation may not even yet exist although the method clearly has intuitive appeal, and one can easily get the feeling that the rigor can be supplied if one is willing to spend the time and effort on it. Clearly, the latter would be a useful and important thing to do. The ultimate worth of the technique depends on how useful people find it for ascertaining where to look for difficulties. Nevertheless, a rigorous background for it will assist in expanding opportunities for application. It is also quite possible that with a rigorous background one can show in what way it is related to traditional statistical procedures. Regardless of the above pros and cons, this is a technique with which reliability engineers should be familiar and about which they can easily become enthusiastic.

R69-14688 ASQC 833; 712; 837
UNDERSTANDING AND PREVENTING INTEGRATED CIRCUIT PROBLEMS.
Robert E. Roberts (Motorola, Inc., Reliability and Components Engineering, Scottsdale, Ariz.).
In: Annual Technical Conference Transactions, 23rd; Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p 305–311.
Avail: $13.00

Semiconductor integrated circuits and discrete semiconductor devices are reviewed with respect to similarities in materials, processing, and environmental capabilities. Common failure modes are tabulated to again show similarity to discrete devices, as well as describe differences. Several specific troublesome failure modes are analyzed as to cause. Detection methods and preventative measures are covered as applicable. Testing complexity is discussed with respect to present integrated circuits and the relationship to medium and large scale integration. Author

Review: This is a good paper. It is written in a language that the non-expert can understand and discusses well the difficulties that can be experienced with semiconductor devices, especially integrated circuits. For additional ease of learning, the integrated circuit properties are compared with those of discrete devices. Designers and reliability engineers who are becoming acquainted with integrated circuits would do well to be aware of the contents of this paper and even those with some experience might benefit by comparing that experience with the lists given in the paper. The discussion of plastic encapsulation is mostly negative although the reasons are given for that point of view. Not all difficulties that can be experienced with integrated circuits are mentioned, but they would make an inordinately long list and not be suitable for introductory material.

R69-14697 ASQC 830; 612

Sperry Rand Corp., Philadelphia, Pa. Univac Div.

DEVELOPMENT OF A COMPUTER PROGRAM FOR GENERATING TROUBLE-SHOOTING DECISION TREES Final Technical Report, 1 Apr. 1966–31 Mar. 1967

T. J. Barry Hannom, Anthony J. Azzari, Alan I. Brooks, John R. Hunter, Leon Steinberg et al Wright-Patterson AFB, Ohio AMRL Sep. 1967 273 p refs

(Contract AF 33(615)-3666)

(AD-664603; AMRL-TR-67-83; N68-18775)

The general properties of troubleshooting decision trees are enumerated in detail, and the assessment of various, proposed algorithms for generating cost optimized trees is described. This assessment resulted in the selection of two algorithms (entropy and Cohn-Ott methods) for subsequent use in the set of programs developed. A Tree Building routine was designed so the user can select which algorithm is to be used on a given run or when to switch from the entropy to the Cohn-Ott method when their joint use is desired. Two additional programs (the Digital and Analogue Test Criterion Generators) were written to help the user determine the tolerance limits for a particular test. From the output of these routines, the user should be able to more easily construct the input to the Tree Building routine. Other input data required for running the Tree Building program include: (1) failure probabilities, and (2) time estimates of the testing subtests for each test. A demonstration test was completed and is described showing how the programs would be used. Input data were prepared using the Current Reference module of Tracking Antenna Electronic Amplifier (for the MG-13 fire control system of the F-101) as a representative equipment item. An explanation of the computer output is given, and the flow charts and listing for each of the programs developed in this study are documented. Author (TAB)

Review: This report is intended to "serve as a basic operator's manual for the project engineer" and to "acquaint the test/checkout engineer with a new tool for constructing test procedures." It fulfills both of those purposes admirably. The material is clearly presented, although for some purposes the authors go into too much detail. The mathematics in the paper was not checked in detail, but appears reasonable. The technique of presenting an overview of the state-of-the-art, followed by an overview of the work to be presented in the report, orients the reader and makes the report more useful. This is a very easy paper to read. The bibliography is excellent.

R69-14700 ASQC 830

ADAPTIVE COMPUTERS.

Melvin A. Breuer (University of Southern California, Dept. of Electrical Engineering, Los Angeles, Calif.).

Information and Control, vol. 11, Oct. 1967, p 402–422. 10 refs.

(Grants AF AFOSR-496-67; AF AFOSR-68-1287)

(A68-23159; AD-670887)

Discussion of some design aspects of a computer which has two new modes of operation. One new mode of operation is the computers' ability to carry out useful computation even when component failures are present. This operation may be achieved at the expense of computational rate of accuracy. The ability to achieve this mode of operation is called graceful degradation, and its implementation differs from the redundancy techniques normally used to increase the reliability of a computer. The second mode of operation consists of the computer's ability to automatically increase the throughput at the expense of computation time and accuracy. Both hardware and software procedures for accomplishing these goals are outlined. The results of this work are applicable to the design of those spaceborne computers which need to be operational for long periods of time, such as a year or two. IAA

Review: This paper, while available for some time in the journal literature, has only recently become available from CFSTI. It is a good paper and tries to improve a system by changing the figure of merit for it. An analogy to people which the author makes is "if a man cannot walk, perhaps he can limp." Some details about restructuring the design and software of the computer for this purpose are given. Using another of the author's analogies, perhaps the computer can be taught to *hurry*. In the *hurry* mode, it would do the same kinds of calculations as before but with less precision and possibly a greater chance of making errors. These kinds of considerations, which the author studies and illustrates, are very worthwhile in trying to create equipment which will have a very long life. Before the concepts can be completely implemented, a great deal of time and effort will have to be spent in analyzing them, but this time and effort will be very profitable. It is often in this kind of redirection of goals, in being able to find a way to be satisfied with something less than perfection, that important advances can be made in creating high reliability.

84 METHODS OF RELIABILITY ANALYSIS

R69-14647 ASQC 844

DETECTION AND CORRECTION OF MATERIAL PROBLEMS VIA ANALYSIS OF FAILURES.

James A. Clanton (Radio Corp. of America, Defense Electronic Products, Camden, N.J.)

In: Seminar on Failure Analysis, 1968, Philadelphia, May 21, 1968, Seminar sponsoree by IEEE Philadelphia Section and Reliability Group. p 7–10.

Organic and metallic material problems are described and some solutions discussed. Failure analysis is acknowledged to be a valuable aid in detecting causes and making solutions evident. Details are presented for the solution of several problems: soldered Kovar lead failures, cracked solder joints, tantalum capacitor electrolyte leakage, explosion-supporting components, resin-starved printed wiring board laminates, and potting units with the wrong resin system. L.B.H.

Review: This is another paper about *horrible hardware*. Seven examples show problems which were not anticipated in design and which were cured by finding the cause of failure and then redesigning. Not only is this kind of paper good for younger engineers (since they may not realize how simple-minded their conceptual models of electronics are and that there are many things they do not know), but also for more experienced ones who may have forgotten that designers do make avoidable mistakes and that their checklists can be profitably expanded to include more details to which attention should be paid. The paper is brief and to the point. There are no photographs.

R69-14649 ASQC 844; 775

INTEGRATED CIRCUIT FAILURE ANALYSIS TECHNIQUES.

R. H. Soltau (Philco-Ford Corp., Microelectronics Div., Blue Bell, Pa.).

In: Seminar on Failure Analysis, 1968, Philadelphia, May 21, 1968. Seminar sponsored by IEEE Philadelphia Section and Reliability Group. p 25–30.

Through failure analysis, considered indispensable for rating and predicting the reliability of semiconductor devices, is discussed in terms of analysis techniques. Report forms, with simple, carefully formulated checklists, are found to be essential tools for applying failure analysis data to reliability computation and are found to release engineering personnel from tedious testing and recording duties. The standardized forms record significant background information on devices and fabrication methods, as well as the results of visual inspection, X-ray analysis, electrical measurements, leak tests, internal visual inspection, probing, scratch depth measurements, pinholes and oxide contact cuts, and infrared probing. L.B.H.

Review: This is a very brief paper giving barely more than a list of overall techniques for analyzing failures in integrated circuits. The report form itself is considered to be very important and a sample is shown. Five photographs of various kinds of failed devices are given. In Figure 8, it is not obvious where the crack on the chip is located and in Figure 9, it is not obvious what it is supposed to show. It is not clear whether this is the kind of failure analysis that is supposed to be performed by a user in order to uncover the Manufacturer's mistakes or whether this is a preventive program by the manufacturer to improve his product. In brief, while this might have been an interesting and useful talk, the paper itself will serve as an introduction only to those who are virtually uninformed in this area. The material that does appear is competent. (This is the kind of paper to be expected in view of the instructions given to speakers at this seminar.)

R69-14650 ASQC 844; 851

INTEGRATED CIRCUIT FAILURE ANALYSIS AS A PRODUCTION TOOL.

P. V. Gott (Philco-Ford Corp., Microelectronics Div., Blue Bell, Pa.).

In: Seminar on Failure Analysis, 1968 Philadelphia, May 21, 1968. Seminar sponsored by IEEE Philadelphia Section and Reliability Group. p 31–34.

A failure analysis program is examined from such standpoints as (1) how necessary it is to integrated circuit (IC) production, (2) what its objectives are, and (3) why most high reliability IC procurements specify reliability and corrective requirements. Current areas for which IC failure analysis is used are outlined, and the purposes which it serves are illustrated. Several examples are included to show the effective use of failure analysis. L.B.H.

Review: This is a companion paper to the one immediately preceding it in the Seminar Proceedings and is also quite brief. It shows by example how the manufacturer of integrated circuits can improve them by analyzing failures and by creating these failures with over-stress testing. For those who are not aware that this is a useful procedure (regardless of the product), the paper will be of value. It should be noted that this kind of procedure is standard in the development of many products, and has been so for years, especially in the mechanical field.

R69-14651 ASQC 844

INTEGRATED CIRCUIT FAILURE ANALYSIS TECHNIQUES.

C. D. Root and John Gaffney (Raytheon Co., Space and Information Systems Div., Sudbury, Mass.).

In: Seminar on Failure Analysis, 1968, Philadelphia, May 21, 1968. Seminar sponsored by IEEE Philadelphia Section and Reliability Group. p 35–62. 7 refs.

Three items common to failure analysis laboratory activity are discussed. The first concerns the analysis of nor gate failures from a module. Shunting paths through parasitic elements in the integrated circuit led to some unusual failures when the devices were subjected to overstress due to static charge. The second item deals with the common problem of contact resistance in integrated circuits, and describes a method of measuring these resistances. The last item concerns the mechanisms which can lead to degradation of hFE in transistors. A practical example is considered and the steps used in determining the specific mechanism causing the problem are presented. While this example was concerned with discrete switching transistors, the general method may be used in analyzing similar problems in many integrated circuits. Author

Review: This paper, in contrast to the two others on integrated circuits in this same Seminar Proceedings, intensively discusses three particular case histories— —two of them in integrated circuits, one in discrete devices (although the latter presumably also appears in integrated circuits). The three cases show many of the trials and tribulations, not to mention false starts, that are involved in some failure analyses. The authors have not mentioned those analyses wherein the problem was handled in a straightforward, quick manner. This paper will be of value to reliability engineers and integrated circuit designers both for the nature of the failures themselves and in the descriptions of the techniques used to find them. The paper is accompanied by many good photographs; in most of them, it is reasonably easy to see the point the authors are trying to make.

R69-14652 ASQC 844; 775

THE USE OF THE SCANNING ELECTRON MICROSCOPE IN ANALYZING MICROCIRCUIT FAILURES.

Robert J. Anstead (NASA, Goddard Space Flight Center, Greenbelt, Md.).

In: Seminar on Failure Analysis, 1968, Philadelphia, May 21, 1968. Seminar sponsored by IEEE Philadelphia Section and Reliability Group. p 63–69. 4 refs.

The scanning electron microscope (SEM) has proven itself as an effective instrument in analyzing microcircuit and transistor failures. The wide magnification range, low limit of resolution, and in particular, wide depth of field of the SEM have enabled the investigator to diagnose many failures which hitherto either went undetected or were simply postulated. Included in these failure modes have been such circuit problems as opens in the evaporated interconnect, anomalies in the wire bonds, extraneous diffusions, etc. Photographs taken using the SEM are included and the correlation between the detail available in these pictures and the physical phenomena causing the failure is also given. Author

Review: This is a very short paper which, in contrast to the others at this Seminar, discusses in some depth the application of a particular instrument. The properties of the scanning electron microscope are given only very briefly, although three references for supplementary reading are listed. Reliability engineers and those involved in the manufacture of integrated devices will find the paper of value if they are not already familiar with this instrument. To those who are familiar with the instrument, the paper will have no value. There are some excellent photographs, most of which are reproduced well.

R69-14653 ASQC 844

USING FAILURE ANALYSES TO PREDICT RELIABILITY.

Bernerd Tiger and David I. Troxel (Radio Corp. of America, Defense Electronic Products, Camden, N.J.)

In: Seminar on Failure Analysis, 1968, Philadelphia, May 21, 1968. Seminar sponsored by IEEE Philadelphia Section and Reliability Group. p 71–74. 5 refs

A summary is presented of some of the results reported in previously published papers on Integrated Circuit (IC) reliability. Emphasis is placed on reliability prediction via failure mechanisms, and the significance of a stress survival matrix test is indicated. It was found that performance and strength of the matrix units were not affected by exposure. Important reliability characteristics of integrated circuits are identified and lead to the derivation of a new equation to describe IC reliability. This new approach requires identification of quality related failure mechanisms, estimation of the relative frequency of each of these failure mechanisms occurring and not being detected, and estimation of the life distribution of the units which have each of these failure mechanisms. It is noted that the ability to predict reliability is contingent upon suitable application of the product, and that a stress survival matrix test should be employed whenever there is a new or changed production process to assure reliability. L.B.H.

Review: This paper is essentially a very brief summary of five references as mentioned by the authors. Four of these references were covered by R64-11525, R68-13838, R68-13914, and R68-14120.

R69-14654 ASQC 844

National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

PROBLEMS OF INCREASING THE RELIABILITY OF AUTOMATIC MINING EQUIPMENT

L. G. Mel'Kumov and V. B. Ginzburg Redstone Arsenal, Ala. Redstone Sci. Inform. Center 19 Apr. 1968 17 p Transl. into ENGLISH from Mekhaniz. i Avtomatiz. Proizv. (Moscow), no. 7, 1966 p 50–52 Prepared by Army Missile Command

(NASA-TM-X-61123; RSIC-786; N68-25716) Avail: CFSTI

Discussed are problems of reliability of automation equipment in coal mines. Special emphasis is placed on the actual operating reliability of the equipment, the nature of possible breakdown, and recommendations for improving reliability. Author

Review: The major value of this paper is to give the practicing reliability and design engineer some perspective on his task. It shows how reliability practitioners in another field and another country are describing and reacting to their difficulties. There is a table of failure rates and repair times. Most of the actual hazard (failure)rates of elements such as relays, semiconductors devices, and switching equipment are on the order of 10^{-5} to 10^{-4} per hour and typically are ten times as bad as their tabulated hazard rates. It is a relief to be able to view with impartiality and unconcern the causes of their failures which are listed.

R69-14655 ASQC 844

National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

RELIABILITY INDICES OF SOME ELEMENTS OF AUTOMATIC SYSTEMS

V. F. Yevstratov and Yu. V. Tul'Chinskii Redstone Arsenal, Ala. Redstone Sci. Inform. Center 5 Apr. 1968 13 p Transl. into ENGLISH from Mekhaniz. i Avtomatiz. Proizv. (Moscow), v. 1, 1966 p 43–45 Supported jointly by Army

(NASA-TM-X-61106; RSIC-777; N68-24783) Avail: CFSTI

As various automatic systems find an ever increasing application for calculating the reliability of certain devices, data on the reliability of various elements and parts are cited to show the possibilities of using such information for evaluating the intensity of operational failures. The data concerning the reliability of elements are the results of statistical processing of information obtained by testing an experimental system of automatic control of refrigerating units on a fishing trawler. Author

Review: The introduction of the article has some generalities about reliability and failure rates. Then the automatic equipment and the conditions of operation are described roughly, and some estimated failure rates of components are given. It is the table of failure rates that will be of interest to American readers. On those parts which experienced failures, viz., elements of the magnetic logical system and the semiconductor logical system, transistors and diodes, all have hazard rates on the order of 10^{-6} per hour. The resistors and magnetic-core components had no failures and an upper limit for those failure rates is also about 10^{-6} per hour. These numbers are of the same order as those based on much American experience.

R69-14657 ASQC 844

National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

PROBLEMS OF CLASSIFYING FAILURES OF MACHINES AND THEIR COMPONENTS

R. V. Kugel' and Ya. B. Shor Redstone Arsenal, Ala. Redstone Sci. Inform. Center Apr. 1968 19 p refs Transl. into ENGLISH from Vestn. Mashinostr. (Moscow), no. 1, 1966 p 13–18 Supported by Army Missile Command

(NASA-TM-X-6099; RSIC-787; N68-28913) Avail: CFSTI

Problems pertaining to the nature of failures of machines and components, their classifications, recording, and analysis, are analyzed. Discussed are the fundamentals of problems of reliability of machine-building products, to organization of tests and observations of the performance of products in operation, and also to the analysis of the results of observations using the methods of the theory of reliability. Emphasized are the following (1) What is a failure and can any specific event be regarded a failure? (2) How should the failures appearing during the operation of a complex multicomponent machine be classified? (3) Which of the failures would be used as a basis for estimating the faultless performance and the service life of a machine? A method for classifying failures according to specific symptoms is proposed and the applicability of the proposed method in analyzing failures under normal and under abnormal operating conditions examined. It is concluded that the reliability of a machine cannot be characterized by a simple summation of all observed failures; therefore, an analysis of failures must cover several subdivisions in order to obtain a complete estimate of the reliability and only in doing so will it be possible to obtain information on relationships between various failures, for example, between essential and unessential, dangerous and safe, and simple and complicated. S.C.W.

Review: This is an interesting paper if for no other reason than that it confines itself solely to one topic, that is, various ways in which failures can be classified. The author has ten groups with two to four possibilities in each group. Some of these are: possibilities of further use of the product (entirely possible, only partly possible); consequences (dangerous, safe, heavy, light); possibility of avoiding the cause of failure (can be avoided, cannot be avoided). The list is reasonably complete although obviously there are many more ways one could devise for classifying (most of the important ones are listed here). Classifying the failures is done to predict both what can be done to eliminate the failures per se and the unpleasant results of their happening. Much of this kind of information is used in a failure modes and effects analysis. Since this report is only 12 pages long and is not hard to read, it is recommended for designers and reliability engineers.

R69-14665 ASQC 844; 775

DEVICE FAILURE ANALYSIS BY SCANNING ELECTRON MICROSCOPY.

P. R. Thornton, I. G. Dvies, D. A. Shaw, D. V. Sulway, and R. C. Wayte (University College of North Wales, School of Engineering Science, Bangor, Wales)

Microelectronics and Reliability, vol. 8, Feb. 1969, p. 33–53. 37 refs

Scanning Electron Microscopy (SEM) is discussed as a contributor to semiconductor device manufacture in regard to failure analysis. The need for improvement is noted, however, as well as the significance of establishing as far as possible the future role of the SEM in this field. In particular, it is considered important to establish the present limitations of the method as imposed by the availability of hardware, the more fundamental limits arising from the physical mechanism on which the method is based, and to establish a specification for an SEM designed specifically for the semiconductor industry. The discussion is limited solely to device applications. Several main areas are considered: (1) the needs of device engineers, (2) meeting those needs by supplementary existing microscopes, (3) an assessment of the SEM role in the device field and its relation to other methods, (4) a brief synopsis of some current research aimed at extending the technique, and (5) a working specification for an SEM design specifically for the semiconductor industry. L.B.H.

Review: This paper is not a discussion of how to analyze failed devices by using a scanning electron microscope. Rather it is a discussion of the general field of how and why to use such a microscope and how the microscope must be modified (from that commercially available) to be of maximum utility in this kind of work. As such, the article is extremely useful, as is any such complete treatment of an engineering situation. Not everyone would use exactly the same lists and explanations, but those given are very worthwhile. People who are considering becoming involved with such a program (indeed those who are already involved) would do well to become acquainted with the authors' viewpoints. One can certainly take intelligent exception to some of the points, but even this process will stimulate the reader to making even wiser decisions. Very few articles of this type have appeared in the literature. Most of them have shown what a wonderful tool the scanning electron microscope is and what wonderful pictures can be obtained with it. More papers like this one would be a big help in advancing the techniques for analysis of failure mechanisms in semiconductor devices.

R69-14666 ASQC 841

SOLID LOGIC TECHNOLOGY COMPUTER CIRCUITS: BILLION HOUR RELIABILITY DATA.

E. F. Platz (International Business Machines Corp., Components Div., East Fishkill Facility, Hopewell Junction, N.Y.)

Microelectronics and Reliability, vol. 8, Feb. 1969, p. 55–59. (A69-24341)

Description of the reliability of solid logic technology (SLT) and the failure analysis information retrieval program (FAIR) being conducted on the IBM System/360. The SLT module is described, together with the mechanics of the FAIR program and the results. It is pointed out that the failure rate of the SLT resistor is less than 0.000008% per 1000 hr at the 90% confidence level. In terms of mean time to failure, this indicates that the SLT resistor has a mean time to failure in excess of 12 billion hours. IAA

Review: This paper is identical to that published in the Proceedings of the 1968 Annual Symposium on Reliability, p. 602–606, although no reference at all is made to that duplication. That paper was reviewed under R68-13898. It can be noted that that review stated that the paper was sufficiently unclear as to be of little use to the intended readership.

R69-14668 ASQC 844

CONTAMINATION MEASUREMENT AND ITS RELATION TO FIELD FAILURES.

Russell E. Janke (International Harvester Co., Farm Equipment Research and Engineering Center, Chicago, Ill.).

SAE National Combined Farm Construction and Industrial Machinery, Powerplant, and Transportation Meetings, Milwaukee, Sept. 9–12, 1968. Paper. New York, Society of Automotive Engineers, Inc., 4 p

(SAE-680614)

A procedure for predicting when a degradation type of failure is occurring in hydraulic systems is discussed. The procedure, consisting of monitoring the contaminant level of the fluid, is said to provide sufficient advance warning to prevent the entire system from being affected. Author

Review: This is a good practical engineering paper. In plain language, it discusses the care that must be taken in getting a sample and why that care must be taken. The cookbook procedures shown for physically removing the sample from the hydraulic system are good and will be of great value to those who are neophytes in this area. The paper shows how to compare the contaminant level as a function of time with a reference so that abnormal increases in contaminant level can be spotted; one then presumes that something has gone wrong with the system and a failure is impending. Preventive maintenance is called for at this point. Maintenance and reliability engineers who are involved with hydraulic systems should be aware of the practical advice contained in this paper.

R69-14669 ASQC 844

DETERMINATION OF THRESHOLD FAILURE LEVELS OF SEMICONDUCTOR DIODES AND TRANSISTORS DUE TO PULSE VOLTAGES

D. C. Wunsch and R. R. Bell (Braddock, Dunn, and McDonald, Inc., El Paso, Tex.).

(Institute of Electrical and Electronics Engineers, Annual Conference on Nuclear and Space Radiation Effects, University of Montana, Jul. 15–18, 1969.) IEEE Transactions on Nuclear Science, vol. NS-15, Dec. 1968, p. 244–259. 22 refs.

Army-supported research.

(A69-16883)

Summary of the results of an extensive experimental program for determining pulse power failure levels of semiconductor junctions. Approximately 80 different types of silicon diodes and transistors were studied with variations in junction areas from 10^{-4} to 10^{-1} cm^2 and with widely varying junction geometries. A semiempirical formula, based on experimental data and on a single thermal failure model, is given. From the formula the order of magnitude of the failure level can be estimated as a function of pulse length for many silicon diodes or transistors whose junction area is known. IAA

Review: This is a good paper on an important topic. As the authors point out, the information is valuable not only for transients caused by EMP but also for transients from any cause whatsoever. It is not clear how the authors calculated the energy fed into the junction. In a private communication the first author has provided the following clarification. "For both methods, the power inputs to the junctions versus time were determined from oscilloscope traces of the voltage and current. In some instances, the time to failure was observable in those traces due to abrupt changes in the junction parameter at failure. In other cases, the time to failure was determined by slowly increasing the pulse length at a constant power level until failure occurred. This procedure was then repeated on many devices, starting with pulse durations very near failure. The energy was then calculated from the power level and pulse length to failure." In using any information for design/analysis purposes, the user must remember that if he has not specified a particular characteristic of the transistor (such as junction area) the manufacturer is under no obligation to keep that area the same nor to tell him when he changes it. Thus the authors rightly emphasize the order of magnitude nature of the results and the fact that these data are likely to be upper bounds on the energy required to cause failure. A minor adverse comment is on the phrase ". . . statistically valid data . . ." While this is a phrase often used, it is rarely meant since, given the proper statistical analysis, any set of data is "statistically valid." Usually what *is* meant is that if no prior knowledge is introduced into the data analysis, the resulting statistical uncertainties will be so large as to render the answer of negligible *engineering* value.

R69-14671 ASQC 844; 782
DO COATINGS REALLY PROTECT PRINTED CIRCUITS UNDER HIGH HUMIDITY CONDITIONS?
Charles W. Wyble and M. L. Wolf (Westinghouse Electric Corp., Aerospace Div., Baltimore, Md.).
Insulation, vol. 15, May 1969, p. 30–36.

The reliability of various coatings is discussed in relation to preventing electrical deterioration of printed circuit boards in high humidity. Insulation resistance, found to be the critical failure mode, is evaluated in terms of coating characteristics, temperature and humidty factors, conductor spacings, board material, and board etching. A complete review of government specification requirements dictated an evaluation of several types of coatings, and the test boards are described. Designed for statistical analysis, the experiment emphasized randomization. In general, it is concluded that uncoated printed circuit boards perform better in high humidity than coated boards and that there is a wide variation between coatings under high humidity conditions. The effects of conductor spacings and the etching process were found to be negligible, but the type of board material proved to have a very pronounced effect on the electrical performance of all the coatings. Several recommendations are included for determining the necessity of a printed circuit coating. L.B.H.

Review: This is a good report on a timely topic—timely, that is, in terms of hardware manufacture (rather than the journal literature). The program was an important one, and apparently was well conceived and well carried out. The results will be surprising to some, enough so that controversy may arise, especially among those who make and recommend the conformal coatings. It would be interesting to find out the experience of others who may have run tests designed to uncover the same sort of information, but in which the tests themselves were somewhat different. In discussing the results, the lower 95% confidence limit is asserted to be exceeded 95% of the time. It is not entirely clear what is mean but apparently this is a point estimate of the lower 95th percentile of the population.

R69-14673 ASQC 844; 851
RELIABILITY CONSIDERATIONS IN ELECTRONIC TRANSFORMERS FOR SPACE APPLICATIONS.
Edward M. Wiler (California Institute of Technology, Jet Propulsion Lab., Pasadena, Calif.).
Components, Circuits and Systems; Western Electric Show and Convention, Los Angeles, Aug. 20–23, 1968, Technical Papers, Volume 12. Part 2. Convention sponsored by the Institute of Electrical and Electronics Engineers and the Western Electronic Manufacturers Association. North Hollywood, Calif., Western Periodicals Co., 1968, p. 17/1-1 to 17/1-5.
(Contract NAS7-100)
(A68-43792)

Description of the quality and reliability control of toroidal transformers used in spacecraft. In order to ensure that transformers and inductors have the inherent reliability of operating properly for many thousands of hours of a space mission, it is shown that many factors are involved. Every care must be taken in constructing the transformers and inductors including the use of space compatible materials, specially developed termination techniques, and most important of all, personnel who take pride in their work. To eliminate those occasional errors that will creep in, all magnetic components that are placed in a spacecraft are subjected to critical electrical, environmental, and visual tests. The manufacturing techniques and screening tests of transformers are discussed. IAA

Review: As the author implies, many of the things which one must do to make a truly reliable transformer are things which people say ought to be done anyway. The only trouble is, they rarely do them. It is heartening to see stated in the literature that unreliability can be inspected out of a product—leaving the balance more reliable. This paper shows well the kinds of detail to which one must pay attention in the design and manufacture of transformers in order that they will be reliable. Those who use, specify, and design transformers can profit from it.

R69-14674 ASQC 844
Army Electronics Labs., Fort Monmouth, N.J.
IDEALIZED VERSUS OPERATIONAL REALIABILITY OF RF POWER TRANSISTORS AS DETERMINED BY INFRARED SCANNING TECHNIQUES
Edward B. Hakim, Bernard Reich, and Gregory Malinowski Jul. 1968 18 p refs
(AD-673716; ECOM-2991; N68-35998)

Burn-out of power transistors is a continuing problem that we are all aware of. The problem is not only unique with audio devices but is also prevalent with devices for HF, VHF, and UHF operations. Limited technical information is available as to the conditions leading to the failure of RF power devices under operating conditions. By applying infrared scanning techniques, insight has been obtained on the mechanisms leading to failure. The infrared scanning results have proved, by means of operational amplifier results, that failures formerly noted can be eliminated, thus leading to trouble-free operations. The infrared radiometer used is commercially available. It has the potential of resolving a hot spot of 0.3 mils in diameter. RF hot-spot temperature measurements were made on several devices having different design parameters. Evaluation of devices was made by analysis of hot-spot thermal resistance plots. Included are data of experiments made on devices under pulsed dc operation. Results from the operational amplifiers are then compared with the pulsed data. RF operational data is presented at both 30 MHz and 76 MHz. Data of various load terminations are presented and analyzed. From these results it has been possible to realistically rate RF power transistors to operate under nearly any load termination. Author (TAB)

Review: This is a physics-of-failure type of note and conveys the important information that on some kinds of power transistors and certain kinds of operation the thermal resistance (as calculated from hot-spot temperature to the case) is much greater than that given by the manufacturer's data sheets. These results agree very well with others on large-area transistors wherein it has been pointed out that junction temperatures can be extremely non-uniform. This is an explanation for some kinds of transistor failures. It was not pointed out whether this is a characteristic of a transistor type or whether these are individual differences from a process mean. Indirect methods of measuring the junction temperature tend to give averages whereas the method used by the authors measures the temperatures of small areas directly.

R69-14684 ASQC 840; 610; 730; 870

DOCUMENTING AND EVALUATING TROUBLES IN MILITARY SYSTEMS.

Theodore L. Tanner (Bell Telephone Labs., Inc., Whippany, N.J.).
In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers Inc., 1969, p. 33–43 2 refs.
Avail: $13.00

Some of the procedures found effective in documenting and evaluating troubles in military systems are discussed. Thousands of trouble reports processed resulted in the issuance of a considerable number of failure analyses. Computerized tabulations were used to summarize the reports, calculate equipment mean time between failures, and monitor the reliability/maintainability of an operating system. In addition to the computer aids, special studies were conducted to monitor component and equipment performance in selected areas. The aims and findings of such procedures and studies, as well as their overall contributions to the improved performance and reliability of future systems, are discussed. Author

Review: This paper shows how equipment reliability may be monitored and improved by good trouble reports, failure analyses, computerized TABS, and feedback of failure information. While much has been written on these topics, this paper has the following merits to recommend it to the serious reader. (1) The ideas are presented with sufficient clarity and detail to convey useful information. (2) There is evidence that the procedures described are based on the experience of many people gained over a number of years. While the title refers to military systems, the ideas in this paper are clearly applicable to any type of system in which high reliability is a prime objective. (Two earlier papers by the author dealing with component reliability and failure patterns, and cited as references in this paper, were covered by R66-12526 and R68-14125.)

R69-14689 ASQC 844; 775; 851

AN EVALUATION OF INTEGRATED CIRCUIT SCREENING TECHNIQUES.

Peter V. D. Gott (Philco-Ford Corp., Microelectronics Div., Blue Bell, Penn.).
In: Annual Technical Conference Transactions, 23, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 323–329.
Contract AF 30602-67-C-0153.
Avail: $13.00

A program is described involving the development and evaluation of a matrix of reliability testing of integrated circuits. The effectiveness of the sequence of life and environmental tests chosen was established. The tests were designed to remove from any given group of integrated circuits the units which represented potential reliability hazards. The program involved the use of large quantities of devices, as well as extensive planning, testing, and statistical analysis. The results were found to justify the effort, inasmuch as the screens proved to be both effective and nondegrading to the remaining population of good devices. Author

Review: It is difficult to evaluate such a comprehensive program from a very short summary of it. Nevertheless, the program appears to have been carefully thought out with much attention given to working smarter rather than harder. The results which are given in the paper will be of interest and value to reliability engineers. Even though it is stated, "In this program, all stresses were combined.", what is meant is that all stresses were applied sequentially to the devices rather than the devices' being subjected to simultaneous combined stresses. It is stated as a conclusion that the screens were not introducing wear-out mechanisms in the devices. The data to substantiate this are not shown in the paper and it is not clear exactly what is meant by wear-out (one can speak of it statistically in terms of a population, or for individuals). After reading this paper, many reliability engineers who are directly concerned with semiconductors may wish to obtain a copy of the final report so that further details will be available to them and so that the program results can be more readily evaluated.

R69-14692 ASQC 843; 523

STATISTICAL METHODS FOR STUDYING AGING AND FOR SELECTING SEMICONDUCTOR DEVICES.

I. G. Abrahamson, J. F. Gentleman, R. Gnanadesikan, A. F. Walcheski, and D. E. Williams (Bell Telephone Labs., Inc., Murray Hill, N.J.).
In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 533–540.
Avail: $13.00

Six types of semiconductor devices, two transistors and four diodes, were aged under simulated worst conditions of use in submarine cable. After initial screening, all devices of a single type were installed in an aging facility and electrical measurements of relevant device characteristics were made periodically with an automated testing system. When devices were required for use, selection or rejection was based partly on mechanical grounds and partly on accumulated data. Data analysis (1) established norms of aging behavior for the measured characteristics and (2) constructed statistics which describe the aging phenomenon and displayed the observed values of such statistics so as to facilitate the isolation of devices which exhibit unusual aging behavior. Author

Review: This paper shows that statisticians can do something constructive for engineers besides supplying routine statistical tests based on the usual tractable distributions. While there is no indication of how this technique for identifying mavericks has improved the life or reliability of equipment, it is a reasonable engineering judgment that in fact the technique does contribute to reliability. Now, those theoretically-inclined statisticians who wish to work with mathematical models can put their efforts towards trying to find a better estimator for this parameter than the one mentioned in the paper (better in this case not only refers to statistical properties but to the ease of calculation). Other engineers and statisticians may find a similar technique suitable for their purposes in trying to estimate the homogeneity of a particular batch.

R69-14693 ASQC 844

EFFECTIVE FAILURE ANALYSIS AND CORRECTIVE ACTION TECHNIQUES FOR INTEGRATED CIRCUIT APPLICATIONS.

O. J. McAteer and W. J. Lytle (Westinghouse Defense and Space Center, Aerospace Div., Baltimore, Md.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 541–549.

Avail: $13.00

Failure analysis and corrective action techniques for integrated circuits in space mission systems where maintenance is impossible or impractical are described as used at a defense and space center. The sequential procedure for failure analysis is discussed, from initial system malfunction to corrective action, including verification and followup. Illustrative case histories are included which support the usefulness of the described techniques. Critical points along the procedural sequence to a successful solution are keynoted. Author

Review: This is a good tutorial paper. The techniques it discusses are important ones in reliability and the paper presents them in a useful and interesting way. While this kind of material has appeared before, it is worthwhile to build up a body of it in the literature so that it is more available and so that somewhat different viewpoints are expressed. Often, with regard to a general discussion of failure analysis, one can comment that failure analysis need not always be done in as much detail as is given. But in this particular paper the authors have shown that even foolish failures can be cause for redesign to make the system more tolerant of imperfections and human foibles.

R69-14694 ASQC 844

FAILURE ANALYSIS TECHNIQUES USED IN A RELIABILITY ANALYSIS LABORATORY.

R. T. Brown, C. D. Root, and J. Gaffney (Raytheon Co., Sudbury, Mass.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 551–559.

Avail: $13.00

Techniques and skills employed in failure analysis are described, including analysis of both passive and active electronic components and modules. Passive component failure analysis, although generally simpler, is nonetheless considered to be as important as analysis of more complex components. Major causes of failure are found to be poor design, foreign material inclusions, and poor workmanship. Plastic encapsulated module analysis first uses standard circuit analysis techniques to delineate the component or physical area of failure before mechanical means may be used to expose the fault. Analysis of more sophisticated active components such as transistors and integrated circuits requires all of the techniques used in the analysis of modules and circuits as well as a more extensive use of metallurgical sectioning. The need for failure analysis, regardless of the reliability level, is stressed. L.B.H.

Review: This is the usual kind of paper on failure analysis one has come to expect at this kind of conference. It mixes case histories with suggestions for making the analyses. Obviously its authors did not intend it to be complete in the space allotted to them. While there is nothing particularly new in the paper (the case histories of course have not been presented before), those who are involved in this kind of work or are about to become involved can profit from reading it. The advice it gives is generally sound (relay manufacturers may be dissatisfied with the advice given about relays) and can contribute to an increased understanding of failure analysis. This paper is a discussion of the techniques per se; it does not discuss management, what to do when you have the answer, etc.

R69-14703 ASQC 844

ADAPTING FATIGUE DATA TO REAL PARTS.

R. Bruce Hopkins (John Deere Waterloo Tractor Works, Waterloo, Iowa).

Machine Design, vol. 41, Jun. 12, 1969, p. 180–192. 8 refs. (A69-32433)

Description of techniques for adapting available fatigue data to match the particular conditions of a specific design part. The basic concepts related to the fatigue limit are considered, and S-N curves are discussed for various materials. Several types of failure diagrams are described including Soderburg, Goodman, and Gerber diagrams. Other subjects discussed include cumulative fatigue damage and practical modifications. Stress concentrations, hardness, surface-finish effects, and temperature effects are considered. IAA

Review: Fatigue is one of the main causes of metallic failure in most structural members of vehicles and machinery. That it is a continuing problem is attested to by the great many articles on the topic that appear in the literature both in research and for practical application. This paper does not live up to its editorial promise in that it does not clearly solve the questions it raises. For example, statistical scatter is mentioned early in the paper but elsewhere it is ignored. In that early discussion, apparently a Normal distribution is assumed and it is extrapolated much too far out in the tails. Failure probabilities of 10^{-3} and less for real parts are not given by any nominal distribution. Most of the paper is a collection of Rules of Thumb, which in the absence of anything better are of course as good as can be done (by definition). Perhaps the most important sentence in the paper (occurring about two-thirds of the way through) states that " . . . the unfortunate truth is that results obtained from information given in the first part of this article seldom come close to predicting actual fatigue life of a part." The remainder of the article discusses such things as stress concentrations, notch sensitivity, hardness, and surface finish. The value of the material in this article depends on the state of knowledge of the reader. Those designers who are well aware of the problems associated with fatigue will find little of value in it. Those who are only vaguely aware that fatigue can be a difficulty can profit from reading the article. When designing to a given life, it should be remembered that scatter of a factor of 10 to 100 is not uncommon for fatigue life. Many of the illustrations are good; they show poor designs, the kinds of failures that result, and also what the better design should be.

R69-14705 ASQC 844; 833

HOW RELIABLE ARE MOS IC'S? AS GOOD AS BIPOLARS, SAYS NASA.

Leon C. Hamiter, Jr. (NASA, Marshall Space Flight Center, Huntsville, Ala.).

Electronics, vol. 42, Jun. 23, 1969, p. 106–110.

(A69-31851)

Results of an MOS IC reliability study conducted by NASA, including a discussion of the causes of device degradation and failure. Thousands of MOS ICs from a single manufacturer were tested at 25°C operating life, 85°C operating life, 125°C reverse bias, 125°C storage, and 150°C storage. Some 4,339,000 circuit hours were accumulated in this group of tests alone, with only three failures—a failure rate of 0.095% per 1000 hours at maximum stress. This test experience is comparable to NASA's experience with operational systems using MOS ICs. It was found that MOS and bipolar ICs of equal complexity offer approximately the same failure rates. A complex MOS circuits offers a lower total failure rate than discrete parts or less complex ICs that must be assembled on printed circuit boards and interconnected to perform the equivalent function. IAA

Review: MOS transistors have long held considerable promise both for novel circuit applications and for high reliability. Unfortunately for the high reliability, it has been difficult to stabilize the manufacturing process to the point where high reliability could be assured. Ambitious projects have been conceived, tried, and then abandoned because of the difficulty involved in producing large-scale integration with MOS transistors. There have, of course, been some successful applications of these transistors and it is encouraging to find yet another report of success. Having the failure modes screenable is also important and this report shows that much has been accomplished in that line. Those who are interested in applying MOS devices would do well to read this report (there is unfortunately no reference to a more complete government report) because it lists failure modes and mechanisms and gives an idea of how prevalent they are. It is remarkable what manufacturing technology can do when the incentive is there; MOS technology has come a long way in a few years to have achieved this reported reliability. But, as is the case with bipolar transistor circuits, remember that just because this high reliability is within the state of manufacturing art, it does not follow that all items manufactured will in fact have that reliability. The literature abounds with customer problems with conventional bipolar integrated circuits and the necessity for doing extensive incoming inspection (many circuits are delivered just plain defective to begin with). It is necessary to weed those out before running screening tests to eliminate the potential troublemakers. There is no reason to expect that MOS technology will be any different.

R69-14706 ASQC 844; 711; 712

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

ENGINEERING MECHANICS AND MATERIALS

G. Mervin Ault *In its* Selected Technol. for the Elec. Power Ind. 1968 p 221–258 refs

(N69-12583) Avail: CFSTI

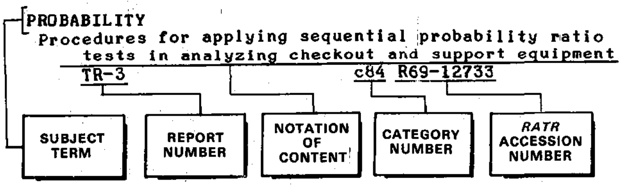
The subjects reviewed in engineering mechanics are: (1) materials in long-time service, specifically prediction of long-time properties and metallurgical embrittlement; (2) thermal fatigue and low-cycle fatigue; and (3) brittle fracture of metals. The review of materials covers materials strengthened by dispersed inert particles, and composite materials from fibers. K.W.

Review: This is a good paper; it is largely concerned with failure modes of metals, ways to predict them, and ways to avoid them. The three topics covered under failures are interpolation and extrapolation of stress-rupture data, estimation of low-cycle and thermal fatigue, and fracture mechanics. The discussions are of an introductory nature and are excellent for the purpose. They have the distinct advantage of being short. The discussions of new ways of strengthening materials by dispersion of inert particles and by fiber reinforcing of both metal and plastics are likewise short, contain little jargon, and are very suitable as an introduction for managers and other non-specialists in the field. When using time-temperature relationships and the curve must be extrapolated to use conditions, it is wise to calculate the statistical uncertainty in the prediction. Often this uncertainty is as large as a factor of ten in life.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 10

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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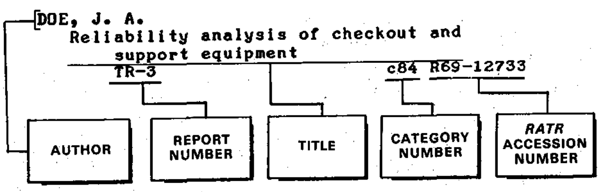
PERSONAL AUTHOR INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 10

Typical Personal Author Index Listing



The category number and the *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 10

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This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR,* and *IAA,* respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 10

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This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each accession number is the category number for locating the abstract-review in the abstract section of *RATR*.

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Reliability Abstracts and Technical Reviews

NOVEMBER 1969

Volume 9
Number 11

R69-14707—R69-14754

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

RATR ACCESSION NUMBER → R69-12733 ASQC 844; 413 ← ASQC CODES
General Equipment Company, Banville, Calif. ← CORPORATE SOURCE
TITLE → **RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**
AUTHOR → John A. Doe 23 Sep. 1968 27 p refs ← PUBLICATION DATE
CONTRACT OR GRANT → (Contract NAS15-13411)
REPORT NUMBER → (AD-629305; N69-15098; TR-3) ← *TAB* AND *STAR* ACCESSION NUMBERS
Avail: CFSTI ← AVAILABILITY SOURCE

RATR ACCESSION NUMBER → R69-12739 ASQC 814 ← ASQC CODE
TITLE → **SEMICONDUCTOR RELIABILITY.**
Joseph A. Smith (Eastern University, Arlington, Penn.). ← AUTHOR AND AFFILIATION
JOURNAL REFERENCE → *Electric Journal*, vol. 8, Apr. 1968, p 478–492.
(A69-12569) ← *IAA* ACCESSION NUMBER

RATR ACCESSION NUMBER → R69-12765 ASQC 773; 221; 823 ← ASQC CODES
TITLE → **TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.**
Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.). ← AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE → *Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*
Available from Assoc. of Reliability Eng., New York: $1.00 ← AVAILABILITY AND PRICE
IAA ACCESSION NUMBER → (A69-12407)

VOLUME 9 NUMBER 11

Reliability Abstracts and Technical Reviews

A Monthly Publication

of the National Aeronautics and Space Administration

November 1969

80 RELIABILITY

R69-14715 ASQC 802

AN ELEMENTARY GUIDE TO RELIABILITY.

G. W. A. Dummer and R. C. Winton.

Oxford, England, Pergamon Press, 1968, 59 p 3 refs.

Booklet explains in simple, largely non-technical language, what is meant by reliability and the various factors which make an equipment or machine reliable. It deals with basic considerations which apply equally to electrical, electronic, or mechanical designs, even though examples are drawn from electronics, where reliability is more widely accepted. All basic facets of reliability are covered, including the significance of reliability, definitions, statistics, reliability calculation procedures, the effect of operating conditions and environments, installation and operability, maintainability, failure reporting, and costs. L.B.H.

Review: This pamphlet is designed ". . . . to provide an introduction to reliability for those without any previous knowledge of it." Reliability is treated as a probability and thus much of the pamphlet's dealing with reliability per se is devoted to the numerics of reliability. The editorial polish of those portions is poor. Examples of this are the following. (1) Failure rate is not defined until long after it is used and there it is defined only as the reciprocal of MTBF. (2) Standard deviation is never defined. (3) The reliability of a system, contrary to the text, is not determined by multiplying the failure rates of the two parts (the authors even give emphasis to their incorrect statement). (4) All measurements are asserted to have a Gaussian distribution—clearly an incorrect statement. (5) Tables 4.3 and 5.2 give MTBF and Failure Rate for similar kinds of equipment. They do not agree at all (the product of MTBF and failure rate should be unity); they are off by as much as a factor of 100. Chapter 5, giving failure numbers, is also rather poor. It is asserted that humidity heads the list of factors causing failure, whereas the column entitled temperature and humidity leads the list. It is then implied that humidity is the most severe environment, whereas it may be merely the most ubiquitous, as far as proving it by the table is concerned. The chapter on "Installation and Operability" deals largely with human factors (called ergonomics in Britain) and is good. The chapter on "Maintainability" is adequate, although some of the blanket assertions are not always correct. Interestingly enough, while reliability is defined as a probability, maintainability is not. The chapter on "Reporting Failures" sounds good in terms of what the authors would like to see happen. But most people have to live with a poor reporting of field failures because the man operating the equipment, especially military equipment, has something else on his mind besides bookkeeping entries. The chapter on "The Cost of Reliability" gives the conventional decreasing maintenance and increasing initial costs vs. reliability with a minimum for total cost. It is asserted that you get what you pay for (would that were so; perhaps more accurately it can be phrased that you rarely get more than you pay for). It is also asserted that more reliable equipment is bound to cost more initially. There have been articles in the literature which assert that this is not so, that with a properly functioning reliability group and with designers who are reliability conscious, the initial cost of equipment can actually decrease. This happens largely by uncovering potential trouble spots during design rather than after the hardware is committed to production. Also reliability engineering emphasizes keeping-it-simple, which can also decrease initial costs. There is no mention of management techniques for high reliability, such as design review, nor engineering techniques such as large safety margins. In short, the elementary in the title can be interpreted for this pamphlet as superficial.

R69-14730 ASQC 802

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

FOUNDATIONS OF RELIABILITY AND OPERATION THEORY FOR RADIOELECTRONIC EQUIPMENT

N. A. Shishonok, V. F. Repkin, and L. L. Barvinskiy 3 Oct. 1967 730 p refs Transl. into ENGLISH of the book "Osnovy Teorii Nadezhnosti i Ekspluatatsii Radioelektronnoy Tekhniki" Moscow, Izd. Sovetskoye Radio, 1964 p 1-551

(AD-668250; FTD-HT-154); N68-26647)

This book treats basic problems of reliability theory and the operation of radioelectronic devices. The authors examine quantitative indicators of reliability and methods of their engineering calculation and statistical evaluation. Methods for basing demands upon reliability are discussed. Ways to increase reliability at the expense of reserving and to operate the apparatus efficiently are taken into account. The authors have considered the influence of preventive measures and repair operations on reliability. The influence of the control systems parameters on the reliability of the apparatus is also treated. Finally, the authors have dealt with problems concerning the efficiency of complex systems and methods for the simulation of their functioning processes which take reliability into account. The book is intended for university students taking courses in the principles of reliability. It can also be used by engineering and technical personnel who are engaged in the design, manufacture and operation of radioelectronic devices.

Author (TAB)

Review: The book is devoted largely to the mathematical theory of reliability, as is Shooman's new book (see R69-14176), but does contain practical engineering considerations much more so than in many reliability textbooks. There is virtually no consideration given to the management aspects of reliability—such as calling out design reviews, or to the engineering aspects—such as accelerated testing and use of large safety margins. The translation is surprisingly good. Apparently it was done by someone skilled in the subject; so virtually all of it reads quite smoothly (in contrast to many of the translations available from CFSTI). Other than its awkward physical form (a bunch of pages stapled together) and the fact that some of the format for figures and tables is a gross compromise with translation, the book is an excellent buy for the price in hard copy. It can serve as a reference (for anyone who has gone through it in a course of study) and is certainly satisfactory for a course in self-study if its imposed limitations are taken into account by the reader. With a little editorial polish, it would be a good book for some publisher to reprint. A chapter by chapter discussion follows. *Chapter 1 - Fundamental Concepts and Definitions of Reliability Theory.* Reliability is not defined as a probability. The discussions of concepts and of the problems associated therewith are generally very good. *Chapter 2 - Probability Methods Employed in Reliability Theory.* The approach to probability is a relative frequency one, unfortunately. A generalized exponential distribution is introduced. It includes the exponential, Rayleigh, Erlang, Weibull, Chi-square, Gamma, and Normal distributions. The discussion of statistics and probability in this chapter is good. Much of it is essentially an elementary text on probability and statistics. Some of the translated nomenclature is different than is usually employed in this country. *Chapter 3 - Quantitative Reliability Characteristics.* There is a good distinction here between repairable and non-repairable systems, so that the differences between renewal theory and elementary reliability theory are clearly brought out. The notion of independence and when it is reasonable are discussed well. However, the assumption is explicitly made only a very few times and then is presumed to follow in the chapter; it is not always obvious from looking at a particular formula that it is for the case of statistical independence. Failure rate (hazard rate) is distinguished from failure frequency which is the non-conditional density. The bathtub curve is introduced along with the notion of constant hazard rate. Notions of maintainability are introduced. In general, the chapter is good. *Chapter 4 - Factors Determining Reliability and Methods for Improving It.* The effects of various unpleasant environments are treated. The discussions are brief but good. The skill and organization of operators is emphasized as well as failure reporting systems and failure servicing. Engineering techniques for improving reliability during design are considered. These include human factors, servicing, and various kinds of developmental tests. Engineering factors to consider during production such as incoming inspection and automation are well brought out. Interestingly enough, even though the book was written in 1964, the beneficial uses of microelectronics are emphasized. This chapter is good. *Chapter 5 - Reliability of Standard Elements.* This largely shows hazard rates for different electronic components and multiplication factors to account for the environment. The discussion of vacuum tubes is quite extensive in terms of failure modes and effects. Semiconductors are treated less fully, but such things as radiation are included. Resistors, capacitors, relays, and coil-wound devices are also discussed. Although each presentation is brief, it is generally good. There is an appropriate emphasis on engineering considerations as opposed to the numbers game. *Chapter 6 - Methods of determining the Reliability of Radioelectronic Equipment.* Some constant hazard rates are included. Repairing is mentioned and the Markov chain process is introduced. Various *quick and dirty* methods for estimating the reliability of systems are given. They are the kinds of things included in the RADC Reliability Notebook. Later in the chapter, there is a discussion for arbitrary laws of hazard rate in addition to the constant one; also non-parametric laws which consider just success or failure are introduced. It is pointed out that there are virtually no data on hazard rates which vary with time. Interaction effects such as secondary failures and drift failures are considered. The treatment is adequate; the emphasis is of course on the numerics. *Chapter 7 - Reliability Requirements.* System effectiveness is introduced along with methods of allocating reliability in similar operational parameters. The optimum reliability versus repair as a function of cost is given. Appropriate cost laws are introduced and conventional conclusions drawn therefrom. Even for non-repairable systems, some cost considerations are given. Reliability allocation from system to subsystems and components is mentioned. They are the conventional treatments. There are numerous examples throughout the chapter. The discussion is at a reasonably elementary level, but that which is given is good. *Chapter 8 - Experimental Evaluation of Reliability.* This chapter is spotty. There is some good information in it and some of it is not at all clear. However, it deals with quite ordinary statistical methods which are covered in many elementary textbooks. In many of the examples, either the exponential law is implicitly presumed to hold or the binomial situation is used (the random variable is the number of equipments failed at the end of the test time). All in all, this chapter is not too good. *Chapter 9 - Redundancy.* At first, there is a discussion of the various kinds of ways in which a system can be made redundant in terms of (a) the way the redundant element is put into service and of (b) how large a subsystem is made redundant. Some of the usual formulas are given for mean-time-to-failure and reliability. Switching failures are considered, both safe and unsafe. There is an interesting discussion of reliability when the spare units have a standby hazard rate different both from zero and from the operating hazard rate. This is called a warm backup. Forms of redundancy such as majority voting are considered, including triplication of the voting device itself. There are practical considerations such as the fact that the models for redundancy are incomplete and often a reliability improvement is less than given by the model. Universal spares, repairable spares, portions of renewal theory, optimization of spares are considered. In general, the discussion in this section is quite good, from both the theoretical and practical standpoints. *Chapter 10 - Characteristics of Restoration Process for Radioelectronic Equipment.* This good chapter considers various aspects of renewal theory, availability, scheduled maintenance, detecting malfunctions, and optimizing the failure location process. *Chapter 11 - Preventive Maintenance.* None of the disadvantages of preventive maintenance are discussed although some optimization procedures are given. Ways of varying the operating conditions to show potential degradation are mentioned as being effective. Various schedules for preventive maintenance are described and analyzed. In general, this chapter is good and reasonably comprehensive. Unfortunately, it does not consider the damage that may be done to the system by the person doing the preventive maintenance. *Chapter 12 - Operation* *of Radioelectronic Equipment.* Servicing considerations, storage (although little data are given), checkout for systems in storage are all discussed. In general, the chapter is good although it is not directly related to the ordinary reliability discipline. *Chapter 13 - Monitoring the Operating Capability of Radioelectronic Equipment.* This has to do with automatic failure detection, failure location, and various optimization procedures associated therewith. It is satisfactory. *Chapter 14 - Evaluating the Performance Effectiveness of Complex Systems with Allowance for their Reliability.* This chapter extends reliability to what some people have called value, namely the value of a system is not either zero or one (corresponding to bad/good), but may take any value between the two numbers. Thus, the probability of operating in a particular condition is weighted by the value of this system at that condition, and an overall figure of merit obtained. Considerable mathematical analysis is provided for different kinds of complex system structures, for example, radio networks as opposed to hardware. It is a good chapter. *Chapter 15 - Employing the Method of Statistical Simulation to Solve Reliability and Operational Problems for Radioelectronic Equipment.* This chapter deals with simulating a system with physical models, deterministic mathematical models, and probabilistic models. In the latter case, Monte Carlo is described in detail, especially for complex structures with complex missions (including repair).

R69-14735 ASQC 801; 844; 870; 880

RELIABILITY VS. EFFECTIVENESS.

Frederick P. Kiefer (Aerospace Corp., El Segundo, Calif.).
In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 775–780.
Avail: $13.00.

The major limitations of the concepts underlying the reliability effectiveness disciplines are stated and discussed. Attention is then devoted to the types of leading questions that can and should be asked of the studies conducted in the name of reliability and effectiveness. These questions represent the key to deriving from the tasks information geared to be helpful, not only to the designer, but also to the operations planning group, manufacturing personnel, and quality control personnel. A technique of physically melding the disciplines is suggested which may result in objective and balanced answers. Author

Review: The author's list of questions is good. Many reliability engineers and consultants would suggest that these questions are part of most any good reliability program and they would not interpret reliability as narrowly as the author has done. He apparently conceives of reliability as a mathematical/statistical discipline rather than an engineering one (or he may be merely asserting that reliability engineers usually do). There is a widespread difference of opinion in industry about what constitutes a good reliability program. Some have been expressing for years the engineering approach to reliability (e.g., de Coutinho of Grumman). Virtually everyone agrees that when reliability degenerates to a "numbers game" that it is worthless for anything except fulfilling the letter of contractual requirements. It is not clear whether the author intends some of his comments on reliability and effectiveness to be good, bad, or merely worthy of note. Some of them are not clear. The paper will have little value for those without some experience in reliability and systems effectiveness because without some understanding of those subjects the author's points would pass over their heads. Question 6 in the author's list apparently requires at least a moderately quantitative knowledge of reliability (which appears to be deplored earlier, at least in some places). In question 28, it is not clear what the note means. In general the list presents a good engineering approach to high reliability.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14707 ASQC 810

Naval Civil Engineering Lab., Port Hueneme, Calif.

RELIABILITY ENGINEERING FOR NAVAL SHORE EQUIPMENT

Evo Giorgi Nov. 1966 71 p refs
(AD-684434; TN-N-856) Avail: CFSTI

A work unit was assigned to develop techniques, methods, and experience in application of reliability engineering to critical subsystems supporting vital Naval shore facilities. Results of studies are presented in the form of an introduction to the basic theory and methodology of reliability engineering as it might apply to Naval shore facilities. Some management aspects which affect the success of a reliability program and the role of reliability engineering in system effectiveness are also discussed. Author

Review: This report which is only recently available through the CFSTI is best regarded as a very qualitative statement of some of the principles involved in a reliability program. (In a private communication the author has pointed out that it was an internal memo, and thus did not receive the editorial and technical review ordinarily given to published papers.) If one reads it to get a feel for the problem rather than relying on it for specific details, he will be all right. Some of the discussion involving statistics is sloppy at best and inaccurate at worst. For example, (a) the discussion of confidence is naive and misleading; (b) statistical independence is incorrectly defined, (c) the word random is used when the particular Poisson distribution is meant, and (d) some general statements about reliability as a probability are true only when the hazard rate is a constant. The manuscript is poorly edited, with several misprints in equations. A better example of an introductory paper is the one by Seymour C. Himmel (N69-12579) which is reviewed in last month's issue of RATR. There is less emphasis on mathematics and more concern with engineering. In summary, if one is rather ignorant about the reliability discipline and loosely reads the report to get a less vague idea of what it is all about, the report can serve a useful purpose. For anything more than that, reports and books which are more carefully written and edited should be consulted.

R69-14721 ASQC 815; 851

MIL-STD-690B, FAILURE RATE SAMPLING PLANS AND PROCEDURES.

Stanley Grubman (Army Electronics Command, Fort Monmouth, N.J.), Cyrus A. Martin (Department of the Army, Washington, D.C.), and William R. Pabst, Jr.
Journal of Quality Technology, vol. 1, Jul. 1969, p. 205–216. 15 refs.

MIL-STD-690B, which was primarily designed for the reliability of electronic components, is reviewed. It is concerned primarily with process qualification, thus differing in concept from the lot-by-lot acceptance or rejection procedures of other military standards. Its history is discussed, along with its general scheme and application. An example of the use of this standard is provided, with comparison of the roles of equipment and part manufacturers. Further consideration is given to the three major sampling tables, and their mathematical basis, the characteristics of the sampling plan, maintenance of qualification, combined operating characteristics of the standard, and comparison with MIL-STD-781 and H-108. Statistically, MIL-STD-690B is found to be a relatively simple specification. L.B.H.

Review: This is excellent expository description of MIL-STD-690B, which will serve a very useful purpose for those who wish to qualify a component product line to meet this standard. It is clearly-written and authoritative. The history of development of MIL-STD-690 is described, providing useful background information for the potential user. This is followed by a statement of the general scheme of the standard, and then by a description of the procedures. The Established Reliability specifications which reference the MIL-STD-690B are listed. An example of the use of the standard is presented. Also included are brief discussions of the mathematical basis for the tables, the characteristics of the sampling plans, maintenance of qualification, combined operating characteristics of the standard, and comparison with MIL-STD-781 and H-108. Thus all of the pertinent considerations are covered and the reader gets a good working knowledge of the standard in a readily readable form. Both the authors and the journal are to be congratulated for presenting useful material of this kind.

R69-14722 ASQC 813; 844

National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

MSFN RELIABILITY: A SUMMARY OF THEORY AND RESULTS

F. Kalil and R. Wigand Jul. 1968 71 p refs

(NASA-TM-X-63323; X-834-68-299; N68-34278) Avail: CFSTI

Reliability-performance data on AS-502, when combined with data from AS-501 and 204 to provide the largest available statistical basis, indicated a mean time between failure (MTBF) of 100 hours for the unified S-band system during mission status. The 90-percent confidence limits for this MTBF of 100 hours were 54 hours and 192 hours. All reported failures were considered (i.e. hardware, software, and operations) throughout the mission status period, which commences about 2 weeks prior to launch and terminates at the end of mission. The MTBF during flight time was 180 hours, and the availability was 99.5 percent. There was insufficient data during the short flight times (35 hours and 26 minutes total for the three flights) to determine meaningful confidence limits. Author

Review: Results through July, 1968 of the program for assessing the reliability of the Manned Space Flight Network (MSFN) are presented in this report. This network has since provided tracking and data acquisition support for the Apollo manned lunar landing mission. Thus, it is a report on a system and a program the success of which has since been proven. The document will be of interest and value to those who are concerned with the planning of similar programs in the future. The theory which is presented in a brief and simplified form is the conventional material based on the exponential failure law. The presentation is clear and adequate for the purpose. Section III of the report and the Appendices contain specific details which will be of interest mainly to those concerned with the same or very similar equipment. The first two sections of the report will be useful to those who are concerned with the general aspects of the program.

R69-14736 ASQC 816

THE ATTAINMENT OF RELIABILITY IN SUBCONTRACTED COMPONENTS.

Donald L. Roelands (North American Rockwell Corp., Space Div., Downey, Calif.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 785–788.

Avail: $13.00.

Consideration is given to the problem of a prime contractor who is required to establish a reliability goal for his end item before the subcontracts for component design and development, which in large measure determine the reliability of the end item, are negotiated. Emphasis is placed on the need for communication between prime and subcontractors, and a motivation program established by one company for such a purpose is examined. Teams were formed for supplier visits to stimulate reliability and quality control. Results of a feedback program are analyzed, and it is concluded that both prime and subcontractor benefit from such communication. L.B.H.

Review: Sometimes engineers are inclined to ignore the management aspects of reliability. For example, (1) idealized, simple-minded approaches to the subject are likely to be inadequate and (2) one has to remember to deal with people as they are rather than as one would like them to be. The technical expertise to solve the supplier/user problems usually exists somewhere. It is the function of management to handle people in such a way that the experts do get together and do solve the supplier/user problems with a mutually helpful attitude. When people are left to their own devices, these solutions do not usually come about. This paper shows some of the ways in which management is an extremely important part of a reliability program. Apparently this part of the reliability program was very effective and those companies who use subcontractors would be well advised to consider this short case history.

R69-14737 ASCQ 815; 816

VENDOR RELIABILITY PREDICTIONS, FACT OR FICTION.

Alvin A. Seldner (Ampex Corp., Ampex Computer Products Div., Redwood City, Calif.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 801–803.

Avail: $13.00.

A study is made concerning the validity of vendor-furnished mean time between failure (MTBF) data. The reliability of calculations included in specifications to suppliers is open to question. It is noted that the fault often lies with the contractor, not the supplier, as long as contracts specify unrealistic MTBF requirements. A recommended approach is for the contract to specify some basic parts derating policy, and to require the vendor to provide all data and calculated stress ratios to the contractor. L.B.H.

Review: This all-too-short article (two pages) tells reliability engineers the way an MTBF is arrived at—like it is—not the way it ought to be. The article is critical of buyers who specify MTBF based on "unfounded assumptions". The author has not considered, in this paper, the buyer's need to satisfy another requirement, that of *his* customer. He blames the buyer for false calculations and absolves the supplier for accepting a contract without first estimating the proposed product quantitatively. Both supplier and contractor are asking for trouble by not requiring that the supplier – –in his proposal – –quantify his MTBF for the item proposed and bid on the basis of what is currently available for X dollars and provide an alternate estimate at Y dollars to satisfy the "unfounded" MTBF requirement. The author "solves" the problem by offering a Reliability Specification for suppliers. It is interesting but hardly *the* solution to the problem of backing into a requirement. The prime omissions are the following. (1) When are the items (derating policy, parts lists, schematics, and stress ratios) submitted? Is it before the contract is awarded or after? (2) Will this specification assure that the MTBF requirement will be met? (3) Will this specification replace the MTBF requirement? (4) Can the buyer reject the data submitted as being inadequate? (5) Can the buyer direct that changes be made if the MTBF estimated is significantly different from that required? This reviewer feels that answers to these questions will not change the rules of the ball game, nor will they improve reliability without the inclusion of many more elements in the specification. Such elements are, for example, design review, qualification testing of parts, receiving inspection screening or sampling, life testing, failure report analysis. The specification is interesting and probably valuable when a specific requirement is not mandatory. However, this short paper is not a useful contribution to the reliability literature.

R69-14740 ASQC 813
Aerospace Corp., El Segundo, Calif. Systems Engineering Operations.
TECHNIQUES FOR ENSURING HIGH RELIANCE THROUGH ACCEPTANCE TESTING ON DCSP SATELLITE
E.T. Bobak, E. I. Roberts and P. C. Mc Lellan (SAMSO) Aug. 1968 12 p
(Contract F04701-68-C-0200)
(AD-682944; SAMSO-TR-69-24; TR-0200(4111)-1)

The performance of the 17 Initial Defense Communication Satellite Program spacecraft indicates a mean time to failure in excess of 6.4 years at a 90% confidence level. Compared to the 1.5-year requirement and 3-year goal, the performance is noteworthy. This achievement is due in large measure to the program philosophy employed from initial design to final spacecraft acceptance test. Embodied in the text is a brief summary of this adopted approach. The principal thesis is a description of a documentation and review technique for assessing in-process failures in a spacecraft production environment. It is shown that the review technique is essential to preserving the analytically determined reliability of the design. Author

Review: This is a very brief summary of the approach used in design, parts selection, fabrication and assembly, acceptance testing, and documentation in order to achieve the desired reliability in the Initial Defense Communication Satellite Program (IDCSP). It is so brief, in fact, that it is little more than a listing of the tasks or objectives in each phase. Even this will be useful to those concerned with similar programs, serving in the role of a check-list. Papers such as this which report on programs which have proven to be successful serve as sources of useful ideas.

R69-14745 ASQC 810
Defense Dept., Washington, D.C.
ZERO DEFECTS: THE QUEST FOR QUALITY
John J. Riordan, ed. 15 Aug. 1968 232 p refs
(AD-683446; TR-9)

Clear visibility is given to ideas and techniques that are useful in establishing programs to prevent defectiveness. A compendium is presented of the individual points of view and experiences of persons who have used the weapons of psychology, economics, and various management sciences to grapple with quality problems. Specifically, it is aimed at the development and improvement of zero defect programs. Author

Review: This extensive report (232 pp.) consists of a collection of papers on various aspects of Zero Defects (ZD) programs prepared by those who have used them. Topics covered include the psychological, economic, management planning, organizational aspects, causes of defects, needed paperwork, assessment techniques, and steps in the implementation of a ZD program. Sustaining interest is of particular importance, since the lack of this is one of the major criticisms of such programs. The last paper in the volume deals with areas where innovation and research are needed to upgrade quality performance. This volume serves well its purpose of being a textbook on ZD. It is more for reference on particular topics than for reading from cover to cover. The listing of the papers with brief abstracts of each in the outline on pp. vii ix serves to facilitate use of the document. The fact that the papers were prepared by a variety of authors from different companies and government agencies leads to an over-all broad point of view, which is highly desirable in a topic such as this.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14713 ASQC 824; 431
Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
ON THE BOUND OF FIRST EXCURSION PROBABILITY
J. N. Yang and M. Shinozuka 15 Aug. 1968 11 p refs
(Contract NAS7-100)
(NASA-CR-95961; JPL-TR-32-1304; N68-31629) Avail: CFSTI

Because of its direct relation to the reliability or the safe performance of mechanical and structural systems subjected to random external disturbances the bounding technique of the first excursion probability is studied. In particular, the lower bound of the probability proposed previously by one of the present authors is improved. Numerical examples indicate that the improvement is significant. The present method of improvement requires the knowledge of the joint density function of the random process at two arbitrary instants. Other than this, the method is universal; it can apply to stationary or nonstationary, Gaussian or non-Gaussian processes. General expressions for lower and upper bounds are also derived in this study and their potential usefulness is pointed out. Author

Review: This report presents some nice numerical applications of bounding techniques derived elsewhere (see references 9 and

10 in the paper). The examples show quite clearly how the new method improves on previous ones albeit more computations, tables, etc. are needed. The report is clearly written and should appeal to those needing better bounds on the excursion probabilities under consideration.

R69-14714 ASQC 824
RELIABILITY FUNCTION WITH GRADUAL FAILURES.
V. N. Glazkov (*Tekhnicheskaia Kibernetika, Mar.-Apr. 1968, p 103-106.* In Russian).
Engineering Cybernetics, vol. 6, p. 95-98 1968 3 refs.
(A68-33564)

Method for calculating the reliability function for an electronic device during its initial period of operation. The method is based on the use of a lower bound for the probability that the determining parameter will remain within certain tolerance limits. The analysis is developed for the case where the parameter may be considered a normal random process. IAA

Review: This paper presents some heuristic derivations of lower bounds on the probability that a random process will remain below a certain tolerance level for a given mission period. The bounds are based on the expected number of crossings of such levels and are thus not new. The same basic idea may be found in [1], page 337, and in references contained therein. The numerical calculations and corresponding graphs are of interest.

Reference: [1] Harald Cramér and M. R. Leadbetter, *Stationary and Related Stochastic Processes,* John Wiley and Sons, Inc., New York, 1967.

R69-14716 ASQC 821
STRUCTURE AS A FACTOR IN RELIABILITY ANALYSIS OF LOGIC CIRCUITS.
N. I. Dudnikov.
Engineering Cybernetics, no. 3, 1968, p. 21-24. 5 refs.

The possibility of logic circuits reliability analysis taking no account of circuit structure is considered. The approach is found to considerably simplify the theory without introducing any serious error. Author

Review: The author gives upper and lower bounds on the probability of failure which are much simpler to calculate than the exact probability of failure. But it is not entirely clear that even for these approximations one can dispense with the structure of the logic circuit. The example makes things even less clear. Some probabilities are denoted by "λ = constant" which does not help the ease of interpretation. Undoubtedly, with the application of enough time and effort, one could make something from the paper. Whether it is worth doing so is difficult to determine.

R69-14717 ASQC 821; 431
FAULT-FREE OPERATION OF UNREPAIRABLE APPARATUS SUBJECT TO RANDOM DISTURBANCES.
B. L. Solyanik.
Engineering Cybernetics, no. 3, 1968, p. 25-30. 3 refs.

The probability of fault-free operation of unrepairable apparatus subject to random disturbances is considered. A general expression is obtained for the fault-free operating time distribution function. The case of an exponential distribution, whose failure intensity is close to a Gaussian random process, is discussed in detail. Author

Review: One does not often find this topic treated in U.S. literature and the notation and nomenclature are somewhat unusual. An interesting aspect of the results is that sometimes with random disturbances, one can get exponential reliability curves. Thus one should not presume just because a curve is exponential that there are no random disturbances. The situation where strength is a constant and stress fluctuates with time has been treated in the literature and it was obvious that by appropriate choice of the stress function one could have an exponential failure behavior. The mathematics in this paper is too sophisticated for many reliability engineers but those who are theoretically inclined can profit from it.

R69-14718 ASQC 821; 844
APPLICATION OF RELIABILITY THEORY TO A REACTOR SAFETY CIRCUIT.
S. Babik
Applied Statistics, Journal of the Royal Statistical Society (Series C), vol. 17, 1968, p. 137-156.
(W/M(4C))

A reactor safety circuit of a single *r* from *m* design is considered. It comprises *m* guard lines in parallel, continuously monitoring the reactor performance. When *r* or more lines signal the presence of a dangerous reactor condition, the reactor is automatically shut down. Two types of circuit failures are examined: a safe failure which results in a spurious reactor shutdown, and an unsafe failure when no tripping signal can be produced even if the reactor is in a dangerous condition. The repair of a guard line which failed safe starts at once, after the occurrence of a fault, provided that an engineer is available. No circuit failure will occur if the fault is eliminated before r - 1 other faults have occurred. Formulae for the calculation of the frequency of safe and unsafe circuit failures are derived, treating time as a continuous variable. The results obtained differ from those based on time represented by a series of discrete intervals. Some illustrative examples are given. Author

Review: This paper provides a reasonably standard analysis of failures of systems in parallel. The effects of safe and unsafe failures are presumed to be independent as far as calculating spurious shutdowns and dead sensing-systems are concerned. No mention is made of the accuracy of this assumption. A more important assumption from the practical viewpoint is that all failures are assumed to be statistically independent. This means, among other things, that they cannot have a common cause. Where very high reliabilities are concerned, this assumption of statistical independence becomes less satisfactory, because even very small statistical dependencies can affect the result. Little of the mathematics was checked but it appears to be competent. It is a very good and fairly standard application of mathematical reliability to reactor safety. (The term random is used to imply the Poisson distribution—as is unfortunately often true in the literature—whereas the word random actually implies merely the existence of some probability distribution.)

R69-14719 ASQC 824; 433

LIFE TESTING AND RELIABILITY ESTIMATION FOR THE TWO PARAMETER EXPONENTIAL DISTRIBUTION.

S. D. Varde (University of Bombay, India).

Journal of the American Statistical Association, vol. 64, Jun. 1969, p. 621–631. 16 refs.

A Bayesian approach to the estimation of the parameters of a two-parameter exponential distribution and the reliability function associated with it is developed using censored samples. Bayesian point estimates are obtained for these three quantities and it is shown that under a suitable choice of the prior distribution and of the loss function they are approximately equivalent to the corresponding maximum likelihood estimates and minimum variance unbiased estimates. Bayesian probability points and confidence points are obtained for both the parameters and their approximate equivalence is brought out. Author

Review: This paper is essentially an extension of the one covered by R68-13640. The extension takes the form of introducing a location parameter α in addition to the regular parameter θ of the exponential distribution. The two parameters and the reliability function are estimated using a Bayesian approach based on censored samples. A conjugate prior distribution for α and θ is used. The prior quasi-density introduced in the paper covered by R68-13640 is mentioned as a special case. The development is clear and concise, and its relationship to previous work is adequately brought out. Sixteen references are cited. Like the paper covered by R68-13640, this one contains results which should be of value to anyone involved in reliability estimation problems and interested in Bayesian methods. Since its orientation is mathematical, it is for the theorist rather than for the reliability engineer.

R69-14720 ASQC 824; 421

ESTIMATING THE PARAMETERS OF NORMAL AND LOGISTIC DISTRIBUTIONS FROM CENSORED SAMPLES.

M. L. Tiku (University of Reading, Dept. of Applied Statistics, England.)

Australian Journal of Statistics, vol. 10, Aug. 1968, p. 64–74 16 refs.

The ratio of the ordinate and the probability integral of the distribution of a variate is established. A relation is used to derived (1) estimators of the parameters of a truncated normal distribution and (2) estimators of the mean and standard deviation of a logistic distribution from doubly censored samples. The variances and covariances of these estimators are obtained and are shown to be nearly as efficient as the maximum likelihood estimators, as well as easier to compute. Author

Review: This paper makes a useful contribution to the methodology available for. estimation on the basis of censored samples. Such samples are of common occurrence in reliability work, in view of the time and cost of testing. It is very often necessary to cease taking observations before all of the test-items fail. The two distributions considered in this paper, the Normal and the logistic, both have applications in reliability and related work. The Normal distribution is commonly used in stress-strength analyses, and the logistic distribution has pertinence to availability analyses. The estimators and their properties are clearly and concisely presented, and examples are given. The orientation relative to related work is adequately indicated; sixteen references are cited.

R69-14728 ASQC 824; 413

Rand Corp., Santa Monica, Calif.

TESTING GROUPED DATA FOR EXPONENTIALITY

Ernest M. Scheuer Aug. 1968 37 p refs

(Contract F11620-67-C-0015)

(AD-674034; RM-5692-PR)

The problem of testing grouped data for fit to an exponential distribution is treated. A JOSS computer program is provided to implement an appropriate test, and examples are given showing how to use this program. A brief discussion of testing nongrouped data for exponentiality and of testing grouped data for fit to certain nonexponential distributions is also considered. No proofs are given and the mathematical aspects that do appear are presented as more supplementary than essential to the paper. Author

Review: This review is divided into two parts. The first directly comments on the paper; the second makes some observations about the problems the author is treating. The paper itself is competent and is understandable by anyone sufficiently sophisticated to ask the question in the first place. The author expresses the usual cautions in using the chi-square distribution, namely its low power of discrimination (if the data are sufficiently few, it will be almost impossible to reject the hypothesis that they come from an exponential distribution). The uncertainty in the minimum chi-square estimate of the parameter is not treated. This is always an important consideration in any parameter estimation problem. The following are general remarks on this problem. Two difficulties with statistical tests for goodness of fit are that if the data are sparse, the power is low (as mentioned by the author) and if there are a great many data, the power is too high. What many engineers wish to know is whether the exponential formula is a sufficiently good description of the data so that they may use it to interpolate and possibly to extrapolate to some extent. They wish to know whether the fit is good enough in an engineering rather than statistical sense. The use of the particular distributional form with its parameters estimated by some convenient technique should introduce a negligible increased uncertainty in their using the data. In this sense, the use of the chi-square test with sparse data and consequent low power may not be a disadvantage. If in fact the engineer cannot tell that his data did not come from an exponential distribution, he can go ahead and use the exponential, realizing that the uncertainties are high anyway and that as long as his extrapolations are kept to a reasonable degree, he is doing as well as he can with any distribution.

R69-14731 ASQC 824; 831; 853

COMPARISON OF SYSTEM ESTIMATION METHODS.

S. Demskey (General Electric Co., Philadelphia, Pa.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 571–580. 7 refs.

Avail: $13.00.

Various methods have been developed for determining system estimates, both point and lower confidence limits, from component data. Previous surveys with recommendations for application are extended to include various methods. Objectives are defined as (1) to provide simple but rational boundaries for the lower confidence limit of a system estimate, where the system model is composed of independent units in series; (2) to provide the basic formula for variable/attributes/error propagation (VAEP) applicable to an independent series system; and (3) to furnish the estimates yielded by the VAEP for all the sample cases and then to compare the estimates of all the different methods against the boundaries for the lower confidence limits. It is concluded that VAEP is the most practical combination of accuracy and simplicity for estimating the lower confidence limit of the system model. Author

Review: This is a mathematical paper which is difficult to review since the author's main reference is a company report and thus not part of the open literature. The author states that he uses a Normal approximation but does not say exactly for what. His criterion for goodness seems to be how many other estimates fall inside of his. He does not mention which of the others are truly upper and lower bounds for this lower confidence limit. The best system would seem to be one which gave the narrowest distance between the two rather than the widest. Estimating confidence limits for a product of probabilities is a problem on which research is continually being done and on which it is safe to say the best word is not yet in.

R69-14732 ASQC 821; 431; 815

DERIVATION OF RELIABILITY SPECIFICATIONS FOR AVIONICS SYSTEMS.

W. H. Sellers, M. Berssenbrugge, and A. H. Schwartz.

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 581–592. 2 refs.

Avail: $13.00.

A rational approach to deriving meaningful and practical design specifications for the present day avionics system is presented. Derivation of reliability specifications for an aircraft weapons system begins with the definition of the mission profile, which is a quantitative description of (1) the functions which the avionic equipment must perform, (2) the time and duration of time that these functions are required to be performed, and (3) the equipments that are necessary to successfully perform the requirements of the avionics system. These are formulated into a Markov chain equation which establishes the probabilities of mission success for the particular system under study. This method of developing reliability specifications for the complex avionics system is straightforward, traceable, and has been demonstrated to be valid by application to existing avionics systems. Author

Review: This paper is largely a combination of some of the first author's previous papers which have been covered in RATR (see R66-12827, R68-13823, and R69-14267) and those reviews should be consulted, particularly the most recent one. In general, the basic ideas are good but the numerical implementation of some of them is inadequate (see R69-14267). Some attempt is made to be tutorial with regard to Markov chains. None of the tutorial mathematics was checked by the reviewer. The authors' reference 1 is a very good place to learn about Markov chains.

R69-14733 ASQC 823; 222; 413; 421

LIFE-TEST SAMPLING PLANS FOR INSTANTANEOUS FAILURE RATE OF A LOGNORMAL DISTRIBUTION.

Lawrence Danziger (International Business Machines Corp., Components Div., Hopewell Junction, N.Y.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 627 632. 4 refs.

Avail: $13.00.

The lognormal distribution has gained increased consideration as a model of times-to-failure of electronic components. A common parameter for evaluating component performance is its instantaneous failure rate or hazard rate. Single sampling plans can be determined for accepting or rejecting a population of components with this parameter as a criterion. A graphic aid is provided which will map specified instantaneous failure rates of the lognormal distribution into corresponding fraction defectives, thereby allowing conventional single sampling plans for attributes to be used. Author

Review: Insofar as the mathematics of the plan can be evaluated from this brief paper, it is satisfactory. Therefore the remainder of the review will concentrate on the qualitative factors of the plan. 1. The author contends that because one knows the distribution is logNormal, one would probably know its standard deviation. This may be true but one could equally well assert that one would also know its other parameter, and thus there would be no need to run a sampling plan. One should merely assert that the plans are valid when the standard deviation is known. 2. Presume along with the author that one does know the first parameter, the time, and the hazard rate at that time. It is clear that the test is logically equivalent to one for the second parameter. 3. If one measures time in logarithmic units, the distribution will of course be Normal, so that this test by the author is equivalent to estimating the mean of the Normal distribution when the standard deviation is known. The test proposed by the author for doing this is probably less effective than noting the actual failure times of each element, and from those censored data (some elements are runouts at the end of the test) the mean of the distribution can be estimated by standard techniques. Since the distribution of these estimates is known at least approximately, an operating curve can be established for any particular plan. Thus while the author's plan appears to have no miscalculations in it, there needs to be further discussion of its suitability relative to other plans and to one's needs.

R69-14741 ASQC 821; 423

Southern Methodist Univ., Dallas, Tex. Dept. of Statistics.

CHANCE OF ALL SUCCESS FOR INDEPENDENT BINOMIAL EVENTS WITH LARGE SUCCESS PROBABILITIES

John E. Walsh Sep. 1968 8 p refs

(Grant NGR-44-007-028; Contract N00014-68-A-0515)

(NASA-CR-100612; AD-679681; SMU-83-21; REPT-9; N69-23340) Avail: CFSTI

Consider reliability situations where all of n independent steps or operations must be satisfactory (successes) if the overall operation is to be satisfactory. The interest is in reliability levels that are at least moderately high. That is, the probability of obtaining successes for all steps and operations is at least moderately near unity. An approximate expression, also sharp upper and lower bounds, are developed for the probability of all successes. These results are applicable when $n(1 - p) \leq 1$, where p is the arithmetic average of the n probabilities of success for the steps and operations. The approximate expression is near the bounds when n(1 - p) = or < .25 and the relative error is less than one percent when n(1 - p) = or < .17; then, the true probability is at least .75 and at least .83, respectively. These results depend only on n and p. They are applicable for all n = or > 1 and any set of success probabilities. Author (TAB)

Review: This paper consists of the derivation of an approximately sharp upper bound for the probability of all successes in n independent binomial events. Exactly sharp upper and lower bounds are obtained in terms of the arithmetic average of the probabilities of success for the individual binomial events. The value of the results is in predicting whether all of a set of dichotomous events are successes (success or failure being the possible outcomes). While the result will be of interest to the practical reliability analyst, the details in the paper are for the theorist.

R69-14742 ASQC 824; 431; 844

SIMULATION OF METAL FATIGUE BY THE MONTE CARLO METHOD.

V. P. Kogaev (Gosudarstvennyi Nauchno-Issledovatel'skii Institut Mashinovedeniia, Moscow, USSR).

(Zavodskaia Laboratoriia, vol. 34, July 1968, p. 828–832.)

Industrial Laboratory, vol. 34, July 1968, p. 990–994. 10 refs. (A69-19314)

Examination of a stochastic model based on the use of time-uniform Markov processes with a finite set of states and continuous time, and application of this model to programmed loading. A simulation method is described and checked with the aid of the results of steady-state and four-step programmed fatigue tests of El-437-B alloy specimens at 700°C. Smooth samples 7.5 mm in diameter were tested by single-plane bending at 200 Hz, using an electrodynamic resonant test set provided with an electronic unit for stabilization and programming of the stress amplitude. The results of steady-state and programmed fatigue testing are shown in the form of empirical life distribution functions. The results of computer simulation by the Monte Carlo method, one hundred tests per version, are shown as life distribution functions. IAA

Review: Creation of schemes for calculating cumulative damage in fatigue are of interest to mechanical designers. From the early linear assumptions to the present random fatigue tests with their power spectra, there have been many schemes for calculating cumulative damage. This is yet another one. The process of damage accumulation is presumed to be a Markov process with a finite number of states (*n*). The instantaneous transition probability to the next higher adjacent state is presumed independent of time (how long this system stayed in previous states). For *n* of any reasonable magnitude, a prohibitivie number of unknowns would be introduced. Therefore, what the authors have done is to postulate a relationship between these transition rates. But the theoretical results are then much more sensitive to this particular relationship among the transition rates than they are to the initial assumption of a Markov process. The experimental data agree reasonably well with the Monte Carlo data obtained from the Markov process (after adjusting the parameters of the relationship by using the results of some constant-load tests). While this approach is interesting, the complete arbitrariness of the relationship between the transition rates, without any physical or empirical basis whatsoever, means that much more work will have to be done before this is regarded as a satisfactory procedure. Furthermore, the competition that this method will get from random fatigue testing and the relative ease with which random loading can represent actual loadings means that the author's method will have an extremely difficult time.

R69-14744 ASQC 822; 831

THE RELIABILITY OF LONG LIFE REPAIRABLE EQUIPMENT.

Herbert G. Jacks (Singer-General Precision, Inc., Glendale, Calif.). *In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969.* Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 561–571. 7 refs.
Avail: $13.00.

Reliability and mean time between failure (MTBF) is discussed for real life situations in which the equipment contains limited life components and materials, and is operated in a real life maintenance environment. The fact that some limited life parts and materials are used in long life repairable equipment is generally accepted. In determining the probability that the equipment will operate throughout a specified period of time, calculation from MTBF by means of the exponential formula gives reasonably accurate results if the constant failure assumption is valid but results in gross errors when applied to equipment which contains limited-life components. The meaning of the term MTBF and how it relates to equipment reliability are reviewed, therefore, and detailed comments are made on how to measure and predict meaningful reliability values for real equipment. L.B.H.

Review: This is not a very good paper. While most of the phrases and sentences can be said to make sense, it is very difficult to figure out what the whole paper is about. It is just not clear enough. One could fool around for quite a while (as one of the reviewers has done) and figure out what the author could basically be meaning by what he has said and what he was driving at. But by that time, the meaning belongs as much to the person who is assigning it as to the author. This paper is not recommended for the beginner since he might easily get wrong ideas from it. There are many small difficulties in the paper rather than a few large ones which make it even more difficult for the beginner not to get many misconceptions. It is very likely that the author did have some good ideas and that they could be presented in a consistent, informative, helpful way.

R69-14746 ASQC 821; 831

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

APPLICATION OF THE THEORY OF THE BINARY RELATIONS TO THE REGULATION AND DETECTION OF FAULTS IN COMPLEX SYSTEMS

A. M. Bogomolov and V. A. Tverdokhlebov 12 Jul. 1968 26 p refs
(AD-682467; FTD-NT-24-191-68)

The theory of binary relations is applied to solving problems of monitoring and fault location, in which the theory introduces systematization, permits using powerful mathematic set apparatus, and permits partial formalization of solution search. Three examples illustrate the binary relation theory approach. Author

Review: This paper demonstrates the application of the theory of binary relations to solving problems of monitoring and fault location. This approach can make an important contribution to reliability and maintainability by decreasing the time necessary to detect faults. It is thus of importance to designers of complex systems, particularly those which involve devices in which access is difficult or dangerous, or which are to be remote-controlled. The paper consists of a brief presentation of the theory, followed by three examples to illustrate the approach. Unlike many of the documents translated from the Russian, this one is quite clear and readable, except for the superscript and subscript numbers in some of the equations.

R69-14749 ASQC 824
CANNIBALIZATION IN MULTICOMPONENT SYSTEMS AND THE THEORY OF RELIABILITY.
Warren M. Hirsch (New York University, Courant Institute of Mathematical Sciences, New York, N.Y.).
Naval Research Logistics Quarterly, vol. 15, Sep. 1968, p. 331–359.
(Contract Nonr-285(38))
(A69-10651)

Construction of a formal mathematical model of the behavior of a multicomponent system subject to cannibalization (the rectifying of the consequences of failures by interchanging parts within the system). The systems considered are described by monotone functions which take on values in a set of possible performance levels. Two structure functions are found to play a role in describing a system subject to cannibalization: one relevant before cannibalization, the other relevant after. The relation between these functions is described by means of a transformation which characterizes mathematically the notion of cannibalization. The notions of "part types" and "loci" are formalized, certain functions being introduced to measure the dependence of system performance on each individual part type. A theorem is proved which expresses the state of a system as a function of the number of working parts of each type. IAA

Review: This is a highly theoretical paper. It may well have practical applications as the authors state since it treats an important subject, but the uses of the theory are not immediately obvious. The information in the article is accessible only to someone with considerable theoretical training and the willingness to sit down and study the nomenclature in order to be able to follow the theory. The mathematics was not checked by the reviewer. It would be helpful if someone would take this material and put the important results in a form which is more understandable to reliability and maintenance engineers. It would then have to be popularized in the literature so that it is made available again and again to anyone who might be interested in it or have use for it.

R69-14750 ASQC 821
SUBJECTIVE PROBABILITY AND PRIOR KNOWLEDGE.
Ralph A. Evans (Research Triangle Institute, Research Triangle Park, N.C.).
IEEE Transactions on Reliability, vol. R-18, May 1969, p. 33.

Subjective probability, often called degree-of-belief, is discussed as a useful application of probability theory. Its usefulness to engineers is considered. The conclusion is drawn that engineers who represent their degree-of-belief by probability must be farsighted, since prior beliefs are subject to simulated outcomes of many experiments. L.B.H.

Review: The author comments editorially, and amusingly, on the applicability to the reliability field of the notion of subjective probability. He points out that the process of ascertaining one's subjective probabilities is a way of quantifying one's prior knowledge and experiences, and of doing it in such a manner that a new experiment can be used to up-date that knowledge in a similarly quantitative way. The author exhorts the user of this approach to be conscientious in setting his subjective probabilities but, having done so, to be firm and not to let himself be talked out of them. The editorial does not deal with the reproach that is sometimes lodged against subjective probability, namely that different people, faced with the same experimental data, may be led to opposite conclusions and hence that the experiment will have lost some of its traditional scientific value, which is that of settling scientific disagreements.

R69-14752 ASQC 824; 872
HAZARD VERSUS RENEWAL RATE OF ELECTRONIC ITEMS.
Charles A. Krohn (Research Triangle Institute, Research Triangle Park, N.C.).
IEEE Transactions on Reliability, vol. R-18, May 1969, p. 64–73. 27 refs.

Two different indexes, the hazard rate and the renewal rate, which are implied by conventional uses of the bathtub-shaped curve, are often noted in reliability. The hazard rate is applicable for a single failure time of each item, such as that of a nonrepairable part; the renewal rate, for multiple failure times of each item, such as those of repairable equipment. The validity of the assumptions concerning the underlying distributions of failure times affects the accuracy of the results of reliability analyses, such as prediction, data analysis, formal assurance tests, operational planning, and maintenance planning. A study of the applications-oriented literature suggests that the distinction between the hazard rate and the renewal rate, as well as some associated implications, are not generally appreciated. Thus the existing situation is apt to lead engineers astray as well as others with application interests. Basic concepts and definitions are emphasized and extensions and implications are sketched. References are selected and noted. Author

Review: This is a good paper. It is written in language that engineers can understand. It gives an insight into the difference between hazard rate and renewal rate that is severely lacking in the reliability literature. It will undoubtedly help to clear up confusion that must exist in the minds of many practicing reliability engineers. The difficulties with the paper are largely editorial. Several portions are long and drawn out (but those who wish to can merely skip over those portions). The discussion of discrete variables unfortunately contains several important misprints and, contrary to the implication in the text, only one of the equations was obtained from the author's reference 2 (and that equation is given incorrectly). The hazard rate as defined in the reference is $h(n) = p(n) / \sum_{i=n}^{\infty} p(i)$.

R69-14753 ASQC 824

CONDITIONAL MAXIMUM-LIKELIHOOD ESTIMATION, FROM SINGLY CENSORED SAMPLES, OF THE SHAPE PARAMETERS OF PARETO AND LIMITED DISTRIBUTIONS.

Albert H. Moore and H. Leon Harter (Wright Patterson AFB, Dayton, Ohio).

IEEE Transactions on Reliability, vol. R-18, May 1969, p. 76–78. 7 refs.

Use of the functional relationship between the exponential and the Pareto and limited distributions enables one to obtain conditional maximum-likelihood (ML) estimators, from singly censored samples, of the shape parameters of the Pareto distribution and the limited distribution by a simple transformation of the corresponding estimator of the scale parameter of the exponential distribution, based on the first m order statistics of a sample of size n. The estimators based on the first m order statistics of a sample of size $n \geq m$ and their exact distributions are worked out. Exact confidence bounds for the shape parameters are given. Expressions are obtained for the expected values of the ML estimators, which are used to obtain unbiased estimators and for the variances of the unbiased estimator. The Cramer-Rao bounds for the unbiased estimators are derived, and numerical examples which illustrate the computation of both point and interval estimates are given. L.B.H.

Review: This is a mathematical paper. Its main utility to reliability practitioners will be to introduce them to the two distributions and to give them an idea of how one can manipulate maximum likelihood estimators. Even though these distributions are not widely used in the reliability field, they are derivable from the exponential by relatively simple transformations. Therefore the discussion of them can help broaden a reliability engineer's background. The mathematics is competent.

R69-14754 ASQC 824

UNBIASED MAXIMUM-LIKELIHOOD ESTIMATION OF A WEIBULL PERCENTILE WHEN THE SHAPE PARAMETER IS KNOWN.

John I. McCool (Engineering and Research Center, King of Prussia, Pa.).

IEEE Transactions on Reliability, vol. R-18, May 1969, p. 78–79. 4 refs.

The maximum-likelihood (ML) estimator for a percentile of a Weibull distribution with a known shape parameter is considered. Multiplicative correction factors are listed for rendering the ML estimator mean or median unbiased in the cases where the samples are type 1'1 censored with or without replacement. The correction factors depend upon the number of failures and the shape parameter but are independent of the sample size and the percentile being estimated. Author

Review: Most of this short note presents work for which the author gives references; so it can be considered tutorial rather than innovative — it also prepares the background for the new work. The two unreferenced innovations are (1) unbiasing the percentile estimates and (2) median unbiasing the percentile estimates. The latter concept may not be familiar to reliability engineers; so they will learn some theory from the paper. The paper will also serve to remind them of ways that percentiles of the Weibull distribution can be estimated analytically from the data. The mathematics appears to be correct except for an occasional misprint.

83 DESIGN

R69-14712 ASQC 831; 612; 844

THE COMPUTER AS AN AID TO THE SYSTEM RELIABILITY ENGINEER.

J. M. Grange and J. Dorleans (MATRA, S. A., Velizy, Yvelines, France).

Microelectronics and Reliability, vol. 8, May 1969, p. 135 141. (A69-31042)

Definition of what can be done in France at the present time with computer calculations for the reliability of a complex system. Stress is laid particularly on the analysis of circuit design, faults caused by drifts, and the effect of component failure modes on circuits, by using the well-known ECAP, CIRC and IMAG programs which are currently available in France. Mention is also made of the use of component tests and the benefits afforded by these methods to the screening of high reliability components. Author (IAA)

Review: This is a tutorial paper for those who are not familiar with the uses to which reliability engineers can put computers. There are areas other than the ones listed and for a more complete discussion one might refer to the report covered by R69-14628. As the authors point out, computers can be used to relieve much of the tedium of calculations and thus ensure that the calculations are done. It is wise to point out for those who are not familiar with computers that one's first experiences with them are usually much more expensive than had been anticipated and much more frustrating. This is especially true if one is trying to get new programs run on his own computer.

R69-14738 ASQC 830; 870

Boeing Co., Seattle, Wash.

MAINTAINABILITY OF MANNED SPACECRAFT FOR LONG-DURATION FLIGHTS. VOLUME 1: SUMMARY REPORT

Washington NASA Aug. 1968 57 p refs

(Contract NAS2-3705)

(NASA-CR-1108; D2-113204-1; N68-33008) Avail: CFSTI

A 99% probability of crew survival is a basic constraint in the analysis. Spacecraft of four representative but widely varying missions, one Earth-orbital and one interplanetary each in the mid-1970 and mid-1980 time periods, are examined to the replaceable component level. Detailed maintenance analyses of subsystems and components, vehicle configuration optimizations performed with a unique computer program, and statistical results of several hundred mission simulations are described and evaluated.

The effects of hardware reliability and failure rates, skills, environmental factors, mission durations and resupply potential, and various resources are considered in many interrelationships. Optimum distributions of redundant and spare items to be included on board each spacecraft configuration for assuring mission success are identified, and their implications as to operational requirements and design philosophies are discussed. Tables, charts, and graphs summarizing analytical results and displaying parametric sensitivities are provided. Gross cost estimates are also included to indicate trends and place the respective missions in context relative to each other. Author

Review: This is a good summary report. It will provide managers and peripherally interested engineers with as much information as they want and can provide those vitally interested engineers with the summary of the investigation and an indication of where they can get more details. It is noteworthy that almost any kind of maintenance can be regarded as a form of redundancy. One is then concerned with the probability of effecting the replacement or repair and the failure rate of these spares while in storage. The engineering judgments reported appear to be reasonable. They may not be those someone else would have made, but that is the nature of such a judgment. It is interesting that the authors thought the constant hazard rate assumption to be sufficient for their calculations. The idea of commonality for much of the equipment is a very good one. How effective the systems engineers will be in enforcing this position is uncertain since it is one that designers have managed to resist reasonably successfully over a period of years.

R69-14747 ASQC 838

Air Force Systems Command, Wright-Patterson, AFB, Ohio. Foreign Technology Div.

CERTAIN METHODS OF INCREASING THE RELIABILITY OF THE COMBINATION PART OF A DIGITAL AUTOMATON CONSTRUCTED OF THRESHOLD ELEMENTS

I. B. Karosas and K. P. Zhukauskas 21 Jun. 1968 20 p refs (AD-682465; FTD-MT-24-172-68)

The logic function of the combination section of a digital automaton is transformed into the normal form expressed as a tree-like structure and consisting of individual logic lines. The reliability of the combination section of the digital automation is expressed as the reliability of the logic lines. To increase reliability, redundance or redundance with restoration is used with each logic line. The reliability of a single-logic line, the reliability of three logic lines in parallel, and the reliability of a logic line with triple redundance and restoration (by element)—taking into account, as well as not taking into account, errors in the input signals—are determined. The effectiveness of each logic line considered is determined by comparing its reliability with that of an equivalent line without redundance. It is shown that in the case of redundance with restoration the reliability of the lines with redundance is higher than that of lines without redundance when the probability of errors in the logic elements does not exceed 0.0238, even when the number of logic elements tends toward infinity. Author

Review: The topic of this paper is of interest to those concerned with increasing the reliability of digital computers. From the abstract and the early portions of the text, the reader gathers that the approach appears promising. However, the reproduction of the typescript and the equations throughout most of the paper is so poor that a reader capable of deciphering it would be perhaps better off to reconstruct it for himself.

R69-14748 ASQC 830; 838

RELIABLE CONTROL SYSTEMS. PART 1: UPGRADING INSTRUMENT PERFORMANCE; PART 2: SYNTHESIZING DEPENDABLE SYSTEMS.

P. L. Kenny and H. H. Koppel (Bailey Meter Co., Wickliffe, Ohio).

(International ISA Power Instrumentation Symposium, 11th, Chicago, May 13–15, 1968).

Instrumentation Technology, vol. 15, Sept. and Oct. 1968, p. 39–41 and 87–92.

Highly reliable control systems, which minimize process downtime and plant hazards, are considered from two points of view: (1) reliability at the instrument level and (2) reliability at the system design level. In the first part, component and circuit reliability are analyzed in terms of design demands. Failure rates are described, along with influences of environmental conditions. Some emphasis is placed on the need for sufficient inspecting, testing, and servicing to provide good quality control. The second area of discussion shows how the system design can combat equipment failures by combinations of instruments and processes that limit economic losses and improve safety. Consideration is thus given to improving process availability by appropriate control actions, to malfunction detection by monitoring modules, to comprehensive failure detection by concentrating on general effect rather than cause of failure, and to protective control action for plant and personnel. L.B.H.

Review: Good reliability is largely an engineering effort; this paper is properly concerned largely with the wise engineering of control systems to provide for high reliability. The article is a good one for the intended readership. Often papers such as this concentrate excessively on statistics and tend to mislead the reader about the nature of the reliability effort. The discussion of redundancy is good although there are several points of view on its economic effectiveness. There are two items that are not mentioned. These are design review (at every stage of the cycle) and the human factors design of the system, especially those controls and displays available to the operator. The review of the design at each stage from conception to overall system layout is important and can contribute to high reliability in a very economical fashion. The design review can go as far as the Monte Carlo running of a mathematical model of the proposed system on a computer in order to uncover design flaws. The article does not use complicated terminology; it will be understandable to any process or control engineer.

R69-14751 ASQC 838

THE DESIGN OF MULTIPLE-LINE REDUNDANT NETWORKS.

Paul A. Jensen (University of Texas, Dept. of Mechanical Engineering, Austin, Tex.).

IEEE Transactions on Reliability, vol. R-18, May 1969, p. 39–44. (Contract Nonr-4815(00))

One means to assure high reliability in digital electronic equipment is to incorporate multiple-line redundancy in its design. This type of redundancy has been described frequently in the literature. The problems are treated of determining the design of a multiple-line redundant network which maximizes the reliability of the network. There is an extremely large number of feasible designs for moderately sized networks, and no computationally practical method exists for determining the optimum design. To provide a practical solution for this problem an algorithm is described which generates a small subset of all feasible designs. A dynamic programming algorithm then selects the best from the reduced set. Computational results show that the design discovered by these techniques, in most instances, has a reliability very close to that of the optimum, and that the time for the computation increases approximately as the fourth power of the number of logical elements in the network. Author

Review: This is a highly theoretical paper whose sphere of practical application is not immediately obvious. Whether the assumptions are usually fulfilled is a matter of controversy. But since the applicability of a particular theory to hardware is notoriously unpredictable in the long run (and sometimes even in the short run), the paper has value other than as a theoretical exercise. There is enough information in the article to enable one to decide if he would like to try the method, but not enough to enable him actually to use it. Anyone contemplating implementing the method then must obtain some of the other references. The description itself is reasonably clear on the level at which it is pitched and virtually all theoreticians will be able to understand it well enough to decide whether it has any application for them. There is a real dilemma in theoretical work: should one confine his work to "practical" problems? Even though this paper is probably of no immediate practical importance to hardware designers, theoreticians should be aware of its existence.

84 METHODS OF RELIABILITY ANALYSIS

R69-14708 ASQC 844; 838

RELIABILITY IN DIGITAL SYSTEMS WITH ASYMMETRICAL FAILURE MODES.

William S. Meisel and Pembroke C. H. Schaeffer (University of Southern California, Dept. of Electrical Engineering, Los Angeles, Calif.).

IEEE Transactions on Reliability, vol. R-18, May 1969, p. 74–75. Grant NGR-05-018-044, Suppl. 1.

Most present-day reliability schemes using redundancy to mask the failure of individual logic modules employ majority voting with the assumption that the replicated modules have symmetrical failure characteristics. An analysis is presented of such schemes when the modules exhibit asymmetrical failure modes; that is, the probability that it fails with a 1 output. A general expression is presented which gives the reliability of a network consisting of *n* identical modules feeding a *k*-out-of-*n* voter. It is shown that a simple majority element does not always represent the optimal choice. Plots illustrating the results are included. Author

Review: This note deals with a topic with which some designers are quite familiar and yet others appear not to be. Thus, it is worthwhile bringing it to the attention of the group that needs it. The case treated is a specialized one in that the voter is not replicated at all. Presumably, the case is a fundamental one and can be extended readily to replicated voters. For most reliability engineers, the paper will probably have its greatest value in making them aware of the importance of several different failure modes for a circuit and showing how one case was treated. The mathematics itself appears to be correct. This paper appears also as a government report (NASA document N68-30368). The two papers are virtually the same.

R69-14723 ASQC 844

LOAD/LIFE CURVES FOR GEAR AND CAM MATERIALS.

Ralph A. Morrison (USM Machinery Corp., Applied Mechanics Section, Beverly, Mass.).

Machine Design, Aug. 1968, p. 101–108 7 refs.

Surface fatigue is acknowledged as the most frequent cause of failure in gears and cams, and the results of years of testing surface endurance of many common and uncommon gear and cam materials are described. Safe surface loads are considered, taking into account varying Hertzian stresses, and basic equations are derived for contact stresses. Applications of test data are provided in table form, listing experimental load-stress factors for 100 million repetitions of stress for materials combinations subjected to rolling only and rolling combined with 9% sliding action. Load/life curves are then plotted. The tests confirmed the significance of sliding, speed, modulus, and hardness factors in the selection of suitable materials. L.B.H.

Review: Designers often need approximate data to improve on their very subjective analyses of materials. The kinds of data mentioned in this article are such numbers. Unfortunately, they are often the ONLY such numbers the designer has or can economically get. Presumably, the author's data pertain to median life. He gives an approximate factor of safety on stress to give a better probability of survival although the improvement is not stated (it is asserted that the factor is adequate for design purposes, however). In the suggestions for constructing curves, the scatter implications should be kept in mind, that is, the instructions will provide a median line: 50% will fail sooner than indicated by the line, 50% will fail later than that. Engineers who are designing a machine only a few of which will be made, often use only this kind of data. Tests like these are often used in preliminary screening for machines which will go into production, so that the more expensive tests will be confined to the more likely candidates. Thus, this article contains information of value to reliability and design engineers—information, furthermore, that is hard to come by elsewhere.

R69-14724 ASQC 844

STRESS CORROSION.

H. B. Kirkpatrick, H. L. Gegel, and C. T. Lynch (Air Force Systems Command, Research and Technology Div., Materials Lab., Wright-Patterson AFB, Ohio).

Machine Design, vol. 40, July 1968, p. 188–194 11 refs. (A68-37425)

Discussion of stress corrosion, an insidious attack that occurs largely inside a metal. Barely detectable cracks form on the surface then grow inward to destroy the integrity of the metal. Since the cracks not only decrease the load-carrying area, but also cause extreme stress concentrations, the component fails at loads considerably lower than those for which it was designed. The corrosion appears to be triggered by tensile stress. The remedies available today are largely a matter of treating the symptoms, and various means of combating stress corrosion are suggested. Author (IAA)

Review: This is an excellent article; mechanical and metallurgical designers should be aware of its contents. The discussion has three considerable virtues: it is brief, lucid, and sound. The reader does not have to have a metallurgical degree to understand what the authors are talking about. Failure of structural materials is an important problem in reliability, especially so with many of the mathematical analyses which are grossly oversimplified. For example, we still use the term strength-of-a-material (singular rather than plural) and refer to some materials as high-strength, when we mean in particular that only one of their many kinds of strength is high and some of their other strengths, i.e., resistance to other kinds of failure, may be low. It is important to remember that where extremely light weight is not a vital consideration, it may pay to design to much lower stresses than modern practice seems to demand.

R69-14725 ASQC 844

THE RELIABILITY OF MICROWAVE RADIO-RELAY SYSTEMS.

N. A. Elkins (Post Office Research Dept., Telecommunications Hqtrs., London, England).

P. O. Electrical Engineers Journal, vol. 61, 1968, p. 143–148.

Failures of microwave radio-relay systems are to some extent predictable, and, in most instances, the necessary high degree of reliability can most economically be obtained by the use of complete redundant channels (usually referred to as protection channels) which can be brought into service automatically when required. The degree of reliability given by systems incorporating such protection channels is discussed, taking into account the possible effects of failure of the switching equipment or of common equipment, as well as the effects of human error and maintenance work. Author

Review: This paper deals largely with the engineering aspects of equipment reliability. In particular, the reliability is to be increased by switchable spares. Some very rough mathematical models are used to illustrate the amount of protection that spares will provide. Very appropriate cautions are stated concerning common subsystems such as the power supply – one may wish to decrease their failure probability before going into too much redundancy on other equipment. Not all the mathematics was checked but it appears to be adequate for the purpose. The paper has pertinence only to the particular topic of the title. The theoretical aspects are very simple and straightforward.

R69-14726 ASQC 841; 773

General Post Office, London (England). Research Dept.

DEVELOPMENT OF IMPROVED METHODS FOR THE GENERATION AND LOGGING OF DATA FOR THE ASSESSMENT OF TRANSISTOR RELIABILITY

R. Sanvoisin Apr. 1968 8 p refs

A transistor life assessment facility capable of operating 9000 transistors with applied power at elevated temperatures in ovens is discussed. Temperature monitoring and alarm facilities were incorporated and transistor parameter measurements may be made on all the devices while in situ in the ovens using a tape controlled data logger. Author

Review: Those theoreticians who clamor for more reliability data often forget the difficulties involved in obtaining it. This report describes the testing equipment for gathering accelerated testing data on transistors. It is a second-generation machine, developed after the group had experience with less flexible methods. In general, the description is such that the machine appears to be quite adequate, although desires and ability to meet the cost of this kind of equipment vary greatly from place to place. Anyone contemplating getting or changing his own automatic data gathering system would do well to be familiar with the contents of this report, to see what ideas he can get. One of the things that must always be remembered is that, in addition to life-testing the transistors, one is life-testing the test equipment. The test equipment must be much more reliable than the transistors; otherwise the data will reflect the difficulties with the test system rather than the absolute performance of the transistors.

R69-14727 ASQC 844; 833

THE MAKING OF A GOOD CONTACT.

H. N. Wagar.

Bell Laboratories Record, vol. 46, Jul. 1968, p. 228–234.

Contact reliability is examined, with emphasis on causes of such types of failure as poor conductivity and operational unpredictability. Two major sources of failure are identified as harmful films deposited on the contact surfaces and particles lodged between them. Accordingly, industrial projects include (1) the development of improved statistical methods that will permit the prediction of the likelihood of failure of complicated contact-arrangements from a series of simple tests, and (2) the determination of important properties that would characterize the conductive behavior of a contact. Graphical data are provided regarding contact characteristics and test results. L.B.H.

Review: This paper is concerned with what some are wont to call reliability physics. The discussion is generally limited to low-power contacts (contacts for motor starters, for example, are not considered). It is a tutorial discussion written for those who are peripherally or newly interested in the problem and does not go into all of the detail that is otherwise possible. It serves that purpose well; there is no misleading information in the article; and an ordinary electrical background is sufficient for understanding.

R69-14743 ASQC 844; 775

INFRARED MICRORADIOMETRY-PRECISION AND ACCURACY CONSIDERATIONS APPLICABLE TO MICROCIRCUIT TEMPERATURE MEASUREMENTS.

D. D. Griffin (International Business Machines Corp., Components Div., Hopewell Junction, N.Y.).

National Conference of the American Society for Nondestructive Testing, 27th, Cleveland, Ohio, Oct. 16–19 1967.

Materials Evaluation, vol. 26 Oct. 68, p. 215–220. 9 refs.

The problems of infrared microradiometry precision and accuracy are divided into two groups. First, there exist those factors such as signal stability and specimen ambients which are largely dependent upon hardware integrity. A second realm of consideration begins where the hardware ceases to be a significant factor. In this second category, one would necessarily include physical and chemical properties of the targets under investigation. Also included are problems originating in the mathematics of calibration functions. In summation, it is suggested that the experimenter strengthen the capability of his hardware short of major reinstrumentation and, having done so, concentrate largely on measurement technique, using systematic statistical checks as a precision indicator. Author

Review: This paper is essentially the same as that covered by R69-14397.

devices to operating life tests, and carrying out a radioactive krypton hermeticity test. No device failures were obtained in the latter two tests. Author

Review: For those interested in the manufacturing of semiconductors which will have a very long life with negligible chance of failure, this article will be of benefit. The original data were taken four years ago but this does not affect their validity. The manufacturing methods are reasonable. The author shows the engineering considerations used in the various judgments, and the kinds of rough calculations that were performed to have engineering confidence in the decision to use these transistors. Those who are required to provide semiconductors for extremely long space missions must use similar techniques.

85 DEMONSTRATION/MEASUREMENT

R69-14709 ASQC 851
RELIABILITY TESTING DURING DEVELOPMENT.
W. P. Cole (GEC-AE1/Electronics/ Ltd., Applied Electronics Laboratories, Stanmore, Middx., England).
Microelectronics and Reliability, vol. 8, May 1969, p. 81–86.
(A69-31036)

Investigation of certain aspects of reliability testing of development models. Reliability testing of production equipment demands (1) short-term testing of each unit, and (2) a large enough number of equipments to ensure that sufficient equipment hours of testing are accumulated to give a high degree of confidence in the results. Reliability testing does not predict that the equipment is capable of long-term reliability. It is more like a form of quality assurance and is of little use without prior and more detailed testing on development models. IAA

Review: The first part of the paper gives some general comments on testing for proving reliability; the second part illustrates the author's experience. The first part is more tutorial than innovative, but is very practically oriented and contains some excellent comments. It is easy to read and the language is suitable for non-experts. The author's own experience is illuminating and can help those who are considering running similar tests. An important warning that has been emphasized elsewhere is that in addition to testing the intended equipment, one also runs a very severe test on the life test equipment itself. One would like to be sure that indicated failures are caused not by the test equipment but by the parts under development. This means that the test setup must be very very reliable.

R69-14710 ASQC 851; 720; 815
SILICON PLANAR TRANSISTORS AND DIODES FOR DEEP WATER SUBMARINE CABLE REPEATERS.
J. M. Groocock (STC, Transistor Div., Footscray, England).
(*Electrical Communication*, vol. 42, p. 489–498.)
Microelectronics and Reliability, vol. 8, May 1969, p. 91–99. 2 refs.

The methods used for the production and evaluation of high reliability silicon planar transistors and diodes for the first major use of such components in deep water submarine repeaters are described. The production methods were essentially those used for commercial devices; the diodes were encapsulated in a conventional metal transistor can. Especially high reliability was achieved by careful control and by screening. Assurance of high reliability was obtained by performing accelerated tests, subjecting

R69-14711 ASQC 851
LIFE TESTING OF SEMICONDUCTOR RECTIFIERS WITH ENERGY SPARING SYNTHETIC CIRCUITS.
A. P. Kremeny (Hiradástechnikaiipari Kutató Intézet, Budapest, Hungary).
Microelectronics and Reliability, vol. 8, May 1969, p 121–133, 7 refs.
(A69-31041)

Description of an economic method for life-testing semiconductor rectifiers, involving the use of "synthetic" circuits, where the forward and reverse half-periods are separated by an electronically controlled high-voltage, high-current switch such as a thyristor. The switch allows the use of low-voltage, high-forward-current and high-reverse-voltage, low-current transformers and makes possible an energy savings amounting to a factor of 10 to 100. The method is suitable for both maximum average current testing and periodic peak current testing. IAA

Review: This paper describes circuits which enable life testing of rectifiers to be carried out much less expensively in terms of "power consumed during the test" than is the case for applying a sine wave voltage to a rectifier and letting the forward situation develop considerable power in a load. This circuit simulates the action by (a) low voltage high current in the forward cycle and (b) high voltage low current in the reverse cycle, so that no power need be dissipated in a load. The author's analysis shows that the internal action in the rectifier is the same except for a recombination current (which is considered to be of negligible importance in the life testing). Insofar as people have withheld life testing of rectifiers because of this problem, these new circuits will be a distinct advantage. Apparently so far, no one has succeeded in developing the type of circulating power system known in mechanical testing as the "four-square jack". In this device, mechanical power circulates, and the outside source of energy need only make up the losses. In that way, one tests two complete systems at once without ever having to generate or remove the power being transmitted. Another technique that is analogous to one sometimes used in mechanical testing is having the rectifier load be an inverter which puts power back into the line and thus the power system need supply only the losses in the semiconductors, etc.

R69-14729 ASQC 851; 782; 844
FASTER METHOD FOR FINDING THERMAL ENDURANCE OF DIELECTRICS.

John R. Andreotti (Naval Applied Science Lab., Brooklyn, N.Y.). *Insulation*, vol. 16, Jun. 1969, p. 39 46. 4 refs.

A new method is described for shortening the time required to estimate a new material's deterioration resistance, particularly deterioration due to elevated temperature use. The method covers a much wider range of dielectrics than is possible by existing methods, and it enables the user to assign a temperature rating to a material in a short time. Essentially, a Differential Thermal Analysis (DTA) technique is used to determine the rate of chemical decomposition of a dielectric sample in an inert atmosphere. This information is in turn used to find the temperature at which the dielectric would have the required life based on an end point consisting of the percentage of active constituent deterioration. The method is designated Chemical Deterioration Rate by Differential Thermal Analysis (CRD-DTA). Charts and equation derivations are provided, along with discussions on sample preparations, apparatus, and procedures. Means for obtaining decomposition rate curves are analyzed and the results are discussed. It is concluded that the CRD-DTA method shows promise as a means of obtaining a first-order estimate of the operating temperatures of newly developed insulating materials. L.B.H.

Review: This paper introduces a new accelerated test method for evaluating the temperature rating of dielectrics and it contrasts this new method with the older one based on the Arrhenius temperature behavior. The new method appears to be based on sound reasoning and needs to be tried out in practice. The discussion of the older Arrhenius method implies that there will be negligible scatter in the life data if the Arrhenius behavior holds. This is often not true; it is worthwhile using an analytic method that takes the scatter into account (see, for example, R69-14527) even using the author's method. The new method appears to give only a single temperature rating for the dielectric and it is not clear how this would be used to evaluate the life at other temperatures. In a private communication the author states that this kind of calculation does not give meaningful results, but it could be accomplished by reading the deterioration rates off the graph for each temperature, as is customary in the usual method. Also, with the recent emphasis on dielectric *systems* and the necessity of considering the *system* as a whole, it is not clear how this method of estimating the rate of chemical deterioration is used by itself. The author does not state that all of these problems are solved and, in fact, discusses some of these difficulties in applying his method. Thus, the above comments should be interpreted as further discussion on the feasibility of implementation, rather than as denigration, especially since the author emphasized that his contribution is concerned with the dielectric only and that it is intended only as a ". . . first order estimate of the operating temperatures of newly developed insulating materials." In essence, the method is similar to that of Dakin, described in the paper, except that differential thermal analysis is used to estimate the deterioration rate rather than a life-test-to-failure for that purpose.

R69-14734 ASQC 851; 342; 762

UPGRADING OF MICROELECTRONIC TEST PROCEDURES FOR MILITARY HI-REL ACHIEVEMENT.

Joseph L. Bell (Dept. of Defense, Quality Assurance Engineering Div., Los Angeles, Calif.).

In: Annual Technical Conference Transactions, 23rd, Los Angeles, May 5–7, 1969. Conference sponsored by the American Society for Quality Control. Ann Arbor, Mich., Edwards Brothers, Inc., 1969, p. 767–770. 5 refs.

Avail: $13.00.

Certain tests and processes are highlighted that are now listed as standards for microelectronic equipment but are inadequately implemented in the production processes. The lack of conformance to these standards is considered a major factor in the catastrophic and degradation failure modes of end items in current production. Power burn-in, thermal shock, moisture control, and hermeticity are analyzed. It is concluded that a high confidence level in reliability cannot be established without determining the effects of time and stress. It is emphasized that a maximum effort be exerted to implement a well-defined operational power burn-in for an adequate time duration. L.B.H.

Review: In using or analyzing this paper, it is important to remember the limitation indicated in the title, namely, it applies to military high-reliability achievement. Since high reliability is a qualitative concept, it must be considered in its comparative sense, that is, the higher the reliability one wishes, the more attention one must pay to the items mentioned by the author. The less emphasis there is on part cost and the more emphasis there is on part reliability, the more applicable will be the author's exhortations. Many of NASA's requirements are like this and indeed the author makes reference on occasion to NASA applications. Not all aspects of quality control are mentioned here (the author states this limitation), for example, visual inspection is very important. The paper emphasizes the following three areas: power burn-in, thermal shock, and control of moisture through original atmosphere and leak testing. The author is correct of course; these are extremely important techniques and can be cost-effective. Those who were already familiar with those facts will gain little from the very short paper. Those who need to be educated somewhat can profit from reading it. It might also be useful as a reference to demonstrate to one's manager that other people think these are important.

R69-14739 ASQC 851

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

ON DEMONSTRATION OF RELIABILITY LEVEL OF AIRCRAFT GAS TURBINE ENGINES

S. A. Mirzoyan et al 16 Jul. 1968 16 p Transl. into ENGLISH from Standarty i Kachestvo (USSR), no. 4, 1967 p 43–47

(AD-683229; FTD-MT-24-170-68; N69-26990) Avail: CFSTI

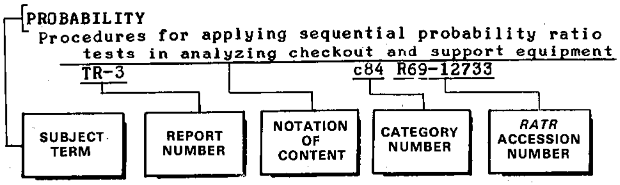
The article describes suggested techniques for determining the optimum reliability level of an aircraft jet engine. The techniques are characterized by the value of faultless service probability within a given time period, and it takes into account the costs of design, production and maintenance. Author (TAB)

Review: This paper tries to evaluate all of the costs concerned with unscheduled servicing of the engine along with the costs of producing engines with a greater or lesser mean time between unscheduled servicing. The exponential distribution for times to unscheduled servicing is presumed. The time value of money and safety are not considered. It is not clear whether ease of maintenance is considered to vary with design, nor does there seem to be consideration of the detectability of impending failures, this being an important variable. In some cases, increasing the reliability may be beyond the state of the art. The analysis is not very sophisticated but is typical of the kinds that are published in this country. Those involved with this kind of research may wish to give the paper a quick look to make sure they are not missing anything. The chances are they are not.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 11

Typical Subject Index Listing



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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 11

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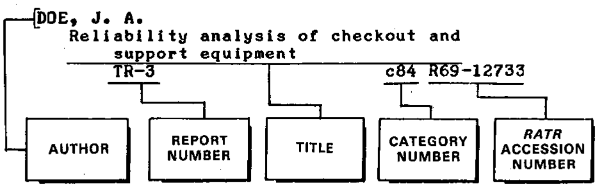

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 11

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This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB*, *STAR*, and *IAA*, respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 11

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Reliability Abstracts and Technical Reviews

DECEMBER 1969

Volume 9
Number 12

R69-14755—R69-14804

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EXAMPLES OF CITATIONS IN *RATR*

Label	Citation	Label
***RATR* ACCESSION NUMBER**	R69-12733 ASQC 844; 413	**ASQC CODES**
	General Equipment Company, Banville, Calif.	**CORPORATE SOURCE**
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	**PUBLICATION DATE**
CONTRACT OR GRANT	(Contract NAS15-13411)	
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	***TAB* AND *STAR* ACCESSION NUMBERS**; **AVAILABILITY SOURCE**

Label	Citation	Label
***RATR* ACCESSION NUMBER**	R69-12739 ASQC 814	**ASQC CODE**
TITLE	**SEMICONDUCTOR RELIABILITY.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	**AUTHOR AND AFFILIATION**
JOURNAL REFERENCE	*Electric Journal*, vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	***IAA* ACCESSION NUMBER**

Label	Citation	Label
***RATR* ACCESSION NUMBER**	R69-12765 ASQC 773; 221; 823	**ASQC CODES**
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).	**AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*	
	Available from Assoc. of Reliability Eng., New York: $1.00	**AVAILABILITY AND PRICE**
***IAA* ACCESSION NUMBER**	(A69-12407)	

VOLUME 9 NUMBER 12

Reliability Abstracts and Technical Reviews

A Monthly Publication
of the National Aeronautics and Space Administration

December 1969

80 RELIABILITY

No abstracts in this issue.

81 MANAGEMENT OF RELIABILITY FUNCTION

R69-14765 ASQC 816
MANUFACTURERS' PROBLEMS IN SELLING RELIABLE EQUIPMENT AND SYSTEMS.
Robert A. Zimmerman (Westinghouse Electric Corp., Sharon, Pa.).
(IEEE Industrial and Commercial Power Systems and Electric Space Heating and Air Conditioning Joint Technical Conference, St. Louis, Mo., May 7–10, 1968.)
IEEE Transactions on Industry and General Applications, vol. IGA-4, Aug. 1968, p. 363–366. 19 refs.

Users must determine the degree of equipment and systems reliability that they require and can justify and must define their reliability requirements in their specifications. Manufacturers must establish reliability programs to determine how they can meet the users' reliability requirements. Industry must collect and publish equipment and system reliability data for use by both user and manufacturer. Author

Review: This article presents the same problems, questions, criticisms, and complaints as articles have in the past dealing with military and aerospace procurement. It may be somewhat comforting to aerospace engineers to realize that they are not alone in their difficulties and that almost any time one strives for higher reliability than is customarily given, he will have some virtually insurmountable problems. Typical difficulties run the gamut from "how good a reliability do you want" to "how good a reliability can you give." This paper states the difficulties well. There appears to be a minor bias against the intervention of government agencies although the points in that regard are well made. It is well known that suppliers often use "plausible" reasons to avoid having to improve their reliability because of the extra effort demanded. It is equally well known that government agencies have sometimes been overzealous in their ignorance. When progress is made, it is usually by people on all sides lifting themselves by their bootstraps amid a myriad of what later turn out to be mistakes. Aerospace reliability and design engineers can profit from reading this paper. The problems are close enough to their own to be understandable but far enough away so that they can read about them with a good degree of detachment. The author gives an extensive bibliography for more complete treatment of the details. (As mentioned in the journal, this paper was presented at the 1968 IEEE Industrial and Commercial Power Systems and Electric Space Heating and Air Conditioning Joint Technical Conference, St. Louis, Mo., May 7–10, 1968.)

R69-14777 ASQC 816
VENDOR EVALUATION/RATING FOR HIGH RELIABILITY AEROSPACE HARDWARE.
Jesse H. Motes (IBM Corp., Space Systems Center, Huntsville, Ala.).
Quality Assurance, vol. 7, Dec. 1968, p. 30–33.

The vendor evaluation and quality control program is discussed in relation to the procedures adopted to assure reliability of the Saturn rocket's instrument unit. The vendor's manufacturing capabilities and the product's design are assessed through worse case testing; failure to meet operational requirements or specified corrective actions could result in disqualification. Delivery evaluation controls include procurement quality requirements, component inspection and test, lot analyses, hardware audits, quality maintenance and reliability test program, and data reporting. The data collected are screened and compiled into pertinent reports and data banks, and a comprehensive data reporting system is maintained for corrective action requirements. M.G.J.

Review: Vendor evaluations and ratings are among the more controversial of reliability activities. Some swear by them; others swear at them. Probably a good deal of the controversy arises because of the different needs of users and the different kinds and qualities of vendor evaluation/ratings. This paper is rather short and there is some difficulty with jargon (for example, exactly what is *acceptance testing*?). Apparently the main ingredient of the vendor rating involves the goodness of the material he ships. It is not clear from the paper whether each vendor has a rating of acceptable vs. not acceptable or whether, rather than a rating, his performance is described in detail. It would be difficult for anyone to use this paper as an example for setting up his own system, but it will be possible to use it to make qualitative comparisons with one's own. Obviously, everyone uses vendor ratings of some sort. They may range from personal subjective feelings about the image of the company to extensively documented formal systems. The vendor evaluation/rating system that one picks should be based on clearly defined needs for such a system and should fulfill those needs as far as feasible. It does little good to send a few purchasing or engineering people off on a three-day boondoggle to visit six plants and get the high brass showing of what a wonderful company it is. It likewise does little good to send out large numbers of forms which are supposedly to be filled in with statements of company policy by the vendor. But the use of many of the techniques suggested in this report, insofar as they are economically and technically feasible and required, can provide valuable information to a manufacturer about his suppliers.

R69-14780 ASQC 814; 817
Logistics Management Inst., Washington, D.C.
GUIDELINES FOR MAKING REPAIR EXPENDITURE DECISIONS
Nov. 1968 88 p
(Contract SD-271)
(AD-681701)

A methodology is developed for establishing repair expenditure limits during the normal service life of an individual unit of equipment. The methodology allows for the variation of repair expenditure limits with equipment use or age. Included is a decision logic network for item managers in establishing repair expenditure limits with respect to a given category of equipment, and for field repair personnel in applying such limits when an individual unit of equipment requires repair. The methodology includes a method of establishing equipment life expectancy and economic repair limits. Principal factors considered are standard inventory price of equipment, support costs, disposal value, obsolescence and equipment downtime. Author

Review: This is a report on a task ". . . to develop a common methodology for the establishment and application of repair expenditure limits which can be used throughout the Department of Defense in making repair vs. replace decisions". In the context of this review a significant part of this report is the methodology developed for determining equipment life expectancy, defined as "... the average amount of use per unit which will cause a minimum total system cost in fulfilling a given requirement." The approach taken is straightforward and involves simple cost functions. This report will be of interest to management personnel concerned with life cycle costing and related matters. It is indicative of a reasonable approach, which has potential applicability to tradeoff evaluations between reliability and maintainability.

R69-14781 ASQC 810; 832; 870
Federal Aviation Administration, Oklahoma City, Okla. Dept. of Transportation.
THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM
1968 303 p refs Presented at the Fourth Annual Maintenance Symp., Oklahoma City, Okla., 3-5 Dec. 1968
(AD-683759)

Experts in their respective fields gathered at a maintenance symposium to discuss the man in the maintenance reliability system. This publication is a compilation of the papers presented to keep the man in the maintenance reliability system current in his vocation and also forecast future trends and needs. Author

Review: Maintenance is essential for much equipment in order to keep the reliability at a high level. Commercial and military aircraft are excellent examples. Since it is people who actually make the inspections, adjustments, repairs, and replacements, it is important to consider their behavior. This entire conference is wisely devoted to that topic. Twenty papers were presented, largely by those in the commercial airlines. Unfortunately, there was no table of contents and the pages are not numbered sequentially; however, a table of contents is included in this review. Most of the papers are well described by their titles. Numbers 1 and 4 are largely case histories of human factors in maintenance for reliability. Numbers 6, 7, and 8 discuss training methods for maintenance technicians. Numbers 13, 14, 15, and 16 deal largely with schools and similar formal training. Numbers 18 and 19 are interesting in that they assert that aircraft manufacturers force their customers to complete the assembly and test the aircraft, and that this places an additional burden on operating maintenance personnel. They also indicate that these aircraft are not fully designed and that many fixes must be made. (Similar complaints are made in the press with respect to automobiles.) Most of the papers are quite adequate and bring up real problems and solutions that have been tried. A few are largely company propaganda. Most of them will be useful for men in the maintenance system of operating companies to see what others are doing. It is good to see the industry officially recognizing that there is a difference between the paper organization and what people really do, and that the most important thing is what people really do. The use of computers, automatic testing equipment, and other machinery to assist the technician in his task is a good idea, although there are very few papers on it.

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R69-14789 ASQC 814
RELIABILITY VS COST.
R. G. Schubert and P. J. McPherson (Leach Corp., Leach Relay Div., Los Angeles, Calif.).
In: Annual National Relay Conference, 17th, Stillwater, Okla., Apr. 22–23, 1969.
Conference sponsored by the National Association of Relay Manufacturers and Oklahoma State University.
Arizona, National Association of Relay Manufacturers, 1969, p. 3–1 to 3–4. 5 refs.

Discussion of cost/reliability tradeoffs in the manufacture of relays, in view of the increasing emphasis on reliability in both military and industrial products. It is pointed out that the cost of reliability of relays to be used in man-rated spacecraft must be measured against the cost of failure in the intended application, and not against the cost of procurement. This statement is found to be the prime justification for the reliability "price tag." I.A.A.

Review: The basic premise of this paper is that the cost for reliability must be measured against the cost of failure in the intended application, and not against the cost of procurement. The authors define the actual cost of a relay at procurement as the sum of the unit cost and the apportioned cost of a future field failure. The "add-on cost" is obtained by multiplying the cost of field failure by the failure rate and by the minimum rated life. The idea is straightforward and the presentation in the paper is adequate. The paper also includes (1) a nomograph for converting from relay failure rate to mean-cycles-before-failure or mean-time-before-failure, (2) a table giving the number of units required to life-test for 100,000 operations each, to demonstrate a given failure rate at the 60% and 90% confidence levels, (3) a nomograph for determining the relationship of confidence level, total test operations, failures observed, and lower one-sided failure rate limit for the exponential distribution, and (4) a nomograph for determining the initial add-on cost for each original relay procurement based on the relay's demonstrated failure rate and the user's estimated total cost of repair due to a failure. A summary of "Questions and Answers on Relay Reliability" is appended at the end of the paper. All of this is useful information for those concerned with relay reliability, and it is presented in a clear and straightforward manner.

R69-14803 ASQC 810; 830; 836
HOW DESIGN CRITERIA AND DESIGN REVIEWS HAVE USED PAST EXPERIENCE TO AVOID REPEATING MISTAKES.
J. S. Alford (General Electric Co., Aircraft Engine Technology Div., Cincinnati, Ohio).
Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Oct. 7–11, 1968, Paper. 27 p refs.

Retrieval of design criteria and calculating techniques from past experience is perhaps the most direct method of preventing repeated errors and duplication of design efforts. This paper presents a detailed plan for developing a utilization program of such experience, one that considers initial training of the engineer, data collection and availability, and methods for documenting, specializing and updating essential design information. Examples of effective design criteria are used to illustrate the plan. Author

Review: This paper is a rather detailed discussion of the subject of the title with specific reference to jet engines. As such, it will be of interest and value to designers of such engines and related equipment. The discussion of the "technical development of engineers" is concerned almost exclusively with the avoidance of needlessly high stress concentrations. A statement of the desirable characteristics of design criteria and calculating techniques is followed by some specifics related to jet engines. The discussions of documentation and retrieval of design data, reliability data center and technical information library, design record books, design reviews, and reviews of top technical problems are very brief. The appendix presents the solution to the problem of calculating the interrelations among flow, frictional losses, pressure, and pressure ratios across ducts and pipes such as those connected to extraction openings in turbomachinery. This, while the title and the length (27 pages) of this paper would suggest that it would have some value to the general design engineer, it is rather specifically directed to the designer of various types of turbomachinery including steam turbines and jet engines. Avoiding unnecessary stress concentrations is, of course, basic to all mechanical design.

82 MATHEMATICAL THEORY OF RELIABILITY

R69-14756 ASQC 824
Rand Corp., Santa Monica, Calif.
ESTIMATION FROM ACCELERATED LIFE TESTS
Richard E. Barlow and Ernest M. Scheuer Sep. 1968 42 p refs
(Contract F44620-67-C-0045)
(AD-676261; RM-5658-PR)

Techniques for analyzing life test data are presented, as well as estimates for the life distributions in the use environment based on data from both the use and the accelerated environments. The techniques require only physically plausible assumptions, not the usual ones involving specification of a family of parametric distributions. Procedures are given for testing those assumptions that are made. Author

Review: This is a statistical paper and even though some examples are given to illustrate the method, the results are accessible only to those with a considerable theoretical background. The theory has the big advantage that less is assumed about the form of the distributions than is often done, but it has the corresponding disadvantages. The hazard rates and distribution function tend to jump discontinuously for no physical reason. It looks as if the hazard rate is presumed to be constant during the intervals between happenings (failures, removals, etc.). The acceleration function presumes true acceleration with respect to the distribution functions, that is, there is some time transformation that will change the accelerated distribution function into the original one. The application to fatigue data is interesting; one set of fatigue data is presumed to follow the exponential distribution. Rarely is this kind of distribution demonstrated in the literature; more often, a log-Normal or Weibull is presumed. No indication of the uncertainty in the estimates is given, which is a disadvantage since the uncertainties are presumably quite large. The mathematics was not checked, but the authors enjoy a good reputation for the high quality of their mathematical work. Many reliability theoreticians will want to become familiar with this method to see whether it has application to their problems. If it is ever to have wide application it must of course be more widely popularized.

R69-14760 ASQC 824; 553
Naval Ship Research and Development Center, Annapolis, Md.
SMALL SAMPLE ACCEPTANCE SAMPLING TABLES USING B SUB 10 RELIABLE LIFE AND B SUB 10 HAZARD RATE CRITERIA BASED ON THE WEIBULL DISTRIBUTION
Donald J. Fisk Aug. 1968 63 p refs
(Contract S-R003-05-02)
(AD-839460)

Acceptance criteria are established for B_{10} reliable life and B_{10} hazard (instantaneous failure) rate, assuming that a Weibull failure time distribution with shape parameter $0.6 \leq \beta \leq 2.0$ applies. B_{10} reliable life is the time at which 90% of all items are expected to be still in operation, and B_{10} hazard rate is the number of failures per unit-time (hours, cycles, etc.) expected at B_{10} life. Acceptance sampling plans based on the binomial probability distribution have been developed, for each criterion, using sample sizes of $2 \leq n \leq 50$, and acceptance numbers of $0 \leq c \leq n-1$, $c \leq 8$, to assure, with minimum confidence of 90% and/or 95% the acceptance of lots for which the survival probability is 90% or more, at some specified time, t. Comparisons between B_{10} reliable life and B_{10} hazard rate indicate that either may be used with equal facility as acceptance sampling criteria. However, B_{10} hazard rate estimates would be most appropriate for establishing correction factors to compare basic environmental test results, with results obtained under other than basic conditions. Author

Review: This paper appears to be adequate for the intended purpose. The descriptions of how to use the tables are sufficient for someone who is reasonably familiar with the distributions. In the section on conversion factors, the author uses the word *estimate* when he apparently means *calculate;* that is, there is no uncertainty due to small sample size involved. As far as the acceptance tests themselves go, the actual failure times of failed elements are not considered. Each element is either good or bad at the end of the test; thus, this is the binomial situation and for small sample sizes tends to throw away some information. If the exact failure times were recorded, presumably one could make a more accurate estimate of whether or not the sample came from the desired population.

R69-14769 ASQC 824; 431
Institute for Defense Analyses, Arlington, Va.
DISCRETE RENEWAL PROCESSES
Michael Muntner Dec. 1968 25 p refs
(Contract DAHC15-67-C-0011)
(AD-680599)

Discrete renewal processes, until recently, have not been applied to the mathematical modelling of physical processes. Analyses of such renewal processes have been proceeded on the basis of generating functions but the results are too complicated to be of use. An alternative approach to discrete renewal theory is presented which calculates many of the more complex statistics of such processes. Author

Review: Discrete time renewal processes (i.e., those in which the events can occur only at fixed times) have been used less widely than continuous time renewal processes. One reason for this is the intractability of the results obtained on the basis of generating functions. This paper presents an alternate way of looking at discrete time renewal processes and presents relatively simple expressions for some of the more complicated statistics of these processes. Topics discussed include: (a) compound counting distribution, (b) aging, (c) bursts of failures, (d) interleaving, and (e) freeze-out problems. The discussion is concise, and suitable references are cited. Some prior acquaintance with renewal processes will be necessary for intelligent reading of this paper. It serves to call attention to the uses of the discrete renewal process, and provides a relatively simple approach to its analysis.

R69-14770 ASQC 824
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
NEARLY BEST LINEAR UNBIASED ESTIMATION OF THE LOCATION AND SCALE PARAMETERS OF THE WEIBULL PROBABILITY DISTRIBUTION BY THE USE OF ORDER STATISTICS
Francis B. Stump (M.S. Thesis) Dec. 1968 263 p refs
(AD-685116; GRE/MATH/68-13; N69-30315) Avail: CFSTI

Five-decimal-place tables are given for the coefficients for nearly best linear estimation of the location and scale parameters of the Weibull distribution. With the shape parameter known, the least squares method of linear estimation as applied to order statistics was used to determine the coefficients of estimation. The tabled coefficients are for the shape parameter equal to 0.5(0.5)2.0(1.0)4.0 with a sample size of N=10(1)40. M-order-statistic parameter estimators are tabled for censored samples with various values of r sub 2 largest observations missing. Also included is the relative efficiency of the estimators. Author (TAB)

Review: This thesis is a continuation of work by the Air Force Institute of Technology in parameter estimation based on the use of order statistics and involving distributions of use in reliability analysis. It is concerned with calculating and tabulating the coefficients of the nearly best linear unbiased estimates of the location and scale parameters of the Weibull distribution. The least squares method of linear estimation is used. In effect this thesis extends up to samples of size 40 results which were previously available only for sample sizes up to 10. This constitutes a valuable extension. The background and applications of the Weibull distribution are discussed briefly, and a short description of order statistics is presented. Expressions for the nearly best linear unbiased estimators of the location and scale parameters of the Weibull distribution on the basis of order statistics are presented. The M-order-statistic coefficients for estimation of the location and scale parameters, computed on an IBM 7094, are presented in Table I. The use of Table I is explained and illustrated. This thesis will be useful to the analyst concerned with data obtained in equipment testing, enabling an analysis to be performed without waiting for the entire sample on test to fail. The underlying theory is presented only briefly, and those who wish to delve into the details of this will need to refer to earlier work for background information. Adequate references are cited in the paper. No method is given for estimating the uncertainties in the calculated coefficients.

R69-14771 ASQC 824
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
NEARLY BEST LINEAR UNBIASED ESTIMATION OF THE MEAN AND STANDARD DEVIATION OF THE LOGISTIC DISTRIBUTION
Joe W. Rodgers (M.S. Thesis) Dec. 1968 431 p refs
(AD-685115; GRE/Math/68-12; N69-30212) Avail: CFSTI

The method of nearly best linear unbiased estimation, which was developed through order statistics, for obtaining unbiased estimators for use in estimating the location and scale parameters of continuous distribution is applied to the logistic distribution. Coefficients for multiplying ordered logistic statistics are developed for full and censored samples of size N = 15(1)40. Two types of censoring are used. First, each sample size, N, is censored from above. The second type of censoring is symmetrical double censoring from both ends. Extensive coverage is given to the development of the estimator in general and the application to the logistic distribution. Author (TAB)

Review: This thesis develops and tabulates the nearly best linear unbiased estimator coefficients for estimating the location and scale parameters of the logistic distribution using order statistics for single and double censored samples. Since the logistic distribution is sometimes used in the analysis of life-test data, these tables are of potential use to the reliability analyst. The underlying theory is developed in some detail, the computation method is outlined, and the use of the tables is explained. Tables I and II occupy the bulk of the thesis. Table I provides coefficients for estimating the scale and location parameter of the logistic distribution when single censoring of the order statistics is performed from above. Table II presents the coefficients to be used when symmetrical censoring is used on the order statistics. The results are in a form suitable for use by the reliability analyst; the theoretical development is competent and adequately referenced. No method is given for estimating the uncertainties in the calculated coefficients.

R69-14772 ASQC 824
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
SIMULTANEOUS ESTIMATION OF THE SCALE AND LOCATION PARAMETERS OF THE GAMMA PROBABILITY DISTRIBUTION BY USE OF ORDER STATISTICS
Guy A. Morgan (M.S. Thesis) Dec. 1968 385 p refs
(AD-685114; GRE/MATH/68-8; N69-30394) Avail: CFSTI

A technique is outlined for simultaneously estimating the location and scale parameters of a Gamma distribution with known shape parameter. The estimators are nearly best linear unbiased estimators (NBLUE). The Gamma distribution is defined and important moments of the Gamma derived. Values of sets of estimator coefficients are listed in a table. A thorough explanation of the table, along with a detailed example of its use, is given. Table ranges include shape parameters equal to 1.0(0.5)4.0 for samples of size 15(1)40. Author (TAB)

Review: The gamma distribution is a pertinent model for the times to failure of certain electrical and mechanical components. However, its use has been limited by the difficulty which is encountered in estimating its parameters on the basis of life-test data. These difficulties arise because of the lack of an explicit closed form of the integral of the general expression for the gamma distribution with an arbitrary shape parameter. A solution to this problem is accomplished through the use of computer approximations of the integral of the gamma distribution. This is one of a series of these devoted to such computer approximations. Following a brief discussion of the gamma distribution and its moments, this thesis presents techniques for simultaneously estimating the scale and location parameters of the gamma distribution by using order statistics. The shape parameter is assumed to be known. The application of the theory to the development of a computer program for computing the estimator coefficients is outlined. These coefficients are unbiased and have nearly minimum variance (hence the term "nearly best" used in their description). A computer printout of the estimator coefficients (Table I) constitutes the bulk of the thesis. A detailed description and an example of the use of Table I is given. This thesis will be useful to the reliability analyst who is concerned with the estimation of the parameters of the gamma distribution. For the theorist, the underlying theory is merely outlined in the first 17 pages of the thesis. However, the work is adequately referenced for those who wish to delve further for the details. No method is given for estimating the uncertainties in the calculated coefficients.

R69-14773 ASQC 824; 423
APPROXIMATING THE LOWER BINOMIAL CONFIDENCE LIMIT.
T. W. Anderson (Stanford Univ., Palo Alto, Calif.) and Herman Burstein (New College of Hofstra Univ. Long Island, N.Y.).
Journal of the American Statistical Assoc., vol. 63. Dec. 1968 p. 1413–1415. 6 refs.

An earlier article [1] presented two formulas for approximating the upper binomial confidence limit $\bar{p}$ from a sample of size n with c "defectives" drawn randomly from an infinite population with probability p of a defective. The present article presents two complementary formulas for approximating the lower binomial confidence limit $\underline{p}$, based on $\underline{m}$, the lower confidence limit for the parameter m of a Poisson distribution. These approximations are easy to calculate and have precisely specified bounds on their error over stated ranges of n and c/n. The error of the simpler formula is guaranteed to be within .1% of the exact binomial confidence limit when $n \geq 16$ and $c/n \leq 1/8$. The relative error of the second formula is not more than .1% when $n \geq 16$ and $c/n \leq 1/2$. Values of m for small values of c are readily available from tables of the Poisson and chi-square distributions. For $c \geq 50$, a simple formula permits approximating *m* with no more than .069% relative error. A procedure is given for approximating *p* when $c/n > 1/2$, which produces relative accuracy of at least .999 except possibly when *p* falls below 1/2; then the guaranteed relative accuracy is at least .998. (Approximation of the upper confidence limit $\bar{p}$ when $c/n > 1/2$, with relative accuracy of at least .999, is also discussed.) Author

Review: Two approximations to the lower confidence limit of the parameter of the binomial distribution are presented. (The corresponding approximations for the upper limit were given in an earlier paper by the authors cited as Reference 1 in the present paper.) These approximations permit easy calculation of binomial confidence limits with small and precisely bounded relative errors. Since the reliability analyst frequently has to deal with dichotomous events (success or failure, defective or nondefective, etc.) these formulas are of practical importance. Illustrations of their use are given in the papers. For the theorist interested in the mathematical background, more of that is presented in the earlier paper, and adequate reference are cited in both papers. (The reader interested in this paper should first note an Editor's correction to it which appears in the June 1969 issue of the same journal, p. 669. The underscores to designate lower confidence limits were omitted from the article as printed.)

R69-14774 ASQC 820

European Space Vehicle Launcher Development Organization, Paris (France).

THE RELIABILITY OF A SPACE VEHICLE LAUNCHER SYSTEM

E. Cambi [1967] 86 p refs

(TM-107)

A tentative theory is proposed, aimed at the evaluation of a reliability test and at the choice of the most convenient testing philosophy. The trial is in any case split into two phases: the adjustment phase, and the reliability test proper. The output of the test consists of a likelihood function giving the a posteriori probability that the reliability may take one value or another, rather than a figure representing the experimental reliability. The knowledge of the likelihood curve can be more concisely represented by some of its numerical parameters, e.g., the mean value, the variance, the value of the reliability that has a certain probability (confidence) of being exceeded. The resolving formulas are stated without justification; and their mathematical deduction is discussed. Graphs are given to ease the computation in the most laborious cases. Author

Review: The author's summary states that this paper proposes a tentative theory "aimed at the evaluation of a reliability test and at the choice of the most convenient testing philosophy." This would indicate that it could be of interest and value to the reliability analyst. However, the style and nomenclature in which it is presented preclude the gathering of useful information without a great deal of effort and guessing on the reader's part. Insofar as the reviewer can determine, the material is quite elementary in nature and available in various textbooks on the engineering and statistical aspects of reliability. Thus there is really no point in seeking out this document. In a private communication, the author has acknowledged that this report contains nothing substantially different from what may be found in the existing literature. However, it did prove to be useful in some investigations in the author's organization. A revised and somewhat clearer version of the document has been published in *ELDO/ESRO Technical Review*, vol. 1, no. 1, 1969, pp. 5–58. Those interested in a slightly different presentation of this material might wish to write the author for a reprint.

R69-14779 ASQC 824

Aerospace Research Labs., Wright-Patterson AFB, Ohio.

MAXIMUM-LIKELIHOOD ESTIMATION, FROM DOUBLY CENSORED SAMPLES, OF THE PARAMETERS OF THE FIRST ASYMPTOTIC DISTRIBUTION OF EXTREME VALUES

H. Leon Harter, (Applied Mathematics Research Lab.) and Albert H. Moore (Air Force Institute of Technology) Repr from Am. Statist. Assoc. J., 1968 p 889–901 refs

(AD-685681; ARL-68-0277)

Let x be a random variable having the first asymptotic distribution of smallest (largest) values, with location parameter u and scale parameter b, b greater than 0. The natural logarithm of the likelihood function of a sample of size n from such a distribution, the lowest r_1 and the highest r_2 sample values having been censored, is written down and its first and second partial derivatives with respect to the parameters are worked out. The likelihood equations, obtained by equating to zero the first partial derivatives, do not have explicit solutions, but an iterative procedure for solving them on an electronic computer is described. The asymptotic variances covariances of the maximum-likelihood estimators of the parameters are obtained by inverting the information matrix, whose elements are the negatives of the limits, as n tends to infinity, of the expected values of the second partial derivatives, $q_2 = 0.0(0.1$ $(0.9-q_1)$ from above. The asymptotic variances and covariances are compared with corresponding sample values obtained from a Monte Carlo study of 2000 samples each of sizes $n=10$ and $n=20$ from the distribution of smallest values. Author

Review: This is a competent and concise mathematical paper, and as such will be of interest to the reliability theorist rather than to the reliability engineer or design engineer. In addition to its presentation and discussion of the estimation procedure, it contains a rather extensive discusssion of related work. In particular, for those interested in mathematical models related to reliability, it mentions references discussing the application of the theory of extreme values to fracture problems, dielectric strength of paper capacitors, corrosion pitting, and fatigue failures. Reference is made to several important papers which have considered stochastic models for length of life, including extreme-value models. The relationship between the Weibull distribution and the distribution of extreme values is indicated. Thus this paper makes an important contribution to the theory of mathematical models for reliability, not only for the estimation procedure which it presents but also for its discussion of related work.

R69-14782 ASQC 824

Boeing Scientific Research Labs., Seattle, Wash. Mathematics Research Lab.

RELIABILITY APPLICATIONS OF THE HAZARD TRANSFORM

J. D. Esary, A. W. Marshall, and F. Proschan Dec. 1968 38 p refs

(AD-684489; D1-82-0805)

A systematic study is made of the role of the hazard transform in developing new results in reliability theory, and simplifying the proofs of known results. The hazard transform of a coherent system gives the hazard function (or cumulative hazard rate) of the system in terms of component hazard function. Both new and familiar results obtained in a simple direct fashion by using the hazard transform concept are reported. Author

Review: This report contains a wealth of information in the mathematical theory of reliability. A new concept of the "hazard transform" of a system is introduced and, through this concept, the proofs of many old results are simplified and several new results are obtained. The report, though dealing with theory, is quite full of examples relating the material to special systems and special life distributions. A familiarity with the earlier work in reliability by these authors and their colleagues would be helpful in reading the present report, but not absolutely necessary as it is largely self-contained.

R69-14783 ASQC 824
Boeing Scientific Research Labs., Seattle, Wash.
MEAN LIFE OF SERIES AND PARALLEL SYSTEMS
Albert W. Marshall and Frank Proschan Apr. 1969 17 p refs
(AD-688106; DT-82-0831)

Some inequalities are obtained which yield bounds for the mean life of series and of parallel systems based on the type of component life distributions, such as (a) increasing (decreasing) failure rate, (b) increasing (decreasing) failure rate average, (c) decreasing density, (d) Weibull, and (e) Gamma. Similar inequalities are obtained for the convolution of life distributions, helpful in the study of replacement policies. Author

Review: Some interesting bounds on system mean life in terms of component mean lives are given in this report. The discussion is quite clear and precise and the results should be accessible to a variety of readers. Comprehension of the proofs will require a fairly high degree of mathematical maturity. For example, the basic lemma assumes an elementary knowledge of measure theory on the real line. Unfortunately, at least two papers cited in the report do not appear in the list of references. The first author, in a private communication, has indicated that the two cited papers missing from the bibliography are not basic to an understanding of the paper. They will be listed in a version of the paper to be published in the *Journal of Applied Probability.*

R69-14791 ASQC 824; 851
United Technology Center, Sunnyvale, Calif.
STUDY OF THE RELIABILITY GROWTH IMPLICATIONS OF SUBSYSTEM VERSUS FULL ASSEMBLY TESTING
V. J. Corcoran and R. R. Read Nov. 1968 46 p refs
(Contract NAS7-356)
(NASA-CR-99139; UTC-2140-FR; N69-16388) Avail: CFSTI

During a large scale development program, testing takes place at the individual subsystem level as well as at the full assembly level, and each involves separate kinds of engineering problems. The reliability growth and cost implications of various mixes of these two types of testing are studied. The simulation model is used in an empirical approach to the problem, and the leading prediction scheme is used in an analytic approach. The latter is more economical and more flexible, but is restricted to mean value analysis. The ultimate product of the developmental program will be called the system. A system may consist of several components. Each component is expected to operate for a fixed period of time; and because the functioning of a component may be variable during this period; we may decompose it into a contiguous set of nonoverlapping time intervals. The intervals operate sequentially i.e., interval 1 must complete its usefulness before interval 2 begins, etc. Components may operate concurrently and may or may not be identified with a single interval. The reliability of a system is the product of the reliabilities of its components. Author

Review: This report is based on a follow-on study to those in two previous reports, the second of which was covered by R69-14184. A simulation model previously developed is used to study the reliability growth and cost implications of various mixes of testing at the individual subsystem level and at the full assembly level. Both an empirical and an analytic approach are described. Of these, the latter is more economical and more flexible, but is restricted to "mean value" analysis. The overall objective is to identify the best admissible mixes for achieving minimum cost. A significant aspect of this study is the consideration of an interaction factor, thus carrying it beyond the simple assumption that the components or stages operate or fail independently of one another. The report is copiously illustrated with graphs, the details of which are not well resolved on a microfiche reader. The discussion of the analytical approach is, quite naturally, mathematical in nature. Thus the report will be of more value to the theoretician working on testing strategies than to the reliability engineer.

R69-14795 ASQC 821; 431
Florida Univ., Gainesville. Dept. of Industrial and Systems Engineering.
STOCHASTIC FAILURE MODELS BASED UPON DISTRIBUTIONS OF STRESS PEAKS
R. L. Patterson Dec. 1968 62 p refs
(Contract DAH-CD4-68C0002)
(AD-681947)

A mathematical development of a family of time dependent random processes which can provide a mathematical tool for modeling a stress process in one spatial dimension is described. Probability distributions of peak stress intensity and functions of peak stress intensity occurring in a fixed time interval are developed. Peaks of stress intensity are treated as random and the lengths of the time intervals between peaks are assumed to define a renewal process. A family of first passage times are interpreted as reliability functions and their mean and variance are derived in terms of the parameters of the underlying stress processes. Some possible applications of the models are discussed. Author

Review: The author assumes two simple models for the occurrence of stress peaks, namely, a Poisson model and a renewal model. The heights of stress peaks are independent with a given distribution. He discusses the occurrence of stress peaks exceeding a given level. The usefulness of this paper is that the discussion and various generalizations enable simple models to be obtained for failures of components in systems in stress environments. Consequently, the paper will be of interest to theorists concerned with formulation of such models rather than to the practical reliability analyst.

R69-14798 ASQC 824; 431
Rocketdyne, Canoga Park, Calif.
ESTIMATION OF PARAMETERS IN A TRANSIENT MARKOV CHAIN ARISING IN A RELIABILITY GROWTH MODEL
Bernard Sherman and Morton R. Dubman Wright-Patterson AFB, Ohio ARL Jan. 1969 53 p refs
(Contract AF 33(615)-2818)
(ARL-69-0010)

This report gives results concerning the maximum likelihood estimation of parameters in a certain reliability growth model. Two formulations of the model are considered, leading to two related estimation problems. In the first formulation the number of failures by trial i, denoted by y_i, is a transient Markov chain with transition probabilities $P(y_{i+1}=k+1 \mid y_i=k) = p\beta^k$; $P(y_{i+1}=k \mid y_i=k) = 1-p\beta^k$; $k=0, 1, \ldots$. In the second formulation, the reliability growth model is described by a sequence of independent random variables ζ_k, $k=0, 1, \ldots$ where ζ_k is geometrically distributed with mean $1/p\beta^k$. The ζ_k are defined to be the number of trials for which the accumulated number of failures equals k. In this report it is shown for both formulations of the reliability growth model that the likelihood equations have solutions, $\hat{p}$ and β, which converge in probability to the true values of p and β, and which are jointly asymptotically normally distributed. Author

Review: This report is concerned with a very particular reliability growth model involving two parameters. Although not mentioned by the authors, the second formulation of the model necessitates sequential sampling to obtain the basic data. The main purpose of the paper is to establish the existence, consistency, and asymptotic joint Normality of the maximum likelihood estimates of the two parameters in the model. Almost all of the report is devoted to the proofs of these results and the details are extremely complex.

R69-14804 ASQC 824
C-E-I-R, Inc., Beverly Hills, Calif.
FURTHER RESULTS ON ESTIMATION OF THE PARAMETERS OF THE PEARSON TYPE 3 AND WEIBULL DISTRIBUTIONS IN THE NON-REGULAR CASE
W. R. Blischke, P. B. Mundle, M. V. Johns, Jr., and A. J. Truelove
Wright-Patterson AFB, Ohio ARL Nov. 1968 94 p refs
(Contract AF 33(615)-3152)
(ARL-68-0207)

Analytical results on exact and approximate Pitman estimators are discussed. Approximations based on linear combinations of order statistics and on powers of order statistics are found to have asymptotic variances of the same order of magnitude. Some comments on the estimation problem in the "regular" case are also included. Certain of the analytical results are extended to the Weibull distribution. Numerical studies have also been undertaken. The results confirm the theoretical conclusion that the variances of the approximate and exact Pitman estimators are of the same order of magnitude and the numerical results that the variance bounds are of this order as the sample size increases. Numerical results concerning a joint estimator based on the Pitman estimator of the location parameter and the maximum likelihood estimators of the shape and scale parameters are also included. This procedure is found to be unacceptable except for large sample sizes. Author

Review: This report is another contribution to the theory of statistical estimation of the parameters of distributions which are important in life-testing and reliability applications. The report is extensive and well documented. Because of its mathematical orientation, it will be of interest to the reliability theorist rather than to the reliability engineer or design engineer.

83 DESIGN

R69-14759 ASQC 830
Sandia Corp., Albuquerque, N. Mex.
COMPUTER-AIDED RELIABILITY AND QUALITY ANALYSIS OF ELECTRONIC CIRCUITS
Clint Purdue 1968 16 p refs
(PB-183452)

To produce a system meeting today's "Quality–Reliability" requirements, the design engineer must make effective use of all available tools and techniques. Designers and analysts now use computers to solve a variety of problems. Several "User-Oriented" computer program features will be discussed which make the man–machine interface easier to implement. The usefulness of circuit and system analysis programs is limited by the lack of mathematical models or algorithms which will predict the actual terminal characteristics of the various non-linear elements used. The development of models in a form suitable for computer computation will be discussed briefly since their existence will increase the number of circuits which can be analyzed on the computer. The overall system quality and reliability will thus be increased as a direct result of the computer–program–model combination. Using appropriate programs, the designer and analyst can now simulate many circuits on the computer and optimize the desired performance characteristics. The manner in which a computer, combined with programs such as ECAP, NET-1 CIRCUS, and SCEPTRE can be used to assist the engineer achieve designed-in quality and reliability characteristics, will be described. Author

Review: This report appears to be directed toward the novice in using computer-aided design in electronics. It is a qualitative brief discussion which tells some of the qualities to look for. It might also be directed toward programmers who are attempting to create such programs. It properly cautions them to make the programs very easy to use by electronics engineers who have not been extensively trained in that program and its use. Computer-aided design is often worthwhile and probably should be used more than it is. An engineer's initial attempts to use it will probably not be satisfactory, and he should be prepared for some frustration and expense as he learns to use the tool. Even though design and reliability engineers should be familiar with and make use of the available analytic programs, few of them will need to go out of their way to find and read this paper.

R69-14762 ASQC 833; 844
FACTORS RELATING TO SYSTEM SELECTION OF MAGNET WIRE AND VARNISH TO AVOID COMPATIBILITY FAILURE OF ROTATING EQUIPMENT.
M. V. Thierry (Anaconda Wire and Cable Co., Muskegon, Mich.).
Proceedings of the 8th Electrical Insulation Conference, Los Angeles, Dec. 9–12, 1968.
Conference sponsored by the Institute of Electrical and Electronic Engineers, the National Electrical Manufacturers Association, and the Naval Ship Engineering Center.
New York, IEEE, Inc., Dec. 1968, p. 142–143.
(IEEE-68C6-EI-85)

The basic technical factors relating to system selection are identified as (1) life vs. temperature (hot spot temperature and expected life of the equipment); (2) environmental conditions such as gaseous or liquid dielectric, refrigerants, totally enclosed, and high humidity; (3) bond strength; (4) overload conditions; (5) electrical requirements including corona, electrical losses, and elevated temperature dielectric; (6) conductor metal (copper, aluminum); and (7) chemical interactions. Test methods for wires and varnishes, that can provide data relevant to these factors, are discussed. Author

Review: This is a good paper on magnet wire and varnish insulation for rotating equipment. It shows the complexities involved in the choice of a system and the kinds of ways in which the system may fail. These are often called *reliability physics* or *physics of failure* by reliability practitioners. In any event, they are obviously important as design criteria and considerations. The checklist will be invaluable to those who are new to the field, and will also provide increased understanding and current awareness for those who have been involved for some time. One thing that this article illustrates clearly is that while a piece of hardware may be just a component to someone who purchases it, it is a complex system to the one who designs and manufactures it. Many of the considerations mentioned in the paper are of direct concern to aerospace design and reliability engineers. Sampling uncertainties in insulation life seem to be negligible or ignored and the same holds true for the spread of individuals within the population.

R69-14764 ASQC 831; 844

WHAT CAN BE DONE IN POWER SYSTEM DESIGN TO IMPROVE RELIABILITY.

Walter C. Bloomquist (General Electric Co., Schenectady, N.Y.).
1968 IEEE Industrial and Commercial Power Systems and Electric Space Heating and Air Conditioning Joint Technical Conference, St. Louis, Mo., May 7–10.
IEEE Transactions on Industry and General Applications, vol. IGA-4, Aug. 1968, p. 356–362. 19 refs.

The available quality and variety of present-day power equipment and the system design technology permit the tailoring of a system to meet the reliability requirements of the user. However, system planning must be reemphasized in power system design which has been of deteriorating reliability and not necessarily the most economical. This paper describes some of the system and circuit arrangements and other related factors that are necessary to obtain reliable, economical, and responsive modern power systems. Author

Review: Power systems have much in common with some aerospace systems as far as reliability is concerned in that they deal with massive complex equipments, and a complete system analysis is generally impossible. Instead, one does rough analyses on the entire system, and the detailed analyses are reserved for subsystems or special characteristics of the system. This paper is concerned with overall system design in order to provide reliability. As with most utilities, whether electrical power, airline, etc., reliability is generally interpreted largely as availability although it is often concerned with the happiness of the customer with the service (which as the author points out is one of the definitions of reliability given by a large industrial manufacturer). On large complex systems, simulation is often helpful in making sure all of the potential problem areas are identified and perhaps more importantly to be able to put them in an order of criticality. The specific suggestions for improving the reliability of a plant power system are good, but will often not be of concern to the aerospace reliability engineer. When they are important, such as at Cape Kennedy, they are of course most important. The benefit that the aerospace reliability engineer will get from this kind of paper lies in seeing the kinds of details to which someone else must pay attention and judging whether or not they are applicable to his own work. Sometimes one is able to see more clearly what should be done in a field where he knows the language but with which he is not intensely involved. The author gives an extensive bibliography for more complete treatment of the details. Not everyone would agree with all of the author's recommendations; but each of them should be seriously considered, and none passed over without an extensive amount of thought and analysis. (As mentioned in the journal, this paper was presented at the 1968 IEEE Industrial and Commercial Power Systems and Electric Space Heating and Air Conditioning Joint technical Conference, St. Louis, Mo., May 7–10, 1968.)

R69-14775 ASQC 830; 612

COMPUTER STRESS ANALYSIS.

Ronald Khol
Machine Design, vol. 40, Nov. 21, 1968, p. 136–145.
(A69-12153)

Discussion of the widening application of computers to stress analysis, which is gradually transforming this operation into a high-precision science and may eventually result in automated designs. It is pointed out that while the computer makes it possible to solve difficult stress equations by numerical methods, the most important development is an entirely new computer technique–the finite-element method–which does not involve these equations. Various practical and theoretical aspects of this technique are considered. I.A.A.

Review: Attention to detail is the traditional watchword of high reliability but the details to which one can pay attention are limited by the state of the art. This paper describes in a qualitative way a numerical technique for performing stress analysis. The paper serves as an awareness source only, for designers and reliability engineers. Implementing the method is expensive and complex, although eventually one can hope that it will be available to designers in modest companies and without the expenditure of a large amount of resources. This technique is part of a growing trend toward computer-aided design which is increasingly beneficial to design and reliability engineers alike. It enables them to pay attention to a level of detail they hitherto had to ignore.

R69-14778 ASQC 831; 820

RELIABILITY ANALYSIS OF NUCLEAR REACTOR ELECTRONIC SYSTEMS.

R. A. Rohrbacher (Douglas United Nuclear, Inc. Richland, Wash.).
In: Proceedings of the Western Electronic Show and Convention, Session 20, Aug. 20–23, 1968.
Convention sponsored by Region 6 of the Institute of Electrical and Electronics Engineers, and The Western Electronic Manufacturers Assoc.
Los Angeles, IEEE, Inc., 1968, p. 1–15. 6 refs.

Reliability is defined as the probability of successful performance under specified conditions of time and use. Basic concepts of reliability theory and reliability analysis are discussed, with emphasis placed on the chance or random failures which occur during the useful life period. The need to define and assess system reliability, how to measure it, and means to improve it are stressed. Various reliability analysis techniques are assessed, including failure modes and effect analysis; failure sequence analysis; and reliability models which reproduce the failure characteristics of the system, including block diagrams, part count models, mathematical models, system logic models, and fault tree models. Particular consideration is given to the fault tree models, with commonly used logic symbols depicted. Examples of their use are included, together with simplified fault tree diagrams of a steam supply subsystem, and nuclear reactor cooling systems. M.G.J.

Review: This is a tutorial paper written for electronics and electrical engineers. It discusses the basic concepts of reliability and some techniques applicable to electronic systems. Thus, while it contains nothing new for experienced reliability engineers, it can serve a useful purpose for engineers who wish to get some basic ideas on the subject. As is often the case with tutorial papers, the text contains some misconceptions about which the beginner should be warned. The most important of these are the following. 1. The "weakest link" approach to reliability is said to have led to the "product rule". The product rule is an elementary law of probability related to independent events, and predates any approach to reliability as currently understood. 2. The author states that failures in the useful life period occur randomly. But failures also occur randomly during the infant mortality period and during the wearout period, i.e., the term *random* does not apply uniquely to the useful life period. This misconception occurs quite frequently in the literature. The careful author might state that the useful life period is a period in which the failure rate (hazard rate) is low and approximately constant, by contrast with the period of early failures in which the failure rate starts high and decreases, and the period of wearout failures in which the failure rate increases. With these reservations, the discussion of basic concepts is adequate for its intended purpose. There is also a brief discussion of failure modes and effects analysis, failure sequence analysis, block diagrams, part count models, mathematical models, and system logic models. In connection with mathematical models, the author mentions an important point which is sometimes overlooked by the novice. That is, it should be recognized that the mathematical theory describes the model and not necessarily the system. The point at stake here is the appropriateness or validity of the model in representing this system. Approximately the last half of the paper is concerned with fault tree models; the discussion of these is presented in some detail, and illustrated with examples. It is only these examples which pertain to nuclear reactors, the balance of the paper being equally applicable to any kind of electronic system. It should perhaps be pounted out that the fault tree analysis implies a dichotomous (good or bad) description of the system. While this may be reasonable for electronic systems in the context of the author, the reader should understand that for some systems (e.g., mechanical ones) allowance needs sometimes to be made for degrees of reliability/performance rather than the simple dichotomy of good or bad.

R69-14784 ASQC 830; 870

RELIABILITY AND MAINTAINABILITY PROBLEMS CONFRONTING ENVIRONMENTAL CONTROL/LIFE SUPPORT SYSTEMS FOR LONG DURATION SPACE FLIGHT.

J. R. Burnett and C. D. King (General Dynamics Corp., Convair Div., San Diego, Calif.).

In: Proceedings of the Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Oct. 7–11, 1968.

Meeting sponsored by the Society of Automotive Engineers.

SAE, Inc., 1968, p. 1–12 13 refs.

Discussion illustrating some of the most pressing problems confronting the designer in his quest for progress in the development of reliable and maintainable environmental control/life support system designs. Some of the realities of current experience with respect to these parameters are reviewed, and some of the apparent inconsistencies in concepts concerning the nature of failure and effective in-flight maintenance as a means of augmenting reliability are examined. Two of several analytical and design approaches which promise to be of value in resolving some of the reliability and maintainability problems are illustrated. I.A.A.

Review: The first part of this paper is very pessimistic in that it shows (a) a lot of things that cannot be done to improve the reliability and (b) that many approaches that people are wont to suggest are in fact impractical. An interesting point made by the authors is that many maintenance actions do not require replace-and-repair but (by implication) merely require adjustment. This is especially true for electro-mechanical-hydraulic subsystems. The authors make an excellent point, viz., it is difficult to optimize a design for maintainability without the design's being reasonably mature in the first place; otherwise one is much more worried about making it work and not having a multitude of failures than he is about ease of maintenance. The main ways they suggest for improving maintainability on a mature design are (1) repackaging, often within the same weight and volume constraints, and (2) installing the repackaged assemblies in swing-out modules. It is still not clear that even these techniques will be sufficient to provide the required reliability, especially in view of the authors' remarks in the first part of the paper.

R69-14790 ASQC 833

GUIDELINES FOR RELIABLE RELAY APPLICATION AND SELECTION.

L. W. Wendling (Naval Air Systems Command Hdq., Wash, D.C.). and E. U. Thomas (Grumman Aircraft Engineering Corp., Bethpage, L.I., New York).

In: Annual National Relay Conference, 17th, Stillwater, Okla., Apr. 22–23, 1969.

p. 10–1 to 10–35. 19 refs.

Discussion of the reliability requirements in applying and selecting relays, in view of the fact that different conditions impose entirely different requirements upon the switching device capabilities. To select the proper relay circuit, designers and component selectors must be familiar with the following: (1) the different relay specifications; (2) the significant features of the detail sheets; (3) minimum current; (4) parallel contacts; (5) relay case grounding; (6) predictable catastrophic failures; (7) arc-over; (8) effect of load types; (9) effect of frequency; and (10) the switching mode, to ensure that the item used will not be applied in a manner for which it was not included. I.A.A.

Review: This paper is directed to the avoidance of misapplication of relays, and conveys its message effectively. Consequently, it is highly recommended reading for those who design equipment in which relays are used. The paper is quite long (35 pages), but over half of it consists of illustrative and supporting material presented in the form of tables, figures, and some photographs. The text is clearly and forcefully written, and appears to be a thorough discussion of the subject. Nineteen supporting references are cited. The message of this paper is the kind that needs to be given over and over again, both to reinforce it for the people who have heard it before and to catch the ones who were missed previously. Two conditions which cause much trouble are: (1) the severity level of relay use is not linearly related to voltage-current in the contacts, and (2) the factors which influence severity level are not well known by design engineers. The warnings and messages are similar for switches or anything else that uses make-and-break contacts. Relays can be reliable devices if they are applied properly; papers such as this one can play an important part in the achievement of this reliability. The authors recommend as a supplement to relay selection their first cited reference—Section XI *"Relays, Electro-mechanical"* from *"Design of Electric Systems for Naval Aircraft and Missiles."* Section XI by itself is available from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402 as Catalog Number D217.14:EL2/CH at $2.75.

R69-14796 ASQC 838; 824
Royal Aircraft Establishment, Farnborough (England).
RELIABILITY IMPROVEMENT BY REDUNDANCY IN ELECTRONIC SYSTEMS. PART 1: A METHOD FOR THE ANALYSIS AND ASSESSMENT OF REDUNDANCY SCHEMES
Theresa F. Klaschka May 1968 51 p refs
(TR-68130)

Many schemes for applying redundancy to improve electronic system reliability are known, but their relative merits have not been satisfactorily assessed. By analysing a general model of an ideal redundancy scheme, an apposite measure of the reliability improvement produced by a redundancy scheme is found; and it is shown that the measure is to a close approximation applicable to most real redundancy schemes. The measure overcomes many of the problems previously encountered in redundancy scheme assessment since it is independent of the size of system to which the redundancy scheme is applied. It has a good sensitivity characteristic, and it is relatively easy to evaluate by considering the possible failure modes in a small representative part of the system. The reliability improvement measure, together with an appropriate redundancy "cost" factor, is shown to express the performance of a redundancy scheme adequately and concisely, and some preliminary results of such a comparative assessment of a selection of redundancy schemes are presented. Author

Review: This paper is an expansion of the first part of the report covered by R69-14506 in which a measure for the reliability improvement due to system redundancy is put forth. The review of the earlier paper applies as well to this one, plus the following comments. The idealized redundancy scheme is defined by four postulates, and it is not obvious what are the various logical consequences of these postulates, and what is added later in the report. The following are examples. (a) Redundancy appears to be restricted to one level only. One could not use quadded logic inside some digital circuits and then use parallel redundant subsystems containing those. Otherwise, it would violate postulate 3. (In a private communication the author has stated that the theory can be expanded to cover this situation.) (b) It is not clear whether, in postulate 1, the subdivision into elementary segments is exhaustive and mutually exclusive, although one would presume that it was. If so, the interconnections in the hardware are part of a segment and the lines which apparently connect segments do not represent interconnections but merely represent signal flow. It is not even clear that it is necessary to connect the segments by lines on the paper. (c) Presumably good/bad must be an adequate description of a segment but not necessarily of a component. The components are presumed to have various failure modes. Even in a nonredundant segment, it is not clear whether the segment fails when any component shows a fault. (d) In this connection, the author mentions the potential difficulty with mutually exclusive failure modes since they cannot be statistically independent. This particular problem is thoroughly treated in the statistics of dying from competing risks, and it turns out that in the absence of competing risks the processes can be considered statistically independent whereas in the presence of the other competing risks the processes are mutually exclusive. See, for example, [1]. The author's treatment is adequate since she essentially considers only the independent probabilities. (e) In Section 4.1, it is stated, "Provided the components are statistically independent, . . . the unredundant segment reliability is simply the product of the reliabilities of all its components." This would seem to imply that a fault in any component will cause the unredundant segment to fail, which in turn will cause the system to fail. Therefore, all components in the system are effectively in series and consequently for the unredundant system, each minimum fault set is one component fault and every component fault is a minimum fault set. This does seem to be in accord with the rest of the discussion. The analysis of the errors involved in the reliability improvement factor for non-ideal redundancy schemes is interesting and appears to be reasonably thorough. The graphs showing the various costs of some redundancy schemes should be interpreted very carefully since each point applies only to a specific narrowly-defined scheme and not to all schemes with that generic name. This is especially true of majority voting. All in all, one needs to explore the logical consequences of the assumptions made throughout the text to be sure that they are all consistent. If they are not, of course the analysis would have to be modified. If they are, then this analysis can stand by itself as a reasonably complete treatment.

Reference: [1] *Introduction to Stochastic Processes and Biostatistics,* by Chin Long Chiang, Chapter 11, John Wiley & Sons, Inc., New York, 1968.

R69-14797 ASQC 838; 824
Royal Aircraft Establishment, Farnborough (England).
RELIABILITY IMPROVEMENT BY REDUNDANCY IN ELECTRONIC SYSTEMS. PART 2. AN EFFICIENT NEW REDUNDANCY SCHEME–RADIAL LOGIC
Theresa F. Klaschka Mar. 1969 69 p refs
(TR-69045)

This Report describes an efficient new redundancy scheme called radial logic, which is suitable for binary logic circuitry. Rules for applying radial logic are given, together with rules for achieving satisfactory interfaces with subsystems which are unredundant or have another form of redundancy. The mechanism of error correction in radial logic is analysed, and a general expression for the reliability improvement it produces is derived. Methods of testing redundant systems are also discussed. Radial logic is shown to be very efficient in terms of the reliability improvement produced for the amount of redundancy used. The degree of error correction achieved is flexible, the scheme is relatively simple to apply, and standard circuits can be used. Author

Review: This is an expansion of the paper by the same author covered by R69-14506. As mentioned in that review, (a) the system appears adequate to do what is claimed for it although the calculations were not gone over in detail, (b) a disadvantage is that it must be applied element-by-element to every element in the system; it cannot be applied to groups of elements, as can majority voting for example. A further disadvantage is that the author suggests its use with integrated circuitry and also with resistor-transistor logic. The trend with integrated circuits, however, is away from resistors since they are more expensive than transistors. The author has not shown, for example, how it would be used with transistor-transistor logic. Designers should be aware of this kind of redundancy and toward that end, the author would undoubtedly have to publicize it much more by submitting articles on it to the trade magazines in order for designers to be familiar enough with it to consider it. With regard to the statistical independence of failures on integrated circuits, it depends on the causes of the failures. Some causes might have their failure probability reduced by this redundancy, whereas others would be unaffected.

84 METHODS OF RELIABILITY ANALYSIS

R69-14755 ASQC 844; 833
RELIABILITY OF HYBRID MICROELECTRONICS.
Edward F. Platz (IBM Corp., Components Div., Hopewell Junction, N.Y.).
Western Electronic Show and Convention (WESCON), Aug. 22, 1968, Paper. 4 p

The reliability of hybrid microelectronics with the particular aim of finding reliability problems is discussed. The most important use for field reliability data is to guide development and management organizations in the improvement of current products as well as to give direction to new products insofar as reliability consideration are concerned. The Failure Analysis Information Retrieval (FAIR) program is described. It is a field return system, and all data gathered is actual use information. FAIR provides critical information on the number of failures, the number of hours of operation, and the total sample population (not necessarily constant). Author

Review: This paper does not discuss the reliability of hybrid microelectronics in general but rather that of the IBM SLT (Solid Logic Technology). There is useful detail on the relative occurrence of failure modes, and interconnections are very high on the list. Since this particular technology is limited largely to IBM, the paper can be considered somewhat in the nature of a selling document; also it will be useful to those who wish to compare their own processes with others available on the market. It appears that the use of a particular technology depends more on management decisions than it does on engineering considerations since many techniques can give good results. The paper is easy to read and provides worthwhile information. (An earlier related paper by the same author was covered by R68-13898.)

R69-14757 ASQC 844; 851
Army Natick Labs., Mass. Clothing and Organic Materials Lab.
RELIABILITY OF SOME CRITICAL PERFORMANCE CHARACTERISTICS OF COTTON DUCK FABRIC
Clarence J. Pope (Materials Research Div.) and Stanley J. Werkowski (Quality Assurance Office) Sep. 1968 26 p refs *Its* ser. IS-158
(AD-677385; TR-69-30-CM)

Reliability analyses are made of physical characteristics of a cotton duck material (with a fire, weather, water, mildew-resistant treatment) used in the construction of military tentage and equipage items. The breaking in both the lengthwise (warp) direction and crosswise (filling) direction and also the water resistance property were selected as critical characteristics for analyses. The reliability analyses relate to a commodity situation where these techniques may be useful in assessing how well characteristics of a commercial material meet established requirements. The chi square (χ^2) test for goodness of fit was used to test normality of the distribution of laboratory data for each of the characteristics evaluated. Different methods are used to obtain one-sided lower reliability limits. Point estimates of reliability are also computed. Results of the different methods are compared, and the relative advantages of these methods are discussed. Author

Review: The applications of reliability techniques are of interest to aerospace reliability engineers even when those applications are in non-aerospace fields. There is ordinarily much in common between the many kinds of applications. This article is an extension of the one covered by R69-14426 and applies reasonably straightforward stress-strengh theory wherein the stress is not represented by a distribution but by a fixed specification limit. There are two difficulties in this kind of application. (1) If the tail percentages are too small (e.g., < 1%), the assumed distribution probably does not represent the actual data well enough. (2) Again with small tail percentages, the sample is probably not sufficiently representative of future production. Those who are in the materials field even with reasonably well-known metals are all too aware of this second difficulty. The chi-square test for goodness of fit is well known for its low power in ordinary circumstances (i.e., with few degrees of freedom as in the present situation) and other distributions could have given equally good values of chi-square with much more disastrous results for the reliability. For example, the assumed distribution could be a mixture of a Normal one plus a small percentage defective (that is, a small percentage below specification). For the water resistance property, the data are obviously not Normal (as the authors recognize) but it is possible that they are a sample from some other family such as the gamma distribution or, in this particular case, a mixture of a Weibull and a Normal distribution. But, even without that, a 95% confidence limit could have been set on the fraction defective in addition to using the point estimate (see the table below).

TABLE

	Filling	Warp	Water Resistance
Spec. limit	140	150	200
Number of samples	425	425	255
Number worse than spec.	24	0	17
Normal distr. of strengths			
point est. of unreliability	7.1%	0.06%	--
95% confidence that unreliability* is between 0% and ...	8.8%	0.12%	--
Nonparametric analysis (items are good/bad)			
point est. of unrel.	5.5%	0.0%	6.5%
at least 95% confidence that unreliability is between 0% and ...	--	0.70%	--
95% confidence that unreliability* is between 0% and ...	7.3%	--	9.0%

*includes "continuity correction" (subtract 0.5 from no. failures)

The Table shows the results of calculations which assume a Normal distribution for the breaking strength and also calculations which assume no distribution for the breaking strengths but merely assume that only two test outcomes are possible, viz., good or bad. This is a much less restricted analysis from an engineering point of view since the question of whether the distribution is Normal or not is so uncertain. With the large samples, the unreliabilities calculated each way are quite close and, in one case, the unreliability estimate is even better with the nonparametric assumption than with the parametric one. One of the important things for reliability engineers to learn from this article is that the answers you get depend on the questions you ask and that often an engineer does not know what kind of statistical questions he can ask and a statistician does not know the kinds of engineering questions to which the answers are sought. In this grey region there is a tremendous need for improvement in the entire reliability field.

R69-14761 ASQC 844
ELECTRIC MOTOR FAILURE–A COMPARATIVE STUDY OF ITS CAUSES.
Daniel E. Nourse.
Proceedings of the 8th Electrical Insulation Conference, Los Angeles, Dec. 9–12, 1968.
Conference sponsored by the Institute of Electrical and Electronic Engineers, the National Electrical Manufacturers Association, and The Naval Ship Engineering Center.
New York, IEEE, Inc., Dec. 1968, p. 142–143.
(IEEE-68C6-EI-85)

Results are presented on two surveys dealing with motor failures: the first was concluded in 1950 and encompassed 8000 to 10,000 failures; the second was finished in 1967 and included 4067 failures. A comparative analysis of the data shows that except for the causes of failure occasioned by a frequency change (1945–1948) which accounted for 7.9% of the failures recorded to 1950, the main causes of failure have not changed. However, there is a significant shift in the percentages of the motor population that fail as a result of those various causes. The statistics show: (1) Moisture, oil and grease contamination, and overload have increased 344% in 17 years. This suggests that user excesses or negligence in operation and maintenance schedules are claiming more motors. (2) Bearing failures increased along with oil and grease contamination failures. Equating these two causes to over lubrication seems consistent with the data and current maintenance programs in effect with many users. Author

Review: This is a good and interesting paper. Reliability practitioners often decry the lack of failure data (justifiably), and the figures given by the author alleviate this situation in the area of electric motors. The biggest difficulty with the numbers is that they are conditional probability failures; that is, given that the motor failed, what was the probability that it failed in the certain way? So, for example, while failures due to oil and grease contamination have three times as large a fraction of the total failures in 1967 as they did in 1950, it is quite possible that the probability of a motor's failing (regardless of cause) circa 1967 is enough smaller than it was circa 1950 so that the absolute probability of a motor's failing in this way has actually decreased from ca. 1950 to ca. 1967. To say this in words is more complicated than with formulas. Let $F \equiv$ event of failure, regardless of cause, $\{F_i\} \equiv$ a set of mutually exclusive exhaustive failure causes (e.g., single phasing, bearings, moisture, unknown.), $\Pr\{F_i|F\} \equiv$ the probability of failing by the *ith* cause, given that failure has occurred. These are the numbers which are listed in Tables I and II. They sum to 100%. From the definitions of probabilities, $\Pr\{F_i\} = \Pr\{F_i|F\} \cdot \Pr\{F\}$. What the above discussion has said in words is that even though $\Pr\{F_i|F\}$ may have increased from ca. 1950 to ca. 1967, $\Pr\{F\}$ may have decreased enough so that the $\Pr\{F_i\}$ has actually decreased. There is a direct analogy with human death. Look only at the people who died ca. 1950 and ca. 1967 and get the fractions who died from any cause in each period; some of these will have increased, others decreased, but by definition the totals must be 100%. But if people got much healthier in the times between the two periods, a smaller portion of the total population may be dying from each one of the causes. Tables of this type also give rise to the question (which the author answers) of "just how would you like a motor to die?" The author's assertion is that he wants it to die from gradual insulation deterioration. Sampling uncertainties in insulation life seem to be negligible or ignored, and the same holds true for the spread of individuals within the population. Whether the trend toward manufacturers' building in a smaller factor of safety than prevalent many years ago is to be decried or not is a matter of opinion. The life at rating may be the same, although the overload capacity has apparently drastically decreased. Manufacturers naturally assert that it is not reasonable for them to give the purchaser more than the specification. The assertion that many users find it cheaper to overload and pay the penalty of rewinding rather than buy larger motors possibly suggests a need for reviewing the overall specifications of a motor. Perhaps just raising the temperature of the insulation rating would be a help.

R69-14766 ASQC 844
FREQUENCY AND DURATION METHODS FOR POWER SYSTEM RELIABILITY CALCULATIONS. PART 1: GENERATION SYSTEM MODEL.
J. D. Hall, R. J. Ringlee, and A. J. Wood (General Electric Co., Schenectady, N.Y.).
(IEEE Winter Power Meeting, New York, N.Y., Jan. 28–Feb. 2, 1968.)
IEEE Transactions on Power Apparatus and Systems, vol. PAS-87, Sep. 1968, p. 1787–1796. 18 refs.

As a goal, the evaluation and computation of electric power system reliability requires that a consistent technique be used for all portions—generation, transmission, and distribution. At present, a number of different methods are used for the generation system, while the frequency and duration of outages seems to be developing as a standard measure for the analysis of the distribution system. This paper and a subsequent one will present a reliability calculation method for the generation system that incorporates the frequency and duration of unit outages and includes consideration of the loads. This method leads to calculated generation reliability measures which are the availability, frequency of occurrence, and mean duration of reserve states. These are cumulative states in that they specify system reserve conditions of a given magnitude or less. This paper is concerned with the procedure for calculating the availability, frequency, and outage duration for a number of generating units connected in parallel to form a single system. Numerical data are used to illustrate the technique and make comparisons with other methods. Author

Review: This paper deals with the practical problems of computing the reliability for a generating system, namely, providing an adequate tractable model and implementing the model with actual data. The discussions at the end of the paper throw additional light on the problem and show that there is not a single set of numbers which is equally desired by everyone. The difficulties in modeling a large power system are similar to those in modeling any complex aerospace system and most often accuracy of description has to be sacrificed for tractability.

R69-14767 ASQC 844
MARINE CORROSION.
A. H. Tuthill (International Nickel Co., Marine Industries Section, New York, N.Y.).
Machine Design, Dec 19, 1968, p. 117–122. 10 refs.

The problems of selecting metals and designing equipment to minimize sea water corrosion are discussed, with emphasis placed on galvanic and crevice corrosion, stress corrosion cracking, and the effects of velocity and depth. Tables show the galvanic relationships for fasteners used in sea water pumps and valves, and the fouling resistance of materials in quiet sea water. Figures depict the corrosion potentials of various metals in flowing (8 to 13 fps) sea water at 50° to 80°F; the values for alloys that may become active in low velocity or poorly aerated water, or at shielded areas, and the effects of sea water velocity on corrosion of alloys used for pipe, tube, pumps, and hydrofoils. The need for total cost consideration, including operating and maintenance costs, is pointed out. M.G.J.

Review: In addition to having a fund of knowledge which bears directly on the job at hand, it often pays reliability engineers to have material at their disposal which tells them the kinds of important details about jobs they could be working on next month or next year. For aerospace engineers, this article provides that kind of information. However, it may serve a more immediate purpose for those who must design equipment to service the aerospace industry and which must operate in or very near the sea-water environment. The problem of corrosion is especially insidious because a foundation in it is not part of the general education of electrical and mechanical engineers. Worse than that, as the author points out, some effects in sea water are just the opposite of what one would expect even if he were somewhat knowledgeable. The article is easily readable, contains some good rough and ready data, and is short (qualities which are all too rare).

R69-14768 ASQC 844
RELIABILITY OF REACTOR COMPONENTS.
P. Rubel.
Nuclear Safety, vol. 9. Dec. 1968, p. 481–486. 7 refs.

Probabilistic modeling techniques are currently attracting attention in regard to reliability evaluation of vital systems in reactor plants. Programs are in effect or being considered to develop arrays of component reliability factors for use in system models that are based entirely on failure statistical data. However, there are significant practical reasons why such data may lead to erroneous or irrelevant conclusions regarding performance of critical components in unusual applications; moreover, many system failures cannot be attributed directly to any actual component failure of the types represented statistically. It appears that these modeling limitations can be largely overcome by comprehensive analyses of selected critical components and interpretation by equipment specialists of all available information relevant to component applications. Some simplification of the system models is also desirable and can be accomplished by treating rather extensive subsystems as components. Author

Review: It is sometimes difficult in this paper to tell exactly for what characteristics the author is denigrating the statistical approach; in fact it is not even clear what he means by the statistical approach. From the general tone of the article, he is complaining of any misapplication of numbers such as occurs in the often-criticized "reliability numbers game." Apparently what the author is saying is that reliability is an engineering problem, that failure modes and effects and criticality analyses are important, that attention to detail in these analyses is vital and that if one uses very rough reliability numbers, he should expect to get very rough answers. All of these things are true and any design or reliability engineer who was not aware of them before should be getting up to date in his trade. Statistics, when properly applied, can be invaluable in design and reliability work. When improperly applied, they are just as damaging there as they are anywhere else. The paper is not recommended in general for the average aerospace design and reliability engineer since there are many other articles more accessible to him that explain the problems more clearly. Those in the nuclear business will find some of the points of particular interest, especially since they are written in the nuclear engineering jargon. There undoubtedly has been as much misapplication of statistics in nuclear-power-plant reliability as in aerospace reliability.

R69-14776 ASQC 844
HOW TO CALCULATE THE FATIGUE STRENGTH OF PARTS THAT BEND AND TWIST.
R. E. Little (University of Michigan, Dearborn, Mich.).
Machine Design, Nov. 7, 1968 p. 174–178.

A simple, accurate method is presented for estimating allowable fatigue stresses for critical components subjected to combined bending and torsion. The analytical method circumvents estimation of both the combined stress—concentration factor and the combined fatigue notch sensitivity index. As the fatigue strength of the material depends on the predominant type of stress, the dominant stress is determined analytically by constructing a Mohr's circle for the respective nominal alternating components of stress. The overall intensity of fatigue stress is stated in terms of the range of shear stress; thus, allowable fatigue stress is the same as the allowable range of shear stress for various combinations of bending and torsion. For an unnotched condition, the allowable range of shear stress is specified in terms of fatigue limits under pure bending and under pure torsion. Then, the resulting allowable ranges of shear stress are modified to account for the presence of notches. Several examples are given to illustrate the method. M.G.J.

Review: One of the things design engineers must often do in their designs is to make the best of inadequate information. They need to take into account as many factors as possible with respect to the minimum information at their disposal. This paper presents a technique (of the kind sometimes referred to, not unkindly, as *quick and dirty*) for enabling the designer to do as well as he can with minimal information. These techniques are important to designers when high reliability is essential. To ignore a failure mechanism because one cannot calculate the behavior exactly would be folly. The simplified method presented here has the great advantage that a designer can use it without spending an inordinate amount of time or effort on it. It will make his design better than if he had not used it. It is interesting to compare this paper with *another in the same magazine on using a computer for stress* analysis (the paper by Khol on pp. 136–145 in the issue of November 21, 1968 which is also reviewed in this issue of RATR).

R69-14785 ASQC 844; 775
X-RAY DIFFRACTION ANALYZES RESIDUAL SURFACE STRESS
Theodore A. Renshaw (Fairchild Hiller Corp., Republic Aviation Div., Farmingdale, N.Y.).
Space Aeronautics, vol. 52, Aug. 1969, p. 60–63.

The basic principles involved in the X-ray diffraction method of stress measurement are defined as the recording of diffracted X-ray beams from the microscopic crystals in a material. It is pointed out that X-ray diffraction can discern lattice changes of better than 1×10^{-4} Å. The operations involved in making the measurements are identified as (1) preparing the surface so that it is relatively smooth and clean without introducing new stresses; (2) stably affixing a suitable X-ray tube and camera at the surface to create an X-ray beam and to record the material's characteristic diffraction maxima (5 to 15 min exposure); (3) making very precise measurements of the segments of the diffraction rings on the film; and (4) computing the stress values from these measurements. The limitations of the technique are discussed in terms of error sources, and a validation exercise is recommended for any unfamiliar material or part to assure use of correct elastic constants. M.G.J.

Review: A brief description is given of the X-ray diffraction method of stress measurement, including theory and operations involved in making the measurements. The limitations and uncertainties of the method are discussed. A brief indication is given of the work ahead for the X-ray method. The paper is a worthwhile contribution to the literature on nondestructive methods of testing and measurement. It is easily readable, well illustrated, and serves the purpose of calling attention to the potential of this method. Although no references are cited, none are really needed for the accomplishment of the purpose of the paper.

R69-14786 ASQC 844; 612

USE A COMPUTER TO ESTIMATE RELIABILITY.

H. G. Reinicke and R. N. McDaniel (Westinghouse Corp., Defense and Space Center, Baltimore, Md.).

Evaluation Engineering, vol. 8, Aug. 1969, p. 24–29.

For monitoring failure growth rate, a computer technique was developed to simplify the method of listing the failure rate for each part based on the actual ambient environment and stress on the part. Details are given on key punching the input data, consisting of a part number, actual application information, and the line replaceable unit (LRU) ambient temperature; part number recognition; and the format of the dictionary contained in the computer. The advantages and disadvantages of binary tree chaining are weighed, and it is pointed out that the binary tree is most efficient when the items are entered in a random fashion; its effectiveness decreases as randomness is lost. Ways of updating hand-calculated items are suggested, and a set of rules is provided for transcribing the part identification number used as input to the key punching activity. M.G.J.

Review: What the computer in this situation is going to do of course is calculate a hazard rate for each part according to pre-inserted formulas and according to the "stress" data given it along with the part designation. The program also performs the appropriate addition to give the hazard rate for the assembly. Automating this kind of calculation is very worthwhile since it helps reduce errors and helps to insure that the calculations will in fact be made. It is important for the novice to realize more what the computer will not do than what it will do since the propaganda he has generally heard is on the optimistic side concerning the "intelligence" of computers. There is no magic way in which the computer is able to estimate the reliability without incurring all of the difficulties mentioned in the literature for manual estimation; these range from the inappropriateness of the constant hazard rate assumption to the lack of statistical independence among the failure processes. This paper describes the general outline of the computer program and some of the details of the way it is used. It is the kind of thing that would often accompany a program so that someone would know how to use it and roughly how it was constructed and why. The program itself is not given in the paper but perhaps is available from the authors. This paper will be of value only to those who are rather deeply involved in putting such a program on a computer and thus are aware of the difficulties inherent in that task. For them, it can provide a source of ideas and means of comparison.

R69-14788 ASQC 844

THE ENGINEERING APPROACH TO FAILURE ANALYSIS OF SWITCHING DEVICES.

Harry D. Sauter (American Machine and Foundary Co., Potter and Brumfield Div., Princeton, Ind.).

In: Annual National Relay Conference, 17th, Stillwater, Okla., Apr. 22–23, 1969.

Conference sponsored by the National Association of Relay Manufacturers and Oklahoma State University.

Arizona, National Association of Relay Manufacturers, 1969, p. 2–1 to 2–18. 3 refs.

Demonstration that an engineering approach to failure analysis in the electromechanical switching field provides the optimum amount of data for failure mode determination. This method uses preanalysis planning, open-ended data sheets with check-off lists and documentation of variables, and a uniform reporting of findings. These methods can be expanded or reduced to fit the needs of the individual analyst. Failure analysis requires a standard stereobinocular microscope with a minimum of 10X magnification. Cleanliness of the work area where devices and parts are evaluated is regarded as absolutely essential, and a cluttered workplace is to be avoided. A list of suggested handtools for use in evaluating switching devices and their associated parts is given, and it is pointed out that good data sheets form the heart of a planned analysis. Material analysis is discussed at length, and the necessity of obtaining complete data with a minimum of overlooked details is stressed. It is recommended that an evaluation be continued even after the obvious cause of failure has been found. I.A.A.

Review: This paper is directed toward the analysis of failed relays. One must be careful to distinguish between relays which failed because someone was using them in a poor way and relays which failed because of being made in an obviously improper way. The report is quite long and contains sections on both the principles involved and cookbook procedures for carrying out these principles. It is a good paper for those who are suddenly confronted with the task of performing such failure analyses or advising on them and wondering where they can get the proper information. As is the case with all such engineering presentations, there are undoubtedly points with which other experts would disagree, but it behooves the newcomer to the field to stick with one reasonably good set of principles until he learns enough about it himself to debate the merits of each principle individually. Many of the cookbook procedures are arranged so as to give the best odds on being able to find out what was wrong. One undoubtedly can contrive situations in which the order of tests turns out to obscure rather than pinpoint the difficulties. But anyone who argues about a lack of perfection in an engineering situation is usually wasting his time. This is an easily readable paper, one which both informs and demonstrates and can be of immense practical help to those who need it. (This paper is abstracted in "Relay Failure Analysis," *Evaluation Engineering,* vol. 8, Jul/Aug 69, p. 10–14, 16.)

R69-14792 ASQC 844

National Aeronautics and Space Administration. Washington, D.C. Office of Technology Utilization.

LOCATING SNEAK PATHS IN ELECTRICAL CIRCUITRY

[1968] 24 p

(PB-182362) Avail: CFSTI

Techniques in locating "sneak paths" in an electrical system are described. The term "sneak paths" is defined as unplanned closed current paths, which can be completely described by the electrical diagrams within defined limits. These paths normally contain two undesirable characteristics: (1) the existence of unwanted electrical currents in these sneak paths, and (2) the almost impossible task of locating these sneak paths. To attack the problem, all possible closed loops must be located. The exception to this is the technique for removing a large number of the normally designed power loops. Since it is predicted that the total number of these is low, the task of segregation of these sneak paths from these closed loops by direct examination of the diagram is possible. Another simplification is to separate the task into two levels. The first level is the cable diagram, where each cable is considered as a single path; and the second level is the individual wire path. The first level is reduced to its lowest number of possible cable loops. In turn, each closed wire path within these cables is recorded (if it exists). To aid the engineer in accomplishing this type of two-level task, three techniques are described in detail in the following sections. Author

Review: Some say that reliability is *merely* good engineering; others, that reliability is infinite attention to detail; there is a large amount of truth in both characterizations. This report is an instance of good-engineering and attention-to-detail that are required for high reliability in complicated electronic systems. It will be of help to electronics engineers in two ways: (1) for those who are not familiar with the difficulty of sneak paths, it will introduce the subject, and (2) it shows a methodical way of finding the existence of sneak paths and isolating them. A reasonable knowledge of electronics systems is required for understanding the paper (but most of those who are interested in the problem will have that understanding).

R69-14793 ASQC 844

Army Electronics Command, Fort Monmouth, N. J. Electronics Components Lab.

RELIABILITY OF MILITARY CRYSTAL UNITS UNDER CLIMATIC ENVIRONMENTAL CONDITIONS

Lewis Nelson Nov. 1968 31 p refs

(AD-683460; ECOM-3066)

The results of a 4 1/4 year investigation on military quartz crystal units in the HC-6/U enclosure which have been stored under moderate climatic environmental conditions is presented. Crystal units being reported upon operated on their fundamental, third and fifth overtone modes and covered the frequency range of 4.3 to 100.0 MHz. Data on crystal aging and changes in resistance are discussed. Apparent manufacturing defects which result in crystal unit failures are explained. Author

Review: There is a big emphasis in the reliability field on the reliability of components which have been in storage. This paper presents some good data on quartz-crystal units but unfortunately, as the author points out, the data are out of date. This is a problem with any long-term test—by the time the tests are finished, the product is no longer being made that way. Some physics-of-failure analyses show why crystals being made now are expected to be more reliable than the ones in the test. Those who are interested in either quartz crystal units or reliability in storage will find information of value in this report.

R69-14794 ASQC 844

Ampex Corp., Redwood City, Calif.

RESEARCH ON FAILURE INDICATOR SYSTEM

Bob V. Markevitch and Jacob Van Heeckeren Jul. 31, 1968 33 p

(Contract N00014-67-0401)

(AD-683369)

Recording and frequency analysis by means of coherent optical data processing techniques is described with special emphasis on the detection or diagnosis of failures in rotating mechanisms. Vibration signals from bearing assemblies have showed good correlation with themselves and poor cross correlations, implying the possibility of detection of specific bearing noise signatures. Author

Review: This is a very preliminary report on the subject of most interest, viz., optical processing of spectral data. It is of value only to those doing research in the field or who hope to become involved in it. The failure indicator system is for mechanical parts only and treats acoustics/vibrational data only. The idea is to be able somehow to compare the *signature* of a normally running piece of equipment with that of an unknown one. An "optical computer" is one of the fastest ways of performing this kind of computation since by optical means a Fourier transform is extremely simple. This report will not be of archival value although the discussion can be a help to those who are trying to further the state of the art.

R69-14799 ASQC 844; 775

NONDESTRUCTIVE TESTING.

Francis J. Lavoie.

Machine Design, vol. 41, Sep. 1969, p. 122–135.

Flaw or defect-finding nondestructive testing is described in terms of the technique and the application. The radiographic methods, based on a penetrating beam of radiation passing through an object, include pulse or flash X-ray radiography, gamma ray radiography, neutron radiography, radiation backscatter, fluoroscopy, color radiographs, and xeroradiography. Other techniques given consideration are: (1) ultrasonic tests using a pulse-echo, transmission, or resonance technique; (2) thermal tests conducted by applying heat over the specimen, or measuring the natural thermal emissivity of the object; (3) penetrants for detecting surface defects or internal flaws that extend to the surface; (4) magnetic inspection, particularly useful in detecting microscopic flaws; (5) microwaves for testing nonmetallics; (6) eddy current testers for detecting surface defects; (7) acoustic emission for defect finding and failure prediction; and (8) holography and holographic interferometry. The relative advantages of each technique are assessed. M.G.J.

Review: This is an extensive descriptive paper on nondestructive testing, well written and clearly illustrated. Topics covered include radiography, ultrasonics, thermal techniques, penetrants, magnetic techniques, microwaves, eddy current techniques, acoustic emission, and holography. It will serve the very useful purpose of giving the design engineer a bird's-eye view of these methods and of their potential usefulness to him. Capabilities and limitations of the various methods are brought out, and some indication is given of what can be expected of these methods in the future. Of the methods considered, holography is a relatively new and glamorous development about which relatively little has appeared in the literature up to now. The emphasis throughout this article is on techniques for finding flaws or defects. A related consideration, which, logically enough, is not considered in this paper, is that of what constitutes a defect. This is something which the engineer must take into account in practical applications, since techniques exist for finding defects which in themselves are not important from a reliability point of view.

R69-14800 ASQC 844

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

ULTRASONIC DETECTION AND MEASUREMENT OF FATIGUE CRACKS IN NOTCHED SPECIMENS

Stanley J. Klima and John C. Freche Washington Sep. 1968 31 p refs To be Presented at the SESA Fall Meeting, San Francisco, 28 Oct.–1 Nov. 1968
(Contract 129-03-07-01-22)
(NASA-TN-D-4782; NASA-TM-X-52421; N68-35071) Avail: CFSTI

An ultrasonic technique was developed and used to observe the formation and growth of fatigue cracks in notched cylindrical specimens subjected to reversed axial fatigue loading. Fatigue curves showing cycles to initially detectable cracks as well as cycles to fracture were obtained for an aluminum-, a titanium-, and a cobalt-base alloy and for a maraging steel. Depth of initially detectable cracks ranged between approximately 0.0005 and 0.004 in. (0.013 and 0.10 mm). Also obtained were curves relating ultrasonic system output voltage to crack depths up to 0.030 in. (0.76 mm) for three materials. These curves were used to demonstrate the capability of the device for monitoring crack growth. Author

Review: This paper completely describes the concept, design, calibration and evaluation of an ultrasonic device for the detection and measurement of the formation and growth of fatigue cracks. It is well written and thoroughly documented. Essentially, however, the basic purpose of the paper would be best fitted to the researcher or test engineer. Design engineers and materials engineers might find the fatigue curves which are included in the paper useful. These fatigue curves are a by-product and not the primary purpose of the paper.

R69-14801 ASQC 844; 824
Aeronautical Research Labs., Melbourne (Australia).
A REVIEW OF THE DISCONTINUITY OR HUMP PHENOMENON IN FATIGUE S/C CURVES: THEORIES AND FURTHER RESULTS
J. M. Finney Mar. 1967 45 p refs
(ARL/SM-314; N68-28267) Avail: CFSTI

The discontinuity or hump phenomenon in fatigue S/N curves has been reported for a wide variety of metals and testing conditions. This review outlines the known factors associated with the phenomenon and suggests that its apparent non-observance until about 1958 is a result of both the relatively small number of specimens used to determine S/N curves, and preconceived ideas as to the shape of such curves. There is evidence that the phenomenon is associated with differences in the mechanism of either fatigue crack initiation or propagation or both at different stress levels. The phenomenon is shown to be particularly important in fatigue life estimation and scatter characteristics of fatigue data. Author

Review: This paper reviews the known factors that are associated with the frequently-overlooked discontinuity or hump phenomenon that has been reported for fatigue S/N curves from a wide variety of metals under various testing conditions. Specifically, the author discusses the historical background and some experimental observations pertaining to the subject, discusses factors that tend to influence its occurrence, and speculates on the theoretical cause of the phenomenon. The occurrence of such a phenomenon is important for an estimate of fatigue life and the evaluation of scatter in fatigue lives. A detailed examination of the data would indicate, however, that a total disregard of the phenomenon would place the designer in a conservative position; consequently, the whole concept appears to be rather academic and in need of further research into the mechanisms of fatigue failure. This review paper, which is well written and thoroughly documented, is perhaps more useful to the research engineer or the scientist than to the design engineer.

R69-14802 ASQC 844
EVALUATING COMPONENT FATIGUE PERFORMANCE UNDER PROGRAMMED RANDOM, AND PROGRAMMED CONSTANT AMPLITUDE LOADING.
S. R. Swanson (MTS Systems, Corp., Testing Research Lab.).
International, Automotive Engineering Congress, Detroit, Jan. 13–17, 1969 Paper. 16 p. refs.

The incorporation of either programmed random or nonrandom command signals to an existing test system having continuous frequency response characteristics is discussed. Tests were carried out on a batch of automotive spindles, where the test procedures were varied to study their relative merits. Additional exploratory materials tests are carried out to answer specific questions raised by the spindle tests. Author

Review: Recently, it has been demonstrated that random load fatigue testing generally produces fatigue results more representative of service conditions than either constant amplitude or programmed constant amplitude testing. Most existing fatigue data have been obtained, however, from tests under the latter (deterministic) loading conditions. This paper describes, in considerable detail, direct comparison tests that were carried out to evaluate fatigue performance under programmed random and programmed constant amplitude loading. These tests were conducted in an attempt to develop a judgment concerning the usefulness of existing data and to illustrate the possible dangers of using one set of data for service conditions involving the other type of loading. The results reported in this paper show a trend indicating that RMS and maximum load are not enough information to establish a correlation between random loading and determinate loading. In general, the paper would be more useful to test engineers than design or materials engineers. Some useful fatigue data are included.

85 DEMONSTRATION/MEASUREMENT

R69-14758 ASQC 851
Battelle Memorial Inst., Columbus, Ohio.
STUDY OF SPACE BATTERY ACCELERATED TESTING TECHNIQUES. PHASE 1 REPORT. SURVEY OF TESTING METHODS APPLICABLE TO SPACE BATTERY EVALUATION
R. E. Thomas, E. W. Brooman, J. Waite, and J. McCallum Sep. 1968 65 p refs
(Contract NAS5-11594)
(NASA-CR-97935; N69-13454) Avail: CFSTI

Testing procedures are to be developed to accelerate the aging of electrochemical cells so that years of data may be acquired in significantly less time to enable a valid predication of cell life. The program is divided into three phases. The first phase is to conduct a literature survey. A literature survey of accelerated testing has been made with special reference to spacecraft batteries. Although increased sophistication is shown in measuring equipment and data processing, the survey shows that considerable differences exist among published investigations with respect to basic definitions, terms, and concepts. In particular, the terms "stress", "quality", and "failure" need to be defined in ways that are consistent with laboratory measurement techniques and possible physical mechanisms associated with degradations of quality over time. It is concluded that the greatest single difficulty in accelerated

testing consists of obtaining quantitative evidence that the dominant failure mechanisms are not changed by increasing the stress level.
Author

Review: This is a good report. The emphasis on being quite clear about what is meant by an accelerated test or a stress is especially helpful. The term *stress* has been overworked in the reliability literature and quite often it is devoid of any operational meaning. Anyone who is involved with the accelerated testing of batteries or, for that matter, accelerated testing of almost any type should study this report. The bibliography is most extensive. This is a survey of testing methods; so no definitive procedures were laid down for running the tests. The understanding one can gain from the report will be invaluable in the conduct of accelerated tests especially in a field as complicated as that of electro-chemical batteries.

R69-14763 ASQC 851; 716; 844
AGING OF HERMETIC MOTOR INSULATION.
H. O. Spauschus and R. A. Sellers (General Electric Co., Major Appliance Lab., Louisville, Ky.).
In: Proceedings of the 8th Electrical Insulation Conference, Los Angeles, Dec. 9–12, 1968.
Conference sponsored by the Institute of Electrical and Electronic Engineers, the National Electrical Manufacturers Association, and the Naval Ship Engineering Center.
New York, IEEE, Inc., Dec. 1968, p. 156–161. 23 refs
(IEEE-68C6-EI-89)

A method for determining the aging characteristics of wire enamels and wire enamel–varnish combinations in refrigerant environments is described. The procedures represent a novel approach to electrical aging studies in that dielectric property changes are measured at the environmental aging conditions, as opposed to measurements at room temperature after aging. Aging data for a typical hermetic wire enamel, with and without a varnish overcoat and at two refrigerant gas pressures, are reported and discussed.
Author

Review: This paper deals with better accelerated tests for the particular situation at hand. These motors are not in any great difficulty since they typically have very long lives and carry some of the longest guarantees in any industry. However, designers and manufacturers reasonably want even more information than they now have. The article shows that attention to detail is important. In this particular case, the important details are the exact nature of the environment and the kinds of "stresses" that will produce reasonably true acceleration. It is not total life that is measured but rather degradation rate (it turns out, in this case, to be much more uniform). Reliability engineers can profit from articles such as this both on the occasion where they are involved with the particular subject and also in general to give them a better perspective of their own situation.

R69-14787 ASQC 851; 844
RELAY FACTS—CONTACT CONFUSION.
Waldo Holcombe.
Electromechanical Design, vol. 13, Aug. 1969, p. 10–11.

A case history is presented to prove that special purpose relays should be tested specifically for their intended use, and general purpose relays for the manufacturer's ratings. It is also pointed out that establishing the suitability of incoming relays for intended uses may require testing a single model relay for one or more specific applications, or a line of relays for a wide variety of uses.
Author

Review: Relays are the exception that really prove the rule. (*Prove* in this context obviously means *test* rather than *show that it is true.*) Many air castles are built on flowery words about accelerated testing with high stresses, derating, etc. But when these are all applied to relays one often finds that his concepts were not defined clearly enough and that he had been spouting meaningless tautologies. This article illustrates these problems well in showing that severity level is not linearly related to voltage or current in the contacts. The paper also gives good advice on characterizing the severity level of use for the contacts. Apparently, the author's message is the kind that needs to be given over and over and over again, both to reinforce it for the people who have heard it before and to catch the ones who were missed previously. The warnings and messages are similar for switches and anything else that uses make-and-break contacts. Relays can be reliable devices if they are applied properly; papers such as this one can assist in that effort no end. The proceedings of the Annual National Relay Conferences sponsored by Oklahoma State University and the National Association of Relay Manufacturers are also sources of information on reliable applications of relays.

SUBJECT INDEX

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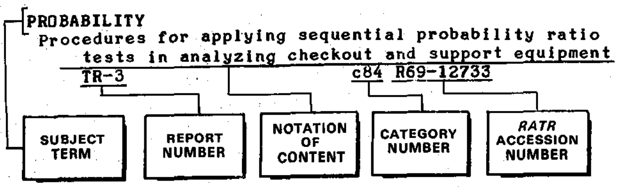
Typical Subject Index Listing



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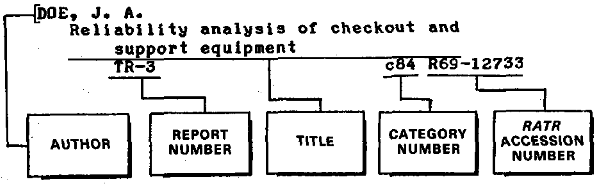
RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBER 12

Typical Personal Author Index Listing



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NASA-Langley, 1969

Reliability Abstracts and Technical Reviews

JANUARY–DECEMBER 1969

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ANNUAL INDEX

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ANNUAL INDEX

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Each entry in this index includes an accession number, e.g., R69-12345, a unique identification number assigned to each abstract-review that was indexed and announced in *RATR* during the year. In addition to the accession number, each entry in the Annual Index includes a 4-digit number (e.g., 10-84). The first two digits identify the issue of *RATR* in which the abstract-review is located. The two digits after the hyphen identify the ASQC category code assigned to the abstract-review.

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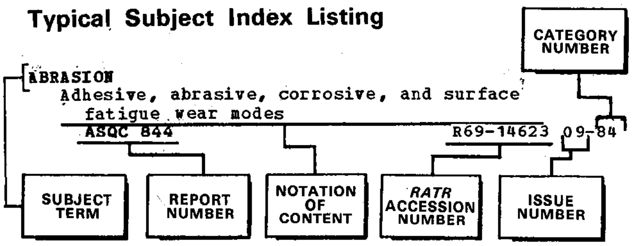
RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBERS 1-12

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The *RATR* accession number, the issue number, and the category number are used to locate the abstract-review in the abstract section of an issue of *RATR*. The first two digits following the accession number identify the issue of *RATR*, and the two digits after the hyphen identify the category in which the abstract-review appears.

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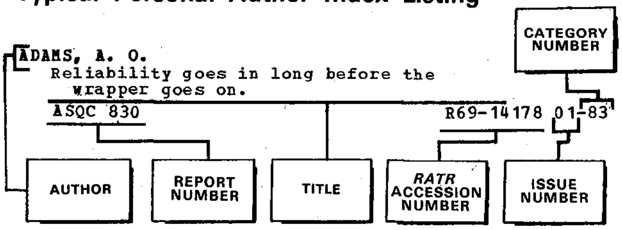
PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



The *RATR* accession number, the issue number, and the category number are used to locate the abstract-review in the abstract section of an issue of *RATR*. The first two digits following the accession number identify the issue of *RATR*, and the two digits after the hyphen identify the category in which the abstract-review appears.

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REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 9 NUMBERS 1-12

List of Report Numbers

This list may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number, followed by a four-digit number for locating the abstract-review in the abstract section of an issue of *RATR:* the first two digits identify the issue of *RATR*, and the two digits after the hyphen identify the category in which the abstract-review appears. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR*, and *IAA*, respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

List of *RATR* Accession Numbers

This list of *RATR* accession numbers may be used to locate numbered abstract-reviews in the abstract sections of the issues of *RATR*. Accession numbers are arranged in ascending order. Following each accession number is a four-digit number: the first two digits identify the issue of *RATR*, and the two digits after the hyphen identify the category in which the abstract-review appears.

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