RELIABILITY ABSTRACTS and TECHNICAL REVIEWS

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The Contents of

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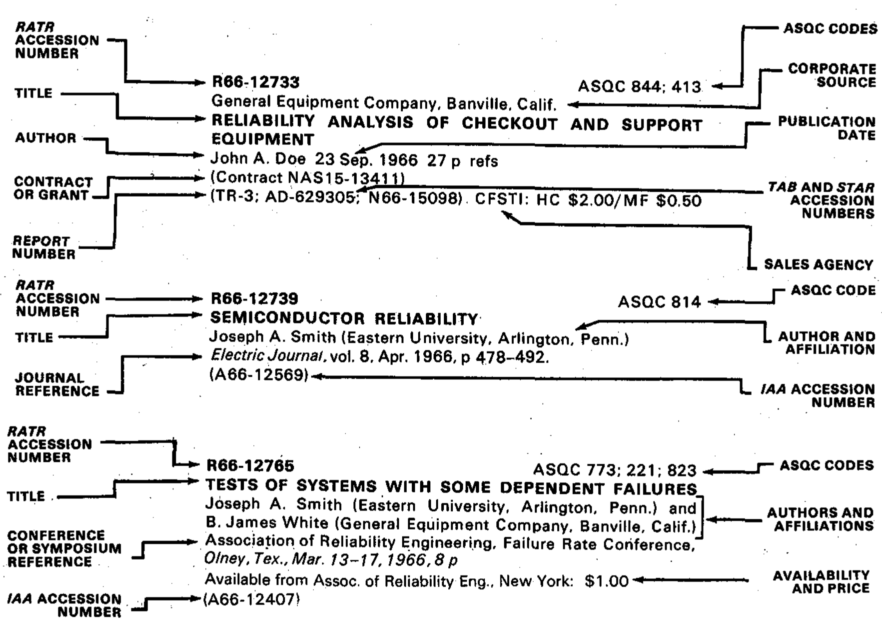
VOLUME 6

Abstract-reviews 2378 through 2732 are serially numbered and appear in consecutive order. The format was changed beginning with Issue 9 (September) of Volume 6. In Issues 9 through 12 the serial numbering is retained, but the serial number is an accession number preceded by R66-1 (R66-12733 through R66-12901). And the abstract-reviews are arranged in topical categories based on the first two digits of the subject-matter codes developed by the American Society for Quality Control. A complete list of these codes appears on the back of this page.

Examples, in the revised format of Issues 9–12, of citations of reports, journal articles, and conference papers are shown below. The principal subject field of an abstract-review (and therefore the category in which the item appears in Issues 9–12) is indicated by the first ASQC code number; related subject fields are indicated by additional code numbers. The appearance of a *TAB, STAR, 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 annual indexes are edited consolidations of the indexing of Issues 1 through 12, expressed in the revised format. Each abstract-review in Volume 6 is identified by the *RATR* accession number. Each entry in the indexes includes the *RATR* accession number and a four-digit number (e.g., 10-84). The first two digits identify the issue of *RATR* in which the abstract-review appears. The two digits after the hyphen identify the category (for use in locating an abstract-review numbered between R66-12733 and R66-12901 in Issues 9 through 12).

There are four annual cumulations: 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 announced; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of items to which the codes have been assigned. The Accession Number Index identifies the issues and the categories in which the abstract-reviews appear in Volume 6.

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(AS REVISED JANUARY, 1963)

Serial Number 2378
ASQC Code 823

TITLE: Insufficiency of instantaneous strength determinations for failure rate prediction

AUTHOR: Howard L. Leve (Douglas Aircraft, Long Beach, Calif.)

SOURCE: IEEE Transactions on Reliability, vol. R-14, p. 77-83, Oct 65

PURPOSE: To derive some relationships between failure rate and a decreasing strength.

ABSTRACT: The stress-strength model of failure is assumed. It is further postulated that the strength function is a non-increasing function of time; that time enters the strength formulas only in the form T_f-T where T is time and T_f is failure time; that the cumulative density functions of T_f-T and of strength are equal; and that if T_{f1} is larger than T_{f2} the initial strength of #1 is higher than that of #2. In general, the cumulative function for T_f is taken as $\exp(-T_f/\mu)$.

REVIEW: This is a poor mathematical paper. Some items stated to follow from the preceding material are in fact further assumptions. The total set of assumptions is not clearly put forth anywhere in the paper. The notation is poor and hard to follow since the text does not distinguish between the random variable (general) and specific values of that random variable. The assumption that time enters only as T_f-T is quite restrictive and may well be responsible for many of the results. It is difficult to tell the examples from the formal development, if in fact there is a distinction.

There will be some difficulty in applying the theory, even if it is adequately developed. The author asserts that the strength of an element (at any time) can be found by abruptly increasing the stress to cause failure. Two of the most common "stresses" in electronics are temperature and electric field. But the damage these do is a function of the length of time they have been applied, so that it is difficult, if not impossible, to find the strength, if indeed it is possible to define it in the stated manner. In those instances where a physical situation reasonably fulfills all the assumptions of the fully developed theory, the theory, of course, can find application. Metallic fatigue is such a possibility (number of cycles takes the place of time) and the theory of cumulative damage has been extensively investigated for it. Dielectric failure via cumulative damage has also received attention. It is important to distinguish between stresses that cause no damage (short of failure) and "stresses" that develop cumulative damage (even in the absence of failure). This is not to say that the ideas in the paper cannot be put into a good and complete theoretical development, just that this paper does not do it. ##

Serial Number 2379
ASQC Codes 431;824;831

TITLE: Mission effectiveness model for manned space flight

AUTHOR: Irwin Nathan (Aerospace Systems Division, General Precision, Inc., Wayne, N. J.)

SOURCE: IEEE Transactions on Reliability, vol. R-14, p. 84-93, 7 refs., Oct 65

PURPOSE: To present a model for estimating mission effectiveness.

ABSTRACT: The most objective manner in which to measure the ability of a system to perform against a specified mission is to estimate the average probability of successfully completing that mission. This probability of success is defined as the Mission Effectiveness of the system. In general, when specifications are stated for military or space application equipment, the reliability aspect far outweighs all other considerations when in reality it is only one important factor in the ability of the system to complete a satisfactory performance of its assigned mission.

In this paper the importance of other factors are illustrated by developing a model which estimates mission effectiveness. This model is developed for a system which undergoes scheduled check-out and up-dating after relatively long stand-by periods during which it is expected to respond to a random demand. The effects upon mission effectiveness as well as upon system accuracy of non-instantaneous and imperfect failure detection and repair are considered. The model is a Markov Chain with one absorbing barrier. The advantage of this type of model is that once the first transition matrix is derived, the factors that enter into mission effectiveness can be readily and automatically extracted.

This technique is quite general and as such is applicable to most types of military and space missions. The model lends itself easily to computer programming and demonstrates that even with the case of one spare the relationships between Reliability and the other factors in Mission Effectiveness are not simple. It points up the penalty for over-simplifying the problem, when perfect failure detection and sparing are assumed. (Author in part)

REVIEW: The evaluation of the model presented in this paper is rendered extremely difficult by the lack of clarity in the definitions and "ground rules." Mission effectiveness is defined as the product of three probabilities, for which the associated events are not explicitly defined. This leaves the reader wondering about the conditional nature of the probabilities. Table I which gives possible system states is not clear, perhaps as a result of excessive brevity. Some of the statements regarding the matrix T on p. 87 pertain to elementary properties of matrices in general. The ensuing mathematical details were not checked, in view of the difficulties with interpretation. It is to be emphasized that this complaint concerns the clarity of the presentation and not necessarily the correctness or otherwise of the work. ##

Serial Number 2380
ASQC Codes 822;824

TITLE: One-order-statistic estimation of the scale parameters of Weibull populations

AUTHORS: A. H. Moore and H. L. Harter (Air Force Institute of Technology and Aerospace Lab., Wright-Patterson Air Force Base, Dayton, O.)

SOURCE: IEEE Transactions on Reliability, vol. R-14, p. 100-106, Oct 65

PURPOSE: To investigate estimators of the Weibull scale parameter based on one order statistic from truncated populations.

ABSTRACT: This paper calculates the minimum-variance unbiased one-order statistic estimator of the parameter of a one-parameter exponential population. The estimator is given for N = 2(1)20 along with its efficiency with respect to an unbiased M-order-statistic estimator from a sample of N items which is truncated after M items have failed. Furthermore, it is shown that by using the estimator for exponential populations one can obtain a consistent estimator for the scale parameter of Weibull populations with any known shape parameter and with location parameter zero. A section on the use of the tabled data and a numerical example are included. (Authors)

REVIEW: This paper is an extension of an earlier one by the second author [1]. The theory is quite straightforward, the bulk of the results being numerical and presented in a four-page table. The estimates obtained for the Weibull scale parameter are biased (except in the special case where the Weibull is actually the exponential distribution), but they are indeed simple, being based on one order statistic and a simple constant. This method may be compared with certain unbiased estimates based on one order statistic obtained by Quayle [2] wherein the required constant is quite complicated. An illustration of the use of the table is given.

REFERENCES: [1] H. L. Harter, "Estimating the parameters of negative exponential populations from one or two other statistics." Ann. of Mathematical Statistics, vol. 32, pp. 1078-1090, 1961

[2] R. J. Quayle, "Estimation of the scale parameter of the Weibull probability density function by use of one order statistic," unpublished thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, O. ##

Serial Number 2381
ASQC Codes 433;822;824

TITLE: A consideration of the Bayesian approach in reliability evaluation

AUTHORS: A. M. Breipohl (Oklahoma State University, Dept. of Electrical Engineering, Stillwater, Okla.), R. R. Prairie and W. J. Zimmer (Sandia Corporation, Albuquerque, N. Mex.)

SOURCE: IEEE Transactions on Reliability, vol. R-14, p. 107-113, 11 refs., Oct 65

PURPOSE: To demonstrate the application of Bayesian procedures to the field of reliability.

ABSTRACT: No attempt is made to justify Bayesian procedures on philosophic grounds; instead, several references are given to the literature. Bayes' theorem is stated in several forms, involving discrete and continuous variables. Reliability is treated as a random variable, contrary to classical statistics. The a priori probability distribution for the reliability which is assumed is the Beta distribution. For certain values of the parameters this reduces to the uniform distribution. The development is limited to success or failure in each of n trials. Both the mode and the mean of the final distribution can be used as point estimates. One-sided confidence intervals are derived for the unreliability and compared to the conventional ones. Confidence limits on multicomponent systems are easily derived. These Bayesian procedures fit well into one of the needs of decision theory.

REVIEW: This is a good introduction to some applications of Bayesian procedures, although reasonable skill with mathematical notation is presumed. More work exploring this kind of application is needed since there is a tremendous amount of engineering prior information that cannot be used in classical statistical analysis. ##

Serial Number 2382
ASQC Codes 775;813

TITLE: Impact testing of plug-in circuit packages for high reliability

AUTHORS: R. C. Kohl and D. J. Wadsworth (Bell Telephone Laboratories, Inc., Holmdel, N. J.)

SOURCE: IEEE Transactions on Reliability, vol. R-14, p. 114-119, Oct 65

PURPOSE: To describe an impact test for isolating some intermittent circuit faults.

ABSTRACT: A mechanical impact test has been incorporated as a quality control tool in the production testing of plug-in packages used in a large special-purpose data processor. The test is used as a method of locating mechanically marginal or intermittent components which could cause future system failures and is not designed to simulate military or space environmental conditions. The test is particularly useful during the development and early production phases when some prototype components may not be up to final quality standards.

The test involves monitoring the electrical output of the plug-in package and comparing this output against a standard while supplying a trigger pulse to a pneumatic hammer which strikes the package. The impulse produced excites mechanical resonances of the components, and any transient electrical failure during the comparison greater than 1/2 microsecond duration is detected by the test set. Instantaneous peak accelerations as high as 800G may occur during the test. (Authors)

REVIEW: This type of screening test can be quite effective in removing potential failures from a system. The paper gives a good description of what is done and why. (The paragraph on "Reliability Improvement Program Goals" goes into some general philosophy, but is a minor part of the paper.) ##

Serial Number 2383
ASQC Codes 814;835;838

TITLE: Reliability and cost of avionics

AUTHORS: E. J. Nalos and R. B. Schulz (The Boeing Company, Seattle, Wash.)

SOURCE: IEEE Transactions on Reliability, vol. R-14, p. 120-130, Oct 65

PURPOSE: To discuss the role of microelectronics in commercial aircraft electronic systems.

ABSTRACT: This paper is an outgrowth of an investigation to determine how avionic equipment reliability might be improved. The high cost of unreliability cannot be overstressed in commercial avionics. The conclusions of this study indicate: (1) Although an aircraft cannot be dispatched without operation of some electronic subsystems, the major portion of avionic systems are generally not considered by the Federal Aviation Agency as vital "safety of flight" functions. However, it is obvious that safety of flight is actually impaired under some flight conditions when systems such as radar are degraded or inoperative. With the decreasing cost of highly reliable components and application of microelectronics, it is feasible to obtain failure rates of 10^{-7} per reasonable mission. (2) On the assumption that costs would be held to those of the more conventional techniques, microelectronics can be incorporated in those systems to which it is most applicable at the present time. This results not only in enhanced reliability, but also makes possible fault detection, automatic fault clearance, etc. (3) Since commercial airlines are an intensely competitive operation, it is natural that they resist cost increases unless there is substantial benefit to be gained, not only in safety of flight but in net earnings. Indications are that this objective can be realized in some equipments.

By utilizing construction techniques made possible by the advent of microelectronics, it is predicted that an order of magnitude improvement in the failure rate of commercial avionic equipment will be obtained by 1970 without a true cost penalty. (Authors in part)

REVIEW: This is the "rough estimate" type of paper and serves the purpose well. Obviously, not everyone will agree on the predictions, but if they are accepted in the sense in which they are offered, the paper is good reading. Of course extrapolation is dangerous, but in discussing the future, that is all we can do. Probably right now greater reliability is well within our technical capability at no appreciable cost increase, but knowing how to purchase it is something else again. ##

Serial Number 2384
ASQC Code 823

TITLE: Statistical tools used in life testing

AUTHOR: Paul J. Hogan (Defense Electronics Supply Center, Defense Supply Agency, Dayton, O. 45401)

SOURCE: Industrial Quality Control, vol. 22, p. 116-120, Sep 65

PURPOSE: To present an insight into the underlying principles and statistics behind the life test plans contained in MIL-STD-690.

ABSTRACT: MIL-STD-690 "Life Test Sampling Procedures for Established Levels of Reliability and Confidence in Electronic Parts Specifications," dated 20 May 1963 provides criteria in establishing, maintaining and monitoring life failure rates for electronic parts. It is based upon the testing of parts which exhibit constant failure rates. Hence the Poisson distribution is applicable. The use of this distribution for reliability purposes is discussed and illustrated. The concept of confidence level is explained.

REVIEW: This is a simplified presentation which provides insight into MIL-STD-690 procedures used in the established Reliability Specification Program. It will be of most use to project engineers and technicians who wish to get an understanding of the principles and statistics behind the life test plans. The material is likely to be familiar to those who have a reasonable background in elementary statistics.

The author in a private communication has advised that MIL-STD-690A dated 29 July 1965 is now available. This document contains more extensive sampling plans with associated OC curves. The above paper will be found to be quite compatible with MIL-STD-690A. ##

Serial Number 2385
ASQC Codes 420;822

TITLE: Results of a gamma, lognormal and Weibull sampling experiment

AUTHOR: J. M. Liittschwager (University of Iowa)

SOURCE: Industrial Quality Control, vol. 22, p. 124-127, Sep 65

PURPOSE: To report on an experiment designed to determine if it is possible to differentiate between underlying gamma, lognormal and Weibull distributions using small samples.

ABSTRACT: The gamma, lognormal and Weibull distributions have been widely used to represent the wearout life of equipment. All three are positively-skewed distributions which can be made to represent a wide variation in equipment life. The gamma and Weibull distributions contain the exponential distribution as a special case and the lognormal can be made to approximate the exponential. All three distributions can be made to approximate the normal distribution.

This paper is concerned with the problem of whether the reliability engineer should attempt to distinguish between these distributions when only small samples of test data are available. An experiment was designed to determine if it is possible to differentiate between them using small samples. It is concluded that a 40-item sample will distinguish between the lognormal and the other two distributions so long as the variance is large. For smaller values of the variance and for gamma-Weibull comparisons either more samples or additional theoretical failure information is needed for the reliability engineer to clearly distinguish between the distributions under study. (Author in part)

REVIEW: This is a worthwhile paper on a topic of practical importance to the reliability analyst. The material is clearly and concisely presented. In the context of this topic, an inherent problem in many reliability analysis situations is the lack of sufficient data to enable a sound decision on the choice of underlying distribution. This can be most troublesome when extrapolation is carried out. The arbitrary selection of a distribution, and extrapolating very far on the basis of it, may give quite misleading results. ##

Serial Number 2386
ASQC Codes 710;810

320;340

TITLE: The inspector--a critical factor in the reliability equation

AUTHOR: John L. Kidwell (Lycoming Division, Avco Corporation)

SOURCE: Industrial Quality Control, vol. 22, p. 135-137, Sep 65

TITLE: Increased product assurance through inspection upgrading and updating

AUTHORS: John L. Kidwell and Edward R. Eidukonis (Lycoming Div., Avco Corporation, Stratford, Conn.)

SOURCE: Industrial Quality Control, vol. 22, p. 183-188, Oct 65

PURPOSE: To define the role of the inspector and the inspection function in today's high-reliability manufacturing operations, to pin-point certain problem areas, and to offer some solutions.

ABSTRACT: Quality control and reliability are composed of four basic and separate functions: reliability engineering, quality engineering, metrology, and inspection and test. Since each of these elements contains a certain dignity in professional development in and of themselves, the qualified inspector without an engineering background should concentrate on his development as a Professional Inspector. Quality control managers who are interested in entering the field of reliability should very carefully preserve their prime obligation of doing a good job of inspection. Without this consideration, the best otherwise planned reliability program will be a miserable failure.

The second article outlines the following methods by which industry may improve inspection activities: personnel upgrading, system updating, and effect evaluation. Three approaches used in personnel upgrading are motivation, training, and supervision. System updating may be effected through inspection environment upgrading and equipment updating.

REVIEW: The first of these papers is a relatively brief and unsophisticated discussion of the importance of the inspection function. The second article presents some practical suggestions pertinent to the problem of achieving an optimum balance between cost and effectiveness in quality control. They may be of interest to some segments of those concerned with the management of manufacturing operations for high-reliability items. ##

Serial Number 2387
ASQC Codes 716;774;823

TITLE: Accelerated life tests

AUTHOR: M. E. Bond (Mullard Radio Valve Co., New Road Mitcham Junction, Surrey, England)

SOURCE: Industrial Quality Control, vol. 22, p. 171-177, Oct 65

PURPOSE: To describe some experiments relating the length of life of cold cathode tubes to their operating stresses and to discuss the general implications of the results.

ABSTRACT: Some ideas on accelerated life tests developed from the results of experiments on cold cathode tubes are described and are shown to apply to other products. The results suggest that if the length of life is related to the applied stress level there is a probability that a plot of stress level against length of life will give a straight line on either log-log or linear graph paper. This straight line is of limited extent and cannot be extrapolated indefinitely. The limits to the straight line relationship occur when the cause of failure changes. The extent of the straight line relationship can sometimes be modified by a change in some other operating condition or in the end point limits. An accelerated life test will truly reflect the life performance at normal operating conditions only if both the accelerated condition and the normal condition lie inside the region where the straight line life/stress relationship applies. If several causes of failure occur in normal use then, in general, separate accelerated life tests will need to be developed for each cause of failure. (Author)

REVIEW: This paper provides some data in the area of accelerated life tests. The material is clearly and concisely presented, with graphical illustrations. Those concerned with accelerated life testing will find the paper of interest, not only for its specific results, but, more importantly, because of the potential applicability of the ideas to a wide class of life-test situations.

Since the type of graph paper on which the curve is plotted is arbitrary, it is difficult to see how the author can be so sure about the significance of the linear portion of the curve (without assuming the answers in advance). This point should have some scrutiny before the results are applied in critical situations.

Earlier papers by this author on the reliability of cold cathode tubes were covered by RATR 800 and 2144. ##

Serial Number 2388
ASQC Codes 800;832

TITLE: Human factors effects on reliability

AUTHOR: Bernard Weiser (Litton Industries, Inc., Van Nuys, Calif.)

SOURCE: Industrial Quality Control, vol. 22, p. 297-299, Dec 65

PURPOSE: To evaluate the effects of human factors on the reliability of complex military electronic equipment and to show that gains in reliability can be realized through human engineering considerations.

ABSTRACT: A careful examination and subsequent comparison of the failure incidence data obtained from similar equipments, some having and some not having human factors engineering considerations, revealed that human engineering techniques have a significant influence on the effects of human-induced equipment failures during system operation.

Over 3500 Failure and Malfunction Reports for Military Tactical Data Systems were reviewed for operator, maintenance, and handling errors which caused a system failure.

The most important result obtained from the study is that proper effort spent on detailed human engineering evaluation of the equipment during the design phases will yield high returns in the form of higher system reliability. Failures introduced by the man-machine interface can be decreased by a factor greater than two, when proper human factors methods are employed. (Author)

REVIEW: This is a very brief paper, serving mainly to call attention to the importance of human engineering techniques in reducing the number of failures induced by the human element in the man-machine system. A few numerical results are given in a short table. The unexplored areas of human factors as they pertain to the design of reliable equipment deserve more study than they are presently receiving. ##

Serial Number 2389
ASQC Code 833

TITLES: Switches and reliability
Relays and reliability

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 4, Mar/Apr 65, p. 6 et seq., p. 39 et seq.

PURPOSE: To report on switches and relays.

ABSTRACT: Defining the life of a switching contact without regard to its use is a pointless task. Reliability numbers on switches and relays are hard to give since these components contain several contacts, each with a different use. Many manufacturers admit privately to having few life data on their products and suggest that the numbers they do give result from specsmanship. The trend in switches seems to be away from standardization in order to do each job better. The blame for lack of relay standardization is tossed back and forth by everyone concerned. The articles have a short paragraph from each of several suppliers giving the official attitude of the company on the problems of and its progress in reliability. Some check lists are provided.

REVIEW: These articles are readable and probably informative for engineers. The official company positions probably suffer from lack of the candidness that is available from off-the-record comments. The standardization problem needs attacking in some fashion--perhaps from a modular point of view. After all, few companies make completely special items if they can avoid it--they like to use standard inventory parts such as coils or contacts when they can. Just because contact life depends on loads does not mean that life data are inapplicable. It does mean that one simple number will not suffice and that many numbers or curves may be needed. ##

Serial Number 2390
ASQC Codes 553;844

TITLE Some plain talk about failure and survival of electronic gear (reliability mathematics corner)

AUTHOR: R. M. Brostowin (Avco Corp., Research and Advanced Development Div.)

SOURCE: Evaluation Engineering, vol. 4, Mar/Apr 65, p. 34-36

TITLE: Reliability table for probability of survival

AUTHOR: Norbert Lloyd Enrick (Stevens Institute of Technology, Hoboken, N. J.)

SOURCE: Evaluation Engineering, vol. 4, Nov/Dec 65, p. 34-35

PURPOSE: To present tables for calculating reliability (R) from the failure rate, mean life, and time.

ABSTRACT: The first article presents R vs. failure rate and vs. time (both in round numbers); mean life is given for each failure rate. The second article presents R vs. mean life. Both authors assume the common negative exponential formula and give examples of the use of the tables. The first article discusses Mean Time Between Failures (MTBF) vs. Mean Time to Failure (MTTF) at some length.

REVIEW: The arithmetic of the tables was spot-checked and only rounding errors were found in either table. (One of the corrections given in the second paper to the table in the first paper corresponds to slightly more than a rounding error. There are at least as many errors in the second table as are given by the second author for the table in the first paper.) The tables may be a convenience for some, but generally the approximation that probability of failure $P(F) = T/M$ (where T is total operating time and M is mean life) is adequate for "quick and dirty" work. The relative error is on the order of $(0.5)P(F)$ for $P(F) < 30\%$. The estimate for P(F) is always high; e.g., for $T/M = 0.30$ and estimated P(F) approximately 0.30, the actual $P(F) = 0.26$, which is 13% below the estimate. For P(F) fairly high as in this case, the estimate is good enough. For exact calculations, tables of the exponential are so ubiquitous (e.g., Chemical Rubber Tables) and slide rules so handy that special tables seem pointless. Especially is this true since they are most unlikely to contain the exact numbers needed and since the proof-reading on tables in magazines is less likely to be adequate than that on books of tables.

In the first paper the discussion on the differences between MTTF and MTBF is quite arbitrary and somewhat misleading. Generally, MTBF means what is says; MTTF is ambiguous, although mean time to first failure is sometimes meant. Anyone who knows what he is doing will have no problems with them. Others need more and better help than they will get from the first paper. ##

Serial Number 2391
ASQC Code 800

TITLE: Keep reliability simple

AUTHOR: W. N. Felton (Westinghouse Astronuclear Laboratory, Box 10864, Pittsburgh, Pa. 15236)

SOURCE: Evaluation Engineering, vol. 4, May/Jun 65, p. 6, 29

PURPOSE: To exhort reliability engineers to "keep it simple."

ABSTRACT: The primary obligation of business is to make a profit. Managers are not concerned with Reliability itself but only with how the effort affects profit. Therefore, when communicating with management, make your ideas simple enough so that managers can readily grasp them; when you have success, show how much money you have saved the company; have some self-doubts about your own conclusions. Even within the reliability field, keep ideas and descriptions as simple as possible; let us not confuse ourselves.

REVIEW: Some of the essentials of this essay are quite worthwhile, some of the incidentals are less appropriate. For example, "...but most everyone understood what reliability meant." Many problems have arisen because of the falsity of this assertion. One may also argue with the concept that profit should be (or is) the prime interest of management. In our nominally religious and humanistic culture (as opposed to our materialistic "enemies") one might hope that enrichment of the lives of people was the primary purpose of business. From this would stem the desire and/or necessity to make a profit and to produce reliable goods. In the latter situation reliability is less likely to be unwisely sacrificed to profit. ##

Serial Number 2392
ASQC Codes 814;838

TITLE: What price un-reliability?

AUTHOR: Jack A. Curtis (General Electric Company, Communication Products Dept.)

SOURCE: Evaluation Engineering, vol. 4, May/Jun 65, p. 22-23 (Part I) and Jul/Aug 65, p. 44-46 (Part II)

PURPOSE: To present the case for reliability in a tutorial way.

ABSTRACT: It is desirable to have total cost to the user for equipment be a minimum. Too much or too little reliability will be too expensive. Improved reliability can be obtained by using parts with proven low failure rates, by certain kinds of derating of the components and by the appropriate use of redundancy. System availability is important to some customers and if mean repair time is known, the MTBF can be calculated. A spec should include some means of verifying the MTBF--usually by theoretical analysis, not by experiments which are too expensive.

REVIEW: For someone new to the field who is trying to learn the language, this article may be useful. The demonstration that the cost of ownership can often be decreased by spending money on improved reliability is most appropriate. Obviously such a short paper is incomplete--for example, design review is not mentioned, constant failure (hazard) rate is assumed, and the limitations of MTBF calculations are not pointed out. The discussion about cost of ownership vs. reliability is also rather limited. Obviously, at times, cost is not the prime figure of merit and the optimum reliability point for the new figure of merit may well not occur at minimum cost.
##

Serial Number 2393
ASQC Codes 773;775

TITLE: Prime pointers for using infrared to evaluate electronic components and circuits

AUTHOR: Nathan Buitenkant (Barnes Engineering Co.)

SOURCE: Evaluation Engineering, vol. 4, Jul/Aug 65, p. 32-33, 41

TITLE: Latest correlation data on new GARD component test system

AUTHOR: Glenn W. Carter (Dale Electronics, Inc.)

SOURCE: Evaluation Engineering, vol. 4, Jul/Aug 65, p. 40-41

PURPOSE: To discuss newer techniques in component and circuit evaluation.

ABSTRACT: Infrared technology is now at the point where the temperature of each part of a circuit can be monitored and incipient abnormalities sensed. The further below room temperature one wishes to go, the more of a problem the detector becomes. Equivalent temperature differences as low as 0.1^{o}C can be sensed with industrial instruments. The response time of instruments is 10 to 100 ms, which can be a limitation in automatic traversing.

The second paper describes a five-second resistor test used as a screen to eliminate those resistors with quirks in their construction. The resistance change vs time is measured while a large power pulse is applied. The method gives good correlation with life tests and if anything, will reject some good units rather than accept some bad ones. Several comparisons are presented.

REVIEW: The infrared paper is a very quick survey and is useful for that purpose. The resistor test has been described elsewhere (see RATR 2056) and this paper brings the comparisons of screening effectiveness up to date. Both methods can be very valuable to screen out potential trouble-making components. ##

Serial Number 2394
ASQC Codes 813;815

TITLE: How to specify reliability requirements in design documents

AUTHOR: Howard A. Van Dine, Jr. (General Electric Co., Missile and Armament Dept.)

SOURCE: Evaluation Engineering, vol. 4, Sep/Oct 65, p. 36-37

TITLE: Is your reliability program a punctured squid?

AUTHOR: Stuart M. Levin (Development Designers, Inc.)

SOURCE: Evaluation Engineering, vol. 4, Sep/Oct 65, p. 38-39

PURPOSE: To help clarify some of the misunderstandings about reliability specifications.

ABSTRACT: There are many examples of poor reliability specifications that neglect important considerations. Five of the foremost requirements for a good reliability specification are:

1. A numerical statement of reliability
2. If and when demonstration is required
3. The environment and conditions of use
4. The kind of life expected for the equipment
5. Acceptable vs. unacceptable performance

Many descriptions and implementations of reliability programs are rather disorganized because no clear flow chart exists. Such a chart can lucidly point out the interrelationships of the program phases and can keep people from putting their effort into wheel-spinning.

REVIEW: Anyone who asserts "things are now done poorly and this is how they should be done" has a difficult task and rarely accomplishes his purpose completely. These papers are no exception. In the first one the general points listed in the abstract are perhaps good enough, although there is considerable controversy about the first and some about the last. The accompanying discussions are certainly not always applicable. For example: (1) An MTBF specification determines reliability uniquely only for a one-parameter distribution such as the exponential. (2) What is the use of a quantitative requirement of any sort without some kind of demonstrable conformance. To specify without requiring conformance is whistling in the dark. (3) To specify a confidence level implies the estimation of a parameter. Other statistical terms are applicable if an hypothesis is being tested.

In the second paper, this is certainly not the first flow diagram for a reliability effort, nor are such diagrams a panacea.

Both papers can be quite helpful if they are read with an argumentative frame of mind by already-knowledgeable people. ##

Serial Number 2395
ASQC Codes 802;812

TITLE: Selected reliability films--1965 updated listing--Parts I and II

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 4, Sep/Oct 65, p. 40, 42 and Nov/Dec 65, p. 30, 32

PURPOSE: To present a selected list of films on reliability.

ABSTRACT: Fifty-one films are listed. The running time, source, and producer are listed for each. For some films there is a small paragraph of description. The running times for most films are in the 15 to 30-minute range.

REVIEW: The listing of films, now an annual feature in this magazine, is useful. Although the title says "selected" there is not the slightest indication what the criteria for selection are. No dates of production are given. Presumably the films are all available free of charge, except perhaps for mailing costs. ##

Serial Number 2396
ASQC Code 800

TITLE: More integrity needed in reliability proposals

AUTHOR: O. L. Holt (Hycon Manufacturing Co.)

SOURCE: Evaluation Engineering, vol. 4, Nov/Dec 65, p. 29, 36

PURPOSE: To make some suggestions on the writing of the reliability portion of a proposal.

ABSTRACT: Several suggestions are made for being honest, comprehensive, original, and accurate in writing the reliability portions of proposals.

REVIEW: This paper is a rather shallow exhortation full of clichés. Many of the points are controversial at best and some are ludicrous, e.g., "...the numerical reliability requirement can be achieved, at least on paper," and "...comment on the caliber of reliability personnel...and on the company's ability...." The author accuses the writers of the reliability sections of most technical proposals of "incompetence, ...laziness, and ...plagiarism." While examples may exist to support this opinion, little is accomplished by stating that such is generally the case. ##

Serial Number 2397
ASQC Code 775

TITLE: X-ray--a necessary tool for detecting incipient structural failures in service aircraft

AUTHOR: Albert D. Edwards (Delta Air Lines, Inc., Atlanta, Ga.)

SOURCE: Presented at the Air Transport and Space Meeting, New York, N. Y., 27-30 Apr 64, SAE-ASME paper 854A, 5p (*Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N. Y. 10017)

PURPOSE: To describe the use and value of an X-ray program for inspection of aircraft.

ABSTRACT: X-ray is an indispensable aid in locating and determining the extent of incipient failures in structure which is inaccessible by position or covered by multiple layers of metal. It is also the most feasible method for checking oil coolers for contamination; bonded honeycomb panels for water; fuel lines for erosion; and with a 360 deg emission tube, fuselage frames for structural integrity without removing the interior upholstery and panels from the passenger compartment or cargo compartments. Examples are given for applications to wing stringers, fuselage frame, horizontal stabilizer, oil coolers, lubrication tanks, fuel injection lines, honeycomb panels, and fuselage circumferentials and stringers. In most of these cases X-ray indications of failure were correct in contrast to other methods which predicted no trouble. (Author in part)

REVIEW: This paper accomplishes its purpose well with its convincing examples. X-rays are used in many areas for non-destructive testing; their application to aircraft is most reasonable. ##

Serial Number 2398
ASQC Codes 822;844;872

TITLE: Reliability disciplines--determine the optimum replacement times for major mechanical components of helicopters

AUTHOR: Robert W. Caseria (Sikorsky Aircraft, Div. of United Aircraft Corp.)

SOURCE: Presented at the Air Transport and Space Meeting, New York, N. Y., 27-30 Apr 64, SAE-ASME paper 855B, 6p; abstracted in SAE Journal, Apr 65, p. 66-67 (*see RATR 2397)

PURPOSE: To show that the Poisson distribution is applicable to some mechanical failures and to indicate the consequent optimum repair policy.

ABSTRACT: Field failure data for some non-castrophe-producing mechanical failures show a constant hazard rate during early life. There appears to be a Gaussian wearout process later on. For a given overhaul period the average costs are calculated. Longer overhaul periods are shown to be more economical.

REVIEW: The assumptions of constant hazard followed by wearout are well illustrated by the example. The calculations appear to take no account of the repaired units; this should, of course, be done--if in fact the units are repaired. Thus the calculated tables are not at all clear. In a private communication the author has stated that repaired units are overhauled in such a manner that they appear to have at least as long a life as the originals; however, the calculations in the text were for unrepaired units. The conclusion of an optimum scheduled repair time extending into the wearout region is of course amply justified in the literature, regardless of the calculations here. ##

Serial Number 2399
ASQC Code 800

TITLE: A progress report on SAE activities in reliability and maintainability

AUTHOR: John de S. Coutinho (Grumman Aircraft Engineering Corp.)

SOURCE: Presented at the Air Transport and Space Meeting, New York, N. Y., 27-30 Apr 64, SAE-ASME paper 856A, 25p, 49 refs. (*see RATR 2397)

PURPOSE: To present an essay on reliability.

ABSTRACT: Reliability and maintainability have reached critical status in the aerospace industry, and product and systems failure require not only a new approach to design, but also new methods of testing to overcome the problem. Team effort must bring designers, engineers, and manufacturers into relationships that facilitate the functions of each and define specific responsibilities. Airworthiness cannot depend upon approximation, but must be designed into each spacecraft as absolute parameters of each component, subassembly, and assembly. This paper reviews the forward steps made to date and elaborates on the essential steps to be taken. (Author)

REVIEW: An essay is a personal expression and this paper certainly falls in that class. In it the author discusses the past and future of reliability as he sees it. It has little reference to SAE activities except in the short historical section. The personal nature of an essay makes for interesting reading and if this paper was presented well, it would have been stimulating to hear. Obviously many of the points are controversial; they could hardly have been intended otherwise. Much of the condemnation of conventional reliability engineers is probably well deserved; but then, on the average, human beings are pretty average--a fact it is wise never to forget. ##

Serial Number 2400
ASQC Code 813

TITLE: The Titan reliability program

AUTHORS: F. A. Thompson and W. D. Stein (Denver Div., Martin Co., Martin-Marietta Corp.)

SOURCE: Presented at the Air Transport and Space Meeting, New York, N. Y., 27-30 Apr 64, SAE-ASME paper 856B, 12p; summarized in SAE Journal, Jan 65 (*see RATR 2397)

PURPOSE: To describe the Titan reliability programs.

ABSTRACT: This paper presents the reliability programs undertaken by Martin-Denver Division while developing the various Titan missile systems. The history and development of these reliability programs and their effect on management decisions and upon actual system hardware are discussed. Summarized tasks to be accomplished for the engineering portion of the Reliability Program for Titan I and Titan II are analyzed. These are:

1. Environmental Prediction and Measurement.
2. Environmental Criteria Determination for Airborne and Ground Equipment.
3. Environmental Control Requirements.
4. Reliability Test Program.
5. Design Analysis for Reliability.
6. Reliability Apportionment.
7. Reliability Measurement and Demonstration.
8. Reliability Achievement Program (RAP).
9. Failure Reporting and Failure Analyses.
10. Equipment Time Recording.
11. Reliability Indoctrination.

The Titan III Reliability Program is based upon the philosophies developed in the other two Titan programs. It is nearly the same, but there are some differences. A critical items list is used, design reviews are expanded and intensified, data recording is done more comprehensively, a malfunction detection system is added, associate contractor relationships have been tightened, a design assurance test program is applied, the approved parts program is expanded, and a publicity program for reliability awareness is kept going. The non-engineering aspects of reliability are also emphasized in a program that makes each functional department aware of its effect on reliability. (Authors in part)

REVIEW: The audience that really benefits from a paper such as this is difficult to define, although it was addressed to non-technical management. While the programs themselves seem to have much merit it is impossible to assess their actual workings and value from the paper. However, one can get a qualitative feeling for the program. (The use of concepts such as inherent-reliability and practice-reliability is fraught with some danger since it is difficult to find the actual event that is associated with the probability. As qualitative descriptors they may have some merit, but then the association of a number with them is quite difficult.) ##

Serial Number 2401
ASQC Codes 830;844

TITLE: Reliability as a criterion in nuclear space powerplant design

AUTHOR: Arthur P. Fraas (Oak Ridge National Laboratory)

SOURCE: Presented at the Air Transport and Space Meeting, New York, N. Y., 27-30 Apr 64, SAE-ASME paper 861A, 8p, 10 refs. (*see RATR 2397)

PURPOSE: To discuss the reliability problems involved in a nuclear space powerplant.

ABSTRACT: While reliability is obviously one of the most important criteria to be considered in the design of equipment, the means by which it can be obtained are elusive and hard to define. Clearly, the problems are extremely complex and tax the competence of the most capable and experienced engineers. However, if its importance is recognized and statistical data are diligently collected to provide a firm foundation for design, some of the experience available indicates that the very high degrees of reliability required for space powerplants may be obtained at the price of some penalties in weight and performance. However, in view of the fact that the reliability must be orders of magnitude better than that of conventional automobiles (an automobile operates for only about 3000 hr in traveling 100,000 miles), and this must be obtained with a small fraction of the amount of test work that has gone into cars, we must realize that an exceptionally high level of engineering competence will be required, and the design philosophy will have to be quite different from that used for any type of powerplant developed heretofore.

The design of nuclear powerplants for space applications is complicated by the lack of reliability data. Analogous operating data on 14 turbine-generator units are described; equations and illustrations are presented to illustrate the data. Materials compatibility; system integrity and the means to achieve it; problems encountered with moving parts; and the reliability of electronic components are discussed in relation to system design. It is concluded that as simple a system as possible with a minimum number of components is necessary to attain a high degree of system reliability. Furthermore, an exceptionally high level of engineering competence will be required, and the design philosophy will have to differ greatly from that presently used for other types of powerplants. (Author in part)

REVIEW: This is a refreshing reliability paper. The engineering problems are clearly stated and examples are given. As Admiral Rickover has consistently pointed out, industry is not geared for high reliability--it is apparently "better" to build it cheaply, then fix it (all the glowing advertisements notwithstanding). ##

Serial Number 2402
ASQC Codes 782;830;844

TITLE: Successes and failures in space gearing

AUTHOR: Darle W. Dudley (Mechanical Technology, Inc., 968 Albany-Shaker Road, Latham, N. Y.)

SOURCE: Presented at the Air Transport and Space Meeting, New York, N. Y., 27-30 Apr 64, SAE-ASME paper 640266 (871B), 5p; summarized in SAE Journal, Nov 64, p. 76-85 (*see RATR 2397); Mechanical Engineering, vol. 87, Apr 65, p. 34-37

PURPOSE: To describe some of the problems in space gearing.

ABSTRACT: Gears are performing successfully on a wide range of applications on space vehicles under conditions of tooth loading, speed, or environment that would have been considered impossible 15 years ago. On the other hand, there have been many cases of premature failures of space gear equipment. The pitfalls of the reliability dilemma, the hazard of space environment conditions, and the hazard of unusual vibrations are analyzed. Gear teeth are subject to failure by four principal modes. These are tooth breakage, pitting of the contacting surface, scoring or seizure of the contacting surfaces, and abrasive wear of the contacting surfaces. Gear webs and shafts are subject to failure by breakage. Bearings may fail by wear of contacting surfaces or seizure of contacting parts. All of these failure modes have a "scatter" pattern. The aggravating factor is either stress, temperature, or a combination of stress and temperature. The severity of the aggravating factor that the part will tolerate becomes less as time becomes longer or cycles become greater. The width of the scatter band is to quite an extent a function of the quality of the material. Some of the things entering into quality are cleanliness of material, preciseness of composition, metallurgical structure, residual stress pattern, surface finish, freedom from minute cracks, and freedom from surface corrosion. Better quality does not make the best material stronger. Rather it limits the things that can be done wrong to weaken a material.

If you have to work without adequate reliability data, (1) make overload tests to find out how far away you are from frequent failure, (2) write rigid material specifications so that the design intent is realized, and (3) analyze the design for dangerous reliability areas. Run at least limited laboratory or bench tests to get at least some reliability data in the danger areas. Several recent failures of gears on space project equipment can be blamed on the following of earthly gear design practices for space conditions. The designer is advised to be wary in his design analysis and thorough in his development testing. Adequate life and reliability can be achieved in space gear work, but often the designers and developers have a stiffer problem to solve than is first anticipated. (Author in part)

REVIEW: This is a good, though brief paper. The material is clearly presented and the points are well made. The discussion is largely concerned with pitfalls and problems; the designer is presumed to know how to design around them once he knows they are there. ##

Serial Number 2403
ASQC Code 782

TITLE: Long-lived lubrication for spacecraft equipment

AUTHOR: Francis J. Clauss (Lockheed Missiles and Space Co., 3251 Hanover St., Palo Alto, Calif.)

SOURCE: Presented at the Air Transport and Space Meeting, New York, N. Y., 27-30 Apr 64, SAE-ASME paper 640267 (871C), 13p; summarized in SAE Journal, Nov 64, p. 76-85 (*see RATR 2397)

PURPOSE: To review studies being conducted on the long-time performance of lubricants under conditions of vacuum and radiation, such as are encountered in space.

ABSTRACT: Vacuum and radiation conditions in space are discussed, since these appear to cause the major limitations on lubrication for spacecraft equipment. The following conclusions apply to the lubrication of lightly loaded instrument ball bearings operating at speeds on the order of 8000 rpm and at temperatures of 160-200 F. These conditions are typical for many servomechanisms in spacecraft equipment.

1. Operation in vacuum can drastically reduce lubricant lifetime below that obtained for operation in air. In order to operate equipment for long periods of time in space, the mechanisms must be housed in pressurized and sealed units, some means of lubricant replenishment must be provided, or the lubricants must be carefully selected from those that have demonstrated satisfactory operation in vacuum.

2. Oils and greases provide the best type of lubrication for ball bearings exposed to vacuum. Special conditions that may favor other types of lubrication (for example, molybdenum disulfide films and reinforced Teflon) include cryogenic temperatures, high temperatures, and excessive exposure to nuclear radiation.

3. Selected oils and greases have demonstrated lifetimes in vacuum of 18 months to two years under the conditions noted above. They have also demonstrated lifetimes in vacuum of over seven months when exposed simultaneously to nuclear radiation of 10^7 roentgens, a large dose even for one year.

4. Ball bearings with retainers of reinforced Teflon, a self lubricating material, have operated successfully in vacuum for over eight months, provided that bearing loads were light. Bonded films of molybdenum disulfide have given shorter lifetimes and generally poor reproducibility of results, although under good conditions they have given lifetimes up to three months under the same conditions as above.

5. No satisfactory correlations have been found between the operating lifetimes of oils in vacuum and the properties of oils measured in simple laboratory tests (for example, vapor pressure and viscosity). (Author in part)

REVIEW: The knowledge in this area is not as great as one might hope, but tests such as these are helping matters considerably. Perhaps the important thing now to remember is that ordinary experience is not directly translatable to these new conditions; therefore one must test, test, test,.... ##

Serial Number 2404
ASQC Codes 830;870

TITLE: Maintenance and reliability requirements for future generation aircraft

AUTHOR: Jack Vidal (West Coast Airlines)

SOURCE: Presented at the National Aeronautic Meeting, Washington, D. C., Apr 65, SAE paper 650222 (*see RATR 2397)

PURPOSE: To note a few improvements in the aircraft industry.

ABSTRACT: The airlines need safety, comfort, and on-time performance. These can be realized through:

Steady improvement in airframe, engine and component integrity through design research and production quality control by the respective manufacturer.

Easier access for components inspection through design of the aircraft.

Simplified methods of installation and/or removal.

Certain essential system duplication built in the aircraft.

Close collaboration on training mechanical personnel enabling them to cope with the sophistry of modern aircraft systems.

(Author in part)

REVIEW: The title of this paper is somewhat misleading. The paper itself is hard to follow since it jumps around too much. It does give a few highlights on some phases of component reliability, but contains little meat for engineers. ##

Serial Number 2405
ASQC Codes 800;835

TITLE: Microcircuit reliability--fact or fancy?

AUTHOR: Rodger R. Lowe (Mesa Scientific Corporation, 2930 West Impêrial Highway, Inglewood, Calif. 90303)

SOURCE: Presented at the Los Angeles District Computer Symposium, IEEE, 12p, Dec 64 (copies available from author)

PURPOSE: To examine some popular beliefs about the reliability of integrated circuits.

ABSTRACT: It seems there are three major tunes being played by industry flacks:

1. They're all very good--except for the bad ones.
2. Complexity doesn't affect reliability.
3. 0.001%/1000 hours is just around the corner.

Under scrutiny some of these sentiments fare better than others. To wit (considering the points in the order listed):

1. Room temperature diffusion is a wearout mechanism inherent in all semiconductor devices. However, the long time associated with this universal wearout makes view number 1 fairly realistic.

2. With any process producing components with a non-zero probability of failure (viz., any real process), the addition of more components must reduce the total reliability, in spite of the fact that these components can be fabricated simultaneously in the same processing. By weighting various sources of defects, failure rates for integrated circuits of 10, 30, and 100 equivalent parts are estimated to be 2, 3.5, and 6 times that of a single transistor.

3. Extrapolation of curves showing failure rate versus unit hours of test indicate that inherent failure rates approaching 0.001%/1000 hours may well be demonstrable, given sufficient test time. (Author in part)

REVIEW: The entertaining, breezy style of this paper undoubtedly makes for enjoyable listening in the heavy atmosphere characteristic of typical symposia technical sessions.

As a written document, read in sober solitude, its sparkle is less contagious. The language is a bit too jovial and the impression created is that of a relatively minor contribution whipped into an informal presentation more reminiscent of the conversation one hears in the hallways between papers than of the sessions themselves.

What the author regards as fancy and what as fact is not always readily apparent. For example, in the introduction, the author is "bugged" about statements like 'Double-oh-one percent per thousand hours is a very reasonable prediction for the near future,' calls such a statement "fancy" but then from his subsequent examination of the facts concludes that this statement is true (see ABSTRACT above), apparently surprising himself but certainly confusing the reader. ##

Serial Number 2406
ASQC Codes 711;713;844

TITLE: Material requirements for long-life pressure vessels

AUTHORS: B. F. Langer (Bettis Atomic Power Laboratory, Pittsburgh, Pa.) and W. L. Harding (Combustion Engineering, Inc., Windsor, Conn.)

SOURCE: Presented at the Winter Annual Meeting, ASME, Philadelphia, Pa., 17-22 Nov 63, ASME paper 63-WA-194, 11p, 10 refs. (The American Society of Mechanical Engineers, 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To discuss various properties of materials which are significant to long-time pressure vessel service.

ABSTRACT: A general discussion of the various modes of failure--plastic deformation and bursting, brittle fracture, fatigue failure, creep deformation and creep rupture, and corrosion--in pressure vessels designed for long-time service is presented. The importance of some of the material properties which affect the modes of failure are pointed out.

Pressure vessels burst by shear or cleavage or by instability resulting from excessive plastic deformation. Strain hardening is characterized as an important property to the plastic-instability type failure. Brittle fracture results from the interrelations between stress, temperature, and notches. The simple design approach based on transition-temperature is frequently not satisfactory; and the more quantitative Griffith-Irwin theory must be employed, particularly for designs using high strength steels.

Fatigue failure of pressure vessels is associated with discontinuities, notches, or thermal shock; and low cycle fatigue resistance (in the region of 10^3 to 10^5 cycles) along with notch sensitivity are two important pressure vessel fatigue design parameters. The use of high strength steel for pressure vessel fatigue resistance must be approached with caution.

There are no generally accepted means of evaluating long-time, high-temperature properties of production lots of materials; therefore, the designer must work with the material manufacturer to obtain assurance of material properties. Furthermore, there are no specific design procedures for combating corrosion; consequently, the designer must rely on past experience concerning stress, temperature, fluid velocity, time, etc.

REVIEW: This is an easy-to-read paper which should be useful to pressure vessel design engineers. The material, in general, is not new; but it is a single summary of important modes of failures and the effects of specific material properties on the failure mode. Included in some of the discussion are methods of obtaining important material properties. The paper would not be important to the researcher. ##

Serial Number 2407 -1
ASQC Codes 716;781;782

TITLE: Some corrosion problems on the F-101 Voodoo aircraft and the Bomarc and Minuteman missiles

AUTHORS: Donald R. Klang and Wilfred Peters (Service Engineering, Hill Air Force Base, Ut.)

TITLE: Corrosion of missile components

AUTHOR: John W. Hensley (U. S. Naval Ordnance Test Station, China Lake, Calif.)

TITLE: Corrosion control on the Saturn S-II

AUTHORS: Wayne M. Gauntt and J. Derbyshire, Jr. (North American Aviation Inc., Space and Information Systems Div., Downey, Calif.)

SOURCE: Materials Protection, vol. 3, Apr 64, p. 16-18, 20, 22, 24; 26, 28-31, 33; 36-43

PURPOSE: To discuss corrosion problems on the systems indicated in the titles.

ABSTRACT: The F-101 aircraft is constructed primarily from 7075 and 7178 aluminum and other materials to a lesser extent, such as 300 series stainless steel sheet, various magnesium alloys, and titanium sheet. The primary corrosion problems are: intergranular corrosion of external aluminum wing surfaces, pitting and galvanic corrosion of internal magnesium castings and forgings, and pitting of 300 series stainless steel sheet. Minor corrosion problems have been encountered in extruded piano hinges, air and fuel line clamps, and electrical plugs and relays. Non-destructive testing techniques, particularly ultrasonic, have been satisfactory for detecting corrosion, and determining when corrective actions are required. Anodize, primers, paints, lacquers, and other coatings have been effective corrosion controls on this aircraft.

The Bomarc missile corrosion problems are in general associated with components and subsystems in contact with the JPX fuel or the inhibited red fuming nitric acid oxidizer. The oxidizer has caused corrosion problems in 300 series stainless steel and 6061 and 2024 aluminum fittings, lines, and tanks. More recent corrosion problems have resulted from the 80 octane ram-jet fuel, and some problems associated with ground support equipment have been encountered. Corrosion patterns common to all missiles have not been detected.

The majority of the Minuteman corrosion problems can be attributed to moisture in the silo and launch control facilities; however, other isolated missile problems have been reported. Galvanic

corrosion on components of ground equipment and permanently installed equipment have been encountered. But, as in the case of the Bomarc, common corrosion patterns have not been detected.

A general discussion concerned with the complexity of current missile systems, their extremes in environment, and associated corrosion problems is presented in the second paper. In general, corrosion problems can be related to poor project coordination or lack of interest or knowledge on the part of the design engineer. Many of the problems originate on the drawing board and are aggravated by production and manufacturing techniques and logistic operations. The majority of the corrosion problems can be grouped into six areas: (1) engineering design, (2) description of environment (3) environmental tests, (4) production, (5) storage, and (6) service. Each of these six areas is discussed and illustrated with specific case histories or examples. Corrosion problems can be reduced with the full development of a coordinated team effort between the designer, materials engineer, and corrosion engineer.

The second stage of the Saturn V launch vehicle has a cylindrical configuration, 82 feet long and 33 feet in diameter, constructed primarily of 2014 Al. The propellant is liquid oxygen and liquid hydrogen; consequently, external insulation is required. The major corrosion problems encountered resulted from difficult implementation rather than a lack of materials or methods.

2014 aluminum is highly susceptible to corrosion which, for this particular application, results from fabrication, testing, and travel. Specific problem areas were: fabrication, explosive forming, chemical processing, and hydrostatic testing and calibrating. Corrosion problems associated with dissimilar metals are minimized, and those related to final environment were considered unimportant. Corrosion control, which was tied primarily to in-shop processing and intra-plant shipping and storage, was maintained from raw materials through fabrication and assembly to delivered end item. Rust proofing or preservative oil conforming to MIL-L-3150, a manually strippable coating, a water soluble hexavalent chromium inhibitor, and a chromate conversion coating were the primary control methods employed. The reasons for selecting the conversion coating and the spray method of application are described. Details of the pilot line development, hydrostatic testing and calibrating, and tank cleaning methods are presented.

REVIEW: These papers are well written and easy to read. However, they contain very little quantitative corrosion data. The procedures are sufficiently described so that a good working knowledge of the control measures is easily grasped. The papers may be useful to those having similar problems.

In general the articles are informative but are not good reference material. ##

Serial Number 2408
ASQC Codes 711;773;782

TITLE: A controlled atmosphere fatigue machine

AUTHOR: K. U. Snowden (University of Melbourne, Baillieu Laboratory, Department of Metallurgy, Victoria, Australia)

SOURCE: Journal of Scientific Instruments, vol. 41, p. 470-471, 11 refs., Jul 64

PURPOSE: To describe a reverse plane-bending fatigue machine for use in performing tests in vacuum or in controlled atmosphere.

ABSTRACT: This paper describes a reverse plane-bending fatigue machine for use in performing fatigue life tests under conditions of vacuum or controlled atmosphere. This machine was designed to make possible the observation of chemical, physical and metallurgical processes that take place during fatigue testing. It also eliminated undesirable creep effects that were encountered with previous machine designs. The machine uses a mechanical deflecting system to cycle flat cantilever specimens; the flatness makes metallographical observation easier. A special tinned steel test chamber with a glass cover is more effective in excluding gases than plastic membrane chambers used in the past. The reciprocating action is transmitted into the chamber by a Sylphon metal bellows. A Penning type ionization gauge is connected to the enclosure by a "high speed" tube for introducing separate gases. The pressure difference between the gauge and chamber due to the pumping action of the gauge is kept to less than 1% by the dimensions chosen for the "high speed" tube.

Results are given from tests on lead and aluminum made to determine the air pressure dependence of fatigue life over an air pressure ranging from atmospheric to approximately 2 μtorr. A substantial variation was found to occur in fatigue life with changes in pressure.

This machine has also been used to study the effects of surface films on fatigue life. Its design makes it possible to determine the strengthening effects of surface films and their ability to screen an active gas from the surface.

REVIEW: This paper offers an improved design for a machine for making fatigue studies in various gases at adjustable pressures. None of the methods are explained for analyzing the chemical, physical, and metallurgical changes that take place during the tests. The paper can serve to generate an interest in the possibilities of such a machine among those engaged in fatigue work. ##

Serial Number 2409
ASQC Codes 711;712;844

TITLE: Plain-bearing failures

AUTHOR: --

SOURCE: Lubrication, vol. 50, Jul 64, p. 77-92 (published by Texaco Inc., 135 East 42nd Street, New York, N. Y. 10017)

PURPOSE: To describe and illustrate common causes of journal bearing failures.

ABSTRACT: The causes of journal bearing failures can often be recognized by examining the bearing surface with only a hand magnifying glass. Failure may result from improper installation, operation, or maintenance; from lubricant contamination, or from faulty manufacture. Sixteen types of failure are discussed and illustrated to aid the observer in making a rapid diagnosis on the site without the necessity for a complex time-consuming laboratory analysis.
In general failures start at bearing surfaces and may be due to:
1. Contamination of the lubricant with particles that enter the bearing area and cause scouring and/or rapid wear of the bearing surfaces.
2. Bearing misalignment stemming from improper installation or structural warping.
3. Fatigue that results from cyclic loading aggravated by occasional overloads or high temperature.
4. Bond failure characterized by a separation of the bearing alloy from the supporting shell.
5. Corrosion of bearing surface due to the presence of electrolytes and organic acids.
6. Porosity which is a condition of surface blisters and cavities resulting from slag inclusions, absorbed and dissolved gas, or impurities in the metal powder used where the bearing is a sintered material.
7. Lead sweating typified by a plastic deformation of the bearing structure because of high loads and temperature which serve to cause the lead to be squeezed from the bearing structure.
8. Cavitation which erodes the bearing surface and is the result of high energy hydraulic pulses in the oil film.
Each of the above modes of failure can be identified by characteristic surface failure patterns which are clearly illustrated in the text.

REVIEW: This paper should serve a critical need for training the observer to diagnose the cause of failure quickly without the need for a complex laboratory analysis. The paper has excellent illustrations of the type of failures described.

Of additional interest might have been a method to detect failures arising from an insufficient amount of lubricant. ##

Serial Number 2410
ASQC Codes 711;844

TITLE: Fatigue characteristics of RP laminates subjected to axial loading

AUTHOR: Kenneth H. Boller (U. S. Dept. of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wis.)

SOURCE: Modern Plastics, vol. 41, Jun 64, p. 145-146, 148, 150, 188, 7 refs.

PURPOSE: To evaluate the fatigue characteristics of typical reinforced plastics.

ABSTRACT: The fatigue characteristics of eleven different resins have been studied under axial type loading in an effort to determine the effect of: (1) the resin itself, (2) typical mat and fabric reinforcement, (3) angle between the fabric warp and load, (4) temperature, (5) humidity, (6) mean load, (7) notches. Only those combinations of resin and reinforcement that were compatible and recommended by the manufacturers were used in these tests.

In general it was found that:

A. The fatigue strength is largely dependent on type of resin at a low number of cycles.

B. Fatigue strength tests on a single resin using several types of fabric reinforcements differ very little as a result of the fabrics used. However, the use of a glass mat with non-oriented fiber gave exceptionally low fatigue strength values.

C. Notches greatly affect the fatigue strength. The shape and location of the notch was an important factor in the fatigue life obtained.

D. No endurance limit was found at 10^6 cycles. Loading at 0^o to the warp is to be preferred to loading at any other angle.

E. There is a loss in fatigue life at upper temperatures (300^o-500^oF). This loss may decrease or increase as the load level is decreased depending on the material and temperature.

F. Moisture has an appreciable effect on fatigue strength particularly at a low number of cycles.

G. The fatigue strength is affected by the mean load for a given load amplitude.

Asbestos mat laminates are inferior to glass fabric laminates at low cycles but superior beyond 10^5 to 10^6 cycles. The highest fatigue strengths were obtained with laminates reinforced with unwoven glass fibers having alternate plies positioned at various angles to the principal axis.

REVIEW: Some knowledge on the subject of plastic laminates is essential for a good understanding of the subject. The reader should be familar with some of the procedures and terms in order to visualize the different constructions used. It would have been helpful if the author could have added sketches of the various constructions in order that they might be more clearly visualized. Aside from this the paper is well written, well organized, and informative. ##

Serial Number 2411
ASQC Codes 711;844

TITLE: How to use time-dependent property data

AUTHOR: (Adapted from a chapter on "Designing with Plastics," in the forthcoming book, "Engineering Design," by Dr. J. H. Faupel, E. I. Du Pont de Nemours & Co., Inc., Wilmington, Del., to be published by John Wiley & Sons, Inc., New York, N. Y.)

SOURCE: Modern Plastics, vol. 41, Aug 64, p. 119-122, 126, 128, 130, 190, and 192

PURPOSE: To show how viscoelastic and rate theories are used to predict long-term plastic material behavior from short-term creep and relaxation data.

ABSTRACT: A viscoelastic deformation occurs in plastics by the occurrence of both elastic strain and time-dependent flow (creep). This viscoelastic deformation makes a mathematical analysis of material behavior under load very difficult. In designing with plastics a compromise must be made between a part which will not excessively deform during a specified period and a part which will not fail by stress-rupture during the same period and under the same load conditions. Viscoelastic and rate theories are discussed which can predict the behavior of plastics from short-term creep and relaxation data (decrease in stress when strain is held constant).

The viscoelastic theory assumes the material to be linearly viscoelastic if it is stressed below about 1/2 the short-time yield stress. Using this theory it is demonstrated that $E = E_o(\sigma/\sigma_o)$, where σ is the stress and E is the time-modified modulus which is used in conventional elastic solutions to mechanical problems. Where Poisson's ratio appears in the elastic solution it is replaced in the viscoelastic solution by (1/2 - E/6B) where B = bulk modulus. Creep and stress relaxation behavior are then shown to be related and either can be predicted from the other. The rate theory applies to more materials than the viscoelastic theory and can be used to predict stress-rupture as well. Using the integrated form of the Arrhenius equation, the assumption that activation energy for plastic deformation does not vary appreciably with temperature, and the definition of rupture as the separation of molecules in the material, a formula for time-to-rupture vs. temperature can be derived with only two unknown parameters. Ways of applying the formula are explained.

REVIEW: In this paper, the linear viscoelastic theory seems to be better explained than the rate theory. Assuming their accuracy, they are adequately dealt with in describing methods for using short-term data in the prediction of material behavior up to 10^5 hours. There are problems with the rate theory, however. First of all, Eq. 8 for time-to-rupture vs. temperature does not seem to follow from the Arrhenius equation. The formula itself does not specify the units for time, and the source of the number 20 is not at all obvious. Whether the "log," is to the base e or 10 is neither explained nor obvious. In the text, 10^{-5} hr is stated where apparently 10^5 hr is meant. ##

Serial Number 2412
ASQC Code 830

TITLE: Structural design Part II--Fail-safe aspects

AUTHOR: W. G. Heath (Hawker Siddeley Aviation Ltd., Avro Whitworth Div.)

SOURCE: Aircraft Engineering, vol. 37, Mar 65, p. 79-81

PURPOSE: To present fail-safe concepts related to crack-free life, prevention of corrosion, simplified inspection and repair, and safety after failure.

ABSTRACT: The concern of any aircraft designer should be to insure that there will not be a structural failure during any phase of a flight. Although the safety of the passengers is of primary importance, economics demands a long aircraft life with good resale value. The airworthiness of an aircraft must therefore not deteriorate with time. To insure that any failure will not be catastrophic, a fail-safe concept has been adopted for the design of the Hawker-Siddeley 748. This aircraft has been designed so that any failure in the aircraft can be tolerated until it is revealed during scheduled inspection periods.

This concept involves: (1) design in which damage due to fatigue and corrosion is unlikely, (2) making provisions in design which permit easy inspection and assurance of discovery and ease of repair, (3) providing alternate load paths even if the primary load path is interrupted for a long period of time. Design techniques and methods are outlined for preventing fatigue and corrosion, simplifying inspection and repairs, and providing safety after failure.

Fatigue is prevented by elimination of stress-raisers, fatigue tests of representative specimens during design, and use of a continuous structure where possible (for example the wing constitutes a single unit of structure). Corrosion is reduced by use of aluminum which is clad, then anodized, then coated with spray paint; and by the elimination of moisture traps. Inspection and repair are simplified by use of "non-handed" components that are interchangeable between port and starboard sides and by providing every section with openings for easy inspection.

Means for accomplishing fail-safeness can be grouped into three categories: Standby provides secondary elements which take up the load when the primary fails. Subdivision divides the load between several elements, each carrying the load and insuring adequate strength under a partial failure. Slow crack propagation is obtained by a careful choice of material and stress levels.

REVIEW: This paper deals specifically with aircraft design and is of interest primarily to those familiar with aircraft structure and design. The fail-safe concept however, can be employed in other design work as well and for this reason should be of interest to anyone in design of structures where catastrophic failure is possible. To obtain a full understanding of the techniques the reader needs a good knowledge of aircraft terminology. ##

Serial Number 2413
ASQC Codes 711;712;713

TITLE: An interpretation of the mechanics of crack growth by fatigue

AUTHOR: B. Cotterell (University of Sydney, Dept. of Mechanical Engineering, Sydney, Australia)

SOURCE: Transactions of the ASME, Series D, Journal of Basic Engineering, vol. 87, Mar 65, p. 230-236, 23 refs. (Paper No. 64-Met-14)

PURPOSE: To present a theory of fatigue crack growth which is analogous to brittle fracture of high-strength materials.

ABSTRACT: Brief descriptions of current theories of static-load crack growth in notched high-strength alloy sheet are presented. From the mechanics of these theories, a theory of stable cyclic crack growth under repeated loads is developed for stage II fatigue.

A crack initiates under conditions of static failure as a result of tearing at a very low load. This crack continues to grow in a stable manner, because of the crack driving force, until a critical value is reached; and, then, the crack grows in an unstable manner. This critical value is dependent upon the resistance to crack growth.

The stable growth of a fatigue crack during each tensile part of the stress cycle is explained by an analogous crack driving force and a resistance to crack growth. The crack driving force is dependent primarily upon the maximum stress and crack length. The resistance to crack growth, at low rates of crack propagation, is dependent on the alternating stresses and resulting strain hardening. At the higher rates of crack growth, there is little if any dependency on the alternating stress. The theory was applied to other investigators' data with inconsistent results--good correlation in some cases and poor correlation in others.

REVIEW: This paper deals with the physics of failure, and it is basically theoretical. The mathematics was not checked in its entirety. A few unimportant typographical errors were detected.

The paper, as published, would be of little value to the design engineer; but, with further refinements and verifications, the theory may be valuable to the design engineer for determining the longest crack which can be tolerated in a structure subjected to cyclic loading. ##

Serial Number 2414
ASQC Codes 711;712;713

TITLE: A method for assessing the probability of the size effect from the damage caused by fatigue macrocracks

AUTHOR: R. D. Vagapov (State Scientific-Research Institute of Machine Science)

SOURCE: Industrial Laboratory, vol. 30, p. 1240-1247, 15 refs., Mar 65 (Translated from Zavodskaya Laboratoriya, vol. 30, p. 1006-1012, Aug 64)

PURPOSE: To present a practical and theoretical concept to account for fatigue-specimen size-effect.

ABSTRACT: Fatigue tests of large specimens are rarely conducted because of the high cost of the tests and the equipment; consequently, it is common practice to extrapolate large-specimen fatigue data from small-specimen data. The hazards and discrepancies of this practice are pointed out, and a mathematical concept to account for specimen size effect is presented. The idea proposed is based on the loss of fatigue strength or damage resulting from fatigue macrocracks which were produced by overstressing the material.

To evaluate the causes for size effect, it is necessary to have the distribution function for the fatigue life or the fatigue strength. The scatter in fatigue strength characteristics is dependent on the working length of the specimen and the distribution of strength along its length. Differences in the rate of damage during the first stage, with uniform and nonuniform stress distribution, are due to strain hardening, vibro-creep, or vibration stress relaxation. The fatigue strengths of small specimens are characterized by the macroscopic heterogeneity of the material, and the fatigue strength of large cross section specimens is determined by the lower boundary fatigue strength of the small specimens. There is, however, a minimum size specimen whose lower boundary of fatigue strength defines the fatigue strength or reduction of fatigue strength of the larger parts.

REVIEW: This is a translation from the Russian. Some of the word order and sentence structures make the paper difficult to follow. There are several translation or typographical errors. The presentation follows a mathematical approach, requiring close attention for complete understanding.

The paper is concerned with the physics of failure. The central idea of the article should be valuable to design engineers. ##

Serial Number 2415
ASQC Codes 711;712;713;
716;782

TITLE: Corrosion fatigue of aluminum alloys

AUTHORS: W. M. Lorkovic, D. Varallyay, and R. D. Daniels (University of Oklahoma, Norman, Okla.)

SOURCE: Materials Protection, vol. 3, Nov 64, p. 16-18, 21-23

PURPOSE: To present corrosion fatigue data for aluminum structural alloys used in high-performance aircraft.

ABSTRACT: Three 0.250-inch thick high strength Al alloys, plate stock, were fatigue tested on plate flexure machines. The materials were clad and unclad 2024-T4 and 7075-T6 and unclad 7178-T6. An aqueous NaCl solution was the corrosive medium. The tests were conducted in order to determine: (1) fatigue properties of clad and unclad materials under dry atmospheric conditions, (2) corrosion fatigue properties for several corrosive environments, (3) some of the factors related to corrosion fatigue, e.g., cyclic speed, and (4) protection afforded by selected organic surface coatings. The details and results of a microscopic examination to determine crack morphology in the 2024-T4 alloy are reported.

Clad plates were inferior to unclad plates--the greatest differences were demonstrated at the lower applied stresses. In comparison to a dry environment, water reduced the fatigue life of the materials; and brine solutions reduced their fatigue lives even further. A 3% brine solution was the most severe environment. Synthetic rubber and epoxy-polysulfide coatings have little if any effect on the fatigue life of the materials in a dry environment, but, in a water environment, the coatings offer some protection. At the 95% confidence level, the epoxy-polysulfide coated 7178-T6 materials in a brine environment demonstrated lives exceeding the median life of the same material with no protection or a synthetic rubber coating.

All three alloys have similar corrosion fatigue behavior and testing speed is one of the most important variables in corrosion fatigue tests. In general, corrosion fatigue testing can provide a rapid means for selecting and screening materials, but absolute answers cannot be expected.

REVIEW: This paper gives a clear and concise account of the tests performed. Many of the findings could have been predicted; however, the authors have collected the necessary data to confirm what might have been expected. A limited amount of statistics was employed to arrive at some of the conclusions.

In general, the paper would be informative to the design engineer.
##

Serial Number 2416
ASQC Codes 711;712;713

TITLE: Tensile failure of fibrous composites

AUTHOR: B. Walter Rosen (General Electric Company, King of Prussia, Pa.)

SOURCE: AIAA Journal, vol. 2, p. 1985-1991, 11 refs., Nov 64

PURPOSE: To present a theoretical and experimental treatment of failures in uniaxially-oriented fiber composites subjected to uniaxial tensile loads parallel to the fiber direction.

ABSTRACT: A failure model of a fiber-reinforced composite is assumed. This model is composed of fibers having a statistical distribution of flaws or imperfections which results in fiber failure at various stress levels. Composite failures result from a statistical accumulation of such flaws over a given region, where the remaining unbroken fibers (at the weakest cross section) can no longer sustain the applied load. Discontinuous fibers are treated as discontinuities which cause high matrix shear stresses. In this model, the extensional stresses in the matrix are ignored relative to those in the fibers; and the shear strains in fibers are neglected in comparison to those of the matrix.

The statistical strength distribution of the fiber segments is expressed as a function of the fiber strength-to-length relationship. These results are then used statistically to establish the strength distribution of a bundle of fiber segments. The composite fails when a bundle fails. Thus the composite strength is determined as a function of fiber and matrix characteristics.

An experimental technique to test the validity of the analytical model is described. This investigation employed single layer glass fiber reinforced plastic composites, which enabled microscopic evaluation of internal failures. Random fiber fractures were observed at less than 50% of the ultimate strength of the composite. In general, the use of this experimental technique offers promise as a means of studying mechanisms of failure, but the model is not likely to give accurate quantitative results. (Author in part)

REVIEW: This paper is concerned with physics of failure. The material is interesting, well organized, and presented in an orderly manner.

The paper, as written, would not be of immediate use to the design engineer. (The mathematical derivations were not checked in their entirety.) ##

Serial Number 2417
ASQC Codes 824;831

TITLE: Techniques for the diagnosis of switching circuit failures

AUTHORS: J. M. Galey, R. E. Norby, and J. P. Roth (International Business Machines Corp., Poughkeepsie, N. Y.)

SOURCE: IEEE Transactions on Communications and Electronics, vol. 83, p. 509-514, 7 refs., Sep 64

PURPOSE: To present effective procedures for diagnosing failures in switching circuits.

ABSTRACT: A Boolean graph is presented and defined. Next, the injection operator is described, and defined by means of an example for a single-output Boolean circuit. The authors limit themselves, in the analysis which follows, to the cases in which only a single failure occurs at a given time. Furthermore, these single failures are of the complete short or complete open type.

The operation known here as "pruning" (of the Boolean tree graph) is described. This consists of successively considering each given branch as though it were an input, and by operating on it discovering whether there is a failure. This algorithm will distinguish between the failed and the perfect machine. The algorithm for computing the totality of all tests is described in detail, with an example given.

The last section of the paper deals with the analysis of Boolean circuits with feedback. The procedure consists of "cutting" the feedback loops and regarding them as pseudo-outputs and pseudo-inputs. An appropriate single "wave" of inputs should reset the machine into some defined initial state. The method finds the totality of sequences of minimum length, of these waves, for which the output of the bad machine and of the good machine will differ. An example is used to set forth the method, and reference is made to the bibliography for details.

REVIEW: Some readers will find this paper a relief from the mathematical masses of theorems, lemmas, etc., found in some papers in this topic area. The authors present their methods by means of examples, an approach which is at times refreshing, at times obscure. They lean heavily on their bibliography, which seems rather inbred (only one reference is from other than their own company publications, and all but one of these is internal.) For this reason it is good to see some of this work presented to a wider audience--the present paper admits to being largely a rehash of one of the others, with some new ideas. ("The theory is based on that of reference 1; several innovations, however, have been added.") On the whole the paper is a worthwhile contribution. ##

Serial Number 2418 -1
ASQC Codes 831;838

TITLE: On the convergence and ultimate reliability of iterated neural nets

AUTHOR: R. H. Urbano (Air Force Cambridge Research Laboratories, Bedford, Mass.)

SOURCE: IEEE Transactions on Electronic Computers, vol. EC-13, p. 204-225, 14 refs., Jun 64

PURPOSE: To present an investigation of the organization and reliability of a class of iterated nets of the "formal neuron" type, and present the conditions for making such nets arbitrarily reliable, though constructed of unreliable elements.

ABSTRACT: The author investigates iterated logical nets each of whose elements perform functions from a selected subset of all possible functions, and shows that such nets either achieve a stable set of output functions or else oscillate. Iteration is the process whereby some or all of the elements of the net are replaced by a copy of the net and this process is repeated indefinitely.

A homogeneous net is defined, and the concept of complete iteration is introduced. Convergence of the net is achieved when further successive iteration in the net produces no change in the output function set. The net is said to oscillate when its output function set changes cyclically when the net is iterated. A net which converges is therefore oscillating with period 1.

An upper bound on the period of an iterated net is given and theorems on convergence which are independent of net structure are proved. A fundamental theorem states that a net oscillates with period which divides p if some set of output function is a subset of an output set occurring p iterations later. Several theorems are given which describe classes of nets which converge. Some of these are: every two element 2x1 completely iterated net; every completely iterated net whose initial function set contains as a subset the functions $(x_{j1}, x_{j2}, \ldots x_{jn})$, the bounds of the j's being 1 and m, where m is the number of inputs and n is the number of outputs; every completely iterated net of a given form (several types); every completely iterated triangular net, etc.

This paper examines reliability - the probability that an iterated net produces a particular output function and examines the probability that an iterated net will be more reliable than a single element (or specifically does iteration improve reliability?) Two examples are given in which this happens and a theorem is given which relates the probability of achieving a given function to a system of iterated polynomials whose behavior under iteration completely describes the reliability properties of the net in question.

Homogeneous nets containing special elements are examined and two theorems are given which deal with convergence and reliability when the unit and null functions are involved. The work of A. M. Ostrowski on the convergence of systems of equations under iteration is described and applied to the problem of convergence of a polynomial system to a simplicial vertex. The author uses these results to

prove a theorem giving criteria under which a net achieves arbitrary reliability.

Generalizations of the above work are considered. More complex net growth schemes are described, and problems for future study outlined. (Author)

REVIEW: At the beginning of the article the author apologizes for "the disconnected character of the development." This fault does not become apparent until after about the midpoint of the work. His partial presentation of then-current work intrudes at that point. On the whole, however, the paper does meet its objectives of studying the character of oscillation and convergence in iterated nets, and the conditions for achieving arbitrary reliability. The author carefully defines terms and concepts, at least during the better first half of the paper, and this is refreshing. The mathematician wishing to look at an exposition of iterative net oscillation theory will find this paper very interesting--the person wishing to use the results will wish to read later work. ##

Serial Number 2419
ASQC Codes 711;830

TITLE: Materials Selector Issue

AUTHORS: Editors, Materials in Design Engineering

SOURCE: Materials in Design Engineering, vol. 62, Mid-Oct 65, entire issue (554p including advertising)

PURPOSE: To provide a convenient summary of the properties of many kinds of materials.

ABSTRACT: This issue of Materials in Design Engineering features the latest available data on engineering materials, parts, forms, finishes and joining methods. It includes three major sections: A Review of the Year's Developments, a Data Section and a Materials & Parts Buyers Guide.

The Data Section consists of ten subsections and contains: (1) comparisons of materials; (2) extensive data on physical, mechanical, chemical, electrical, thermal, and fabricating properties of virtually all important engineering materials, including finishes and coatings; (3) an indication of available forms, and typical uses; (4) a summary of fabricated parts and forms of materials; and (5) a summary of joining methods.

The Materials & Parts Buyers Guide contains the names and addresses of leading suppliers of engineering materials, finishes, forms and shapes. A full explanation of its organization and use is given.

The information in the Data Section of this issue has a specific and limited purpose. Space does not permit a complete description of the materials and test conditions; hence, the data cannot be used directly for final designs. They are intended solely to help narrow the choice of materials, forms or processes for a specific job. In developing final designs, contact individual suppliers for detailed data. In general, the data represent average test results obtained from many different sources and suppliers; in no case do the values represent absolute minimum or maximum specified limits. Where a range is given, it may reflect either the normal variation in that test or variations in the composition, temper, heat treatment, form, or other condition. Available parts and forms listed in these sections are the most important that are readily available commercially. Uses listed are typical and not exhaustive. (Authors)

REVIEW: This type of summary can be very useful to designers. A major part of good reliability is the use of present technology to its fullest and this compendium is a help in that direction. It would be nice if more emphasis had been placed on fatigue properties and if some idea of the variability of the properties could have been introduced. Unfortunately, the latter data are probably difficult to find, if they even exist. See also the comments in RATR 1725. ##

Serial Number 2420
ASQC Codes 762;815

TITLE: A rational approach to inspection and testing of engineering weldments

AUTHOR: Ronald Clough (Canadian Welding Bureau, Div. of Canadian Standards Association, West Vancouver, B. C., Canada)

SOURCE: Welding Journal, vol. 44, Apr 65, p. 261-267

PURPOSE: To investigate the nature of variations relating to the inspection and testing of welds.

ABSTRACT: Often weld inspection requirements are at the discretion of individuals whose background and competence varies over a wide range. The requirements often show a lack of understanding of the relationship of weld defects to service conditions and of suitable standards. The suitability of the weld to service conditions and its cost are both important. The design should take into account appearance, and static and fatigue strengths. These characteristics are rated for each of seven different classes of products, based on the appearance desired, stresses encountered, and whether failure is catastrophic or only an inconvenience. The influence of weld defects under static and dynamic loading is discussed. Defects may be the result of porosity, slag inclusions, or incomplete penetration. Static strength is a linear function of weld area and is not reduced by up to 5% porosity or slag inclusions.

The effect of undercut depends on the direction of the applied load and transverse loading may cause a significant reduction in strength. Under dynamic loads, fatigue becomes a factor and full penetration butt welds should be the rule. About 4% porosity can be tolerated. Changes in the weld should be gradual with no cracks. Acceptable levels of weld quality are given along with procedures for obtaining them. These include degrees of incomplete penetration, lack of fusion, and undercut allowed; crack tolerance, inclusions, porosity, weld profile appearance, and electrode to be used. The effectiveness and relative costs of inspection methods (visual, dye, magnetic particle, ultrasonic, and radiography techniques) are discussed.

REVIEW: The paper is an excellent one dealing with a subject that is difficult to treat adequately, but which is important to the reliability of welded structures. The methods proposed for establishing weld quality appear to have considerable merit. The paper contributes mostly to educating the reader on the importance of weld specification from the standpoint of meeting service conditions at a minimum weld cost. The paper cited as Reference 1 by the author is a collection of results by Kihara and his associates in Japan; in particular it contains data pertaining to the quality of welds in aluminum alloys. Other papers on metal fabricating processes were covered by RATR 2045 and 2046. For other information and standards on welding see, for example, ASTM and SAE standards, and the Welding Handbook of the American Welding Society. ##

Serial Number 2421
ASQC Codes 711;712

TITLE: Tips on fatigue

AUTHOR: Clarence R. Smith (General Dynamics/Convair, Fatigue Laboratory, P. O. Box 1950, San Diego, Calif.)

SOURCE: NAVWEPS 00-25-559, prepared for the Bureau of Naval Weapons, Department of the Navy, 1963 (GPO $0.70)

PURPOSE: To provide the men on the drawing boards and in the shops with an appreciation for the basic causes of fatigue failures.

ABSTRACT: Fatigue of metals is failure due to repeated application and removal of a stress. The breaking of a wire by bending it several times is an example. If stress is thought of as something that must flow along a piece of metal like water in a trough, it can be seen that sudden changes in cross-section or contour can upset the flow. These are called stress concentrations and a part will most always fail at one of these concentrations. There are always many of these at joints of any kind. Riveted, welded, bolted joints, etc. can always be designed to reduce these concentrations. Even bad surface finish, nicks, and sharp edges can be stress concentrators sufficient to cause early failure. Shopmen and draftsmen can be equally guilty of poor practice. Examples of good and bad construction are shown in easy-to-follow pictures and discussion.

REVIEW: This is a good pamphlet that will repay its study many times over for those to whom it is directed. It is very readable with an easily-assimilated message--no big words nor confusing concepts. As in other facets of reliability, infinite attention to detail is required so that no weak points are left undiscovered or uncorrected. ##

Serial Number 2422
ASQC Codes 823;824

TITLE: Imcompletely specified models in life testing

AUTHOR: Dale Owen Richards

SOURCE: Dissertation submitted to the Graduate Faculty, Iowa State University of Science and Technology, Ames, Iowa, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1963, 128p, 51 refs. (Xerographic copies may be purchased from University Microfilms, Inc., Ann Arbor, Mich., order no. 64-3992)

PURPOSE: To investigate the effect of preliminary testing on further testing and estimation in the exponential case.

ABSTRACT: The problem considered in this report is that of using a preliminary test to determine whether a one-parameter (scale parameter) or a two-parameter (scale and location parameters) exponential distribution should be assumed as the distribution of the parent population for subsequent inferences and how this decision affects the properties of such inferences. Comparisons are made between using a preliminary test to specify the model to be used for inferences concerning θ, the scale parameter, and arbitrarily adopting a one- or two-parameter distribution. In comparison of estimation procedures, the bias and mean square error of the resulting estimators of θ are computed and compared. In the study of tests of hypotheses, the size and power of the overall testing procedure is compared with the size and power of the tests which do not involve preliminary testing.

REVIEW: This is a very good statistical paper which gives good insight into the problem considered. From the nature of the problem, many of the results are presented numerically in tables and graphs. Discussion is given on the conclusions obtainable in various situations. ##

Serial Number 2423
ASQC Codes 813;844

714;844

815

813;836;840

TITLE: The determination and analysis of aging mechanisms in accelerated testing of selected semiconductors, capacitors and resistors

AUTHORS: G. E. Best, G. R. Bretts, H. T. McLean, and H. M. Lampert (General Electric Company, Spacecraft Department, Philadelphia, Pa.)

SOURCE: Physics of Failure in Electronics Volume 3, Apr 65, p. 61-80, 9 refs. (*see RATR 2334)

Most of the material in this paper is included in the one covered by RATR 1949, which was presented later.

TITLE: The chemistry of failure of aluminum electrolytic capacitors

AUTHORS: R. S. Alwitt and R. G. Hills (Sprague Electric Company, Engineering Laboratories, North Adams, Mass.)

SOURCE: IEEE Transactions on Parts, Materials and Packaging, vol. PMP-1, Sep 65, p. 28-34, 7 refs.

This is the same as the paper covered by RATR 2226.

TITLE: NASA's reliability requirements

AUTHOR: John E. Condon (NASA Headquarters, Washington, D. C.)

SOURCE: Industrial Quality Control, vol. 22, p. 287-289, Dec 65

This paper is essentially the same as the one covered by RATR 1495.

TITLE: Commercial design review and data analysis program

AUTHORS: Richard M. Jacobs and H. Donnell Hulme (Westinghouse Research and Development Center, Westinghouse Electric Corp., Pittsburgh, Pa.)

SOURCES: Evaluation Engineering, vol. 4, Jul/Aug 65, p. 16, 19
Journal of the Electronics Division, American Society for Quality Control, vol. 3, Mar 65, p. 19-31

The first of these is an abstract and the second the complete text of the paper covered by RATR 2103. ##

Serial Number 2424
ASQC Codes 822;824

TITLE: Parameter estimation for a generalized gamma distribution

AUTHORS: E. W. Stacy and G. A. Mihram* (IBM, Endicott, N. Y., *now at University of Oklahoma)

SOURCE: Technometrics, vol. 7, p. 349-358, 8 refs., Aug 65

PURPOSE: To examine a three-parameter generalization of the gamma distribution and derive parameter estimation techniques for it.

ABSTRACT: It is fairly commonplace in reliability analyses to encounter data which are incompatible with the exponential, Weibull, and other familiar probability models. Such data motivate research to enlarge the group of probability distributions which are useful to the reliability analyst.

In this paper, the authors examine a three-parameter generalization of the gamma distribution and derive parameter estimation techniques for that distribution. Those techniques, in the general case, depend upon method of moments considerations which lead to simultaneous equations for which closed form solutions are not available. Graphic solution is proposed and aids to the computations are provided. Major concepts in the paper are summarized by means of a numerical example.

Details are given for the special case in which only the scale parameter is unknown. Three unbiased estimators for that parameter are derived along with their variance formulas. Minimum variance considerations are discussed by application of the Cramér-Rao Theorem. (Authors)

REVIEW: This paper serves the useful purpose of enlarging the groups of probability distributions available to the reliability analyst. While the discussion is principally mathematical, a computational aid and a numerical example are given. Several probability distributions which are currently used in reliability and other statistical analyses are tabulated as special cases. The results will be of interest to statisticians concerned with reliability analyses in which the data do not fit one of the more conventional models.

The senior author, in a private communication, has pointed out that the generalization given in the paper is an extension of that reported by him in the September 1962 issue of the Annals of Math. Stat. The distributions for the reciprocals are included by the extension for all random variables whose distributions are of the generalized Gamma type. ##

Serial Number 2425
ASQC Codes 414;824

TITLE: Product test planning for repairable systems

AUTHOR: B. J. Flehinger (IBM Watson Research Center, Yorktown Heights, N. Y.)

SOURCE: Technometrics, vol. 7, p. 485-494, Nov 65

PURPOSE: To develop methods of planning product tests in terms of the objectives of (a) detecting failure mechanisms and (b) estimating performance parameters of the product, subject to the manufacturer's economic constraints.

ABSTRACT: Product tests are generally intended to serve two purposes, first to expose those mechanisms which are likely to prove troublesome so that they may be eliminated and second to provide estimates of the performance parameters of the product. In this paper, systems in which the failure rate is the significant performance parameter and in which failures constitute a Poisson process are considered. It is assumed that every system failure may be classified as "correctable" or "intrinsic" and that every correctable failure which occurs during test leads to elimination of the mechanisms which caused it. Optimal test plans are developed based on the purposes of the test and the economic factors of importance to the manufacturer.

Two models are postulated and analyzed. The first of these is useful when the objective is the identification of failure mechanisms which can be eliminated. Necessary input data include estimates of the penalties associated with failures and the cost of testing. While these are assumed to be proportional to the failure rate and the test interval respectively, the proposed methods may be extended to non-linear functions. A knowledge of the number of correctable failure mechanisms in the system is also required; this number is likely to be difficult to estimate.

The second model is appropriate for tests which simultaneously serve to identify correctable failure mechanisms and prevent the release of products with excessively high failure rates. It can be used with no more information than that required for the first model, except for a known cost of rejection. However, in that case the computations involved are very laborious. Whenever a prior distribution of the intrinsic failure rate is obtainable, it leads not only to a better optimization of the strategy but also to considerable simplification in the computations. (Author in part)

REVIEW: This is a good mathematical paper addressed to a worthwhile problem. The material is clearly presented and adequately explained. The neccessary input data for practical application of the model are set forth, and it must be recognized that in many actual situations all of these will not be too readily available. The term "test-planning" is used in the title of this paper in a decision-theoretic rather than an engineering sense. ##

Serial Number 2426 -1
ASQC Codes 822;824

TITLE: Maximum likelihood estimation in the Weibull distribution based on complete and on censored samples

AUTHOR: A. Clifford Cohen (The University of Georgia)

TITLE: Maximum-likelihood estimation of the parameters of Gamma and Weibull populations from complete and from censored samples

AUTHORS: H. Leon Harter and Albert H. Moore (Aerospace Research Laboratories and Air Force Institute of Technology, Wright-Patterson Air Force Base)

SOURCE: Technometrics, vol. 7, p. 579-588, 15 refs., p. 639-643, 15 refs., Nov 65

PURPOSE: To obtain maximum-likelihood estimators of the parameters of Gamma and Weibull distributions based on complete and on censored samples.

ABSTRACT: The first of these papers is concerned with the two-parameter Weibull distribution which is widely employed as a model in life testing. Maximum likelihood equations are derived for estimating the distribution parameters from (1) complete samples, (2) singly censored samples and (3) progressively (multiple) censored samples. Asymptotic variance-covariance matrices are given for each of these sample types. An illustrative example is included.

In the second paper iterative procedures are given for joint maximum-likelihood estimation, from complete and censored samples, of the three parameters of Gamma and of Weibull populations. For each of these populations, the likelihood function is written down, and the three maximum-likelihood equations are obtained. In each case, simultaneous solution of these three equations would yield maximum-likelihood estimators for the three parameters. The iterative procedures proposed to solve the equations are applicable to the most general case, in which all three parameters are unknown, and also to special cases in which any one or any two of the parameters are known. Numerical examples are worked out in which the parameters are estimated from the first m failure times in simulated life tests of n items ($m \leq n$), using data drawn from Gamma and Weibull populations, each with two different values of the shape parameter. (Authors in part)

REVIEW: These two papers represent worthwhile contributions to the theory of the Gamma and Weibull distributions, which are quite important in reliability and life testing. The general problem attacked is the same in each case, but, as the above abstracts indicate, the two treatments are different. There is considerable overlap in the two treatments of the Weibull distribution, the differences being that in the second paper all three parameters are estimated as compared to two in the first, and that the first paper treats the case of progressive censoring, which the second does not. The second paper treats the Gamma population in addition to the Weibull.

An editor's comment appearing with each paper states that they were prepared independently of each other. It is interesting, too, to observe that of the total of 30 references cited in the two papers, 26 are distinct. Thus, there is surprisingly little overlap in the literature cited in the two papers.

For those interested in parameter estimation in the Weibull distribution, these papers supplement each other, and together provide a competent and comprehensive treatment of the topic, along with a wealth of reference material.

A listing of RATR items on other papers dealing with the Weibull distribution and various aspects of its role in reliability analysis is found in RATR 1701. More recent papers in this category have been covered by RATR 2112, 2234, 2239, 2266, 2286, 2288, 2380, and 2385. ##

Serial Number 2427
ASQC Codes 220;414;760;
824

TITLE: Sampling inspection plans for discriminating between two Weibull processes

AUTHORS: A. S. Qureishi, K. J. Nabavian (Service Bureau Corporation, Palo Alto, Calif.), and J. D. Alanen (Yale University, New Haven, Conn.)

SOURCE: Technometrics, vol. 7, p. 589-601, Nov 65

PURPOSE: To present sampling plans based on four procedures for choosing the better of two Weibull processes, and to examine the robustness of the procedures.

ABSTRACT: Four procedures for choosing the better of two processes, the units from which have life times distributed according to the Weibull distribution were formulated in an earlier paper (see RATR 1578). This paper discusses the calculation in the use of these procedures and some sampling plans based on them. The robustness of the procedures is also examined.

The four procedures considered are the following:

- R_1 . A nonsequential, nonreplacement type of procedure,
- R_2 . A nonsequential, replacement type of procedure,
- R_3 . A sequential replacement type of procedure and
- R_4 . An alternative sequential type of procedure in which the life times of failed units are considered in the choice of the better process.

The problem is to select the process with the larger mean life, which reduces to that of selecting the process with the larger value of the scale parameter. Specifications of the procedures are given in terms of the scale parameters. The procedures are discussed briefly, and examples are given. The robustness of the procedures is discussed in terms of the extent of separation of their Operating Characteristic Curves for different values of the shape parameter c. It is found that the procedures are rather sensitive to changes in c.

REVIEW: The background for this paper is found in the one covered by RATR 1578. Those wishing to follow the details will need to refer to the earlier paper, which is more extensive and detailed. Similarly, not all of the sampling plans are included in the present paper. However, the authors cite an address from which more detailed plans may be requested.

As observed in RATR 1578, in practice mean life may not always be the parameter of most interest.

For a listing of RATR items on other papers dealing with the Weibull distribution and various aspects of its role in reliability analysis, see RATR 2426. ##

Serial Number 2428
ASQC Codes 553;824

TITLE: Tables of bounds for distributions with monotone hazard rate

AUTHORS: Richard E. Barlow (University of California, Berkeley) and Albert W. Marshall (Mathematics Research Laboratory, Boeing Scientific Research Laboratories)

SOURCE: Journal of the American Statistical Association, vol. 60, p. 872-890, Sep 65

PURPOSE: To present tables of bounds for distributions with monotone hazard rate.

ABSTRACT: This paper presents in a form convenient for applications a number of bounds for distributions with monotone hazard rate. These bounds, together with their proofs and various generalizations have been obtained by Barlow and Marshall [1]. However, many of them can be characterized only through solutions of transcendental equations, and machine calculation has been necessary to make them accessible. Section 2 gives a listing of the results, and those without explicit forms are tabulated. Section 3 lists various related bounds which are of interest for purposes of comparison, and for use when the hypothesis of monotone hazard rate is not satisfied. Applications of the bounds are discussed in Section 4, together with some numerical examples. (Authors)

REFERENCE: [1] Barlow, R. E. and Marshall, A. W. (1964). Bounds for distributions with monotone hazard rate, I and II, Ann. Math. Statist. 35, 1234-74.

REVIEW: This paper renders certain mathematical results previously obtained by the authors useful for practical applications. The types of problems which can be solved through the use of the tables are indicated by the examples given in the paper. ##

Serial Number 2429
ASQC Codes 831;844

TITLE: Simplified reliability calculations for complicated systems

AUTHOR: James A. Lechner (Westinghouse Defense and Space Center, Aerospace Div., Baltimore, Md.)

SOURCE: IEEE Transactions on Systems Science and Cybernetics, vol. SSC-1, Nov 65, p. 31-36

PURPOSE: To discuss methods for calculating the reliability and availability of systems, and to present a method based on the rarity of component failures.

ABSTRACT: Well-known general methods of calculating the reliability and availability of systems are reviewed briefly. A practical method is presented for use when the time period involved is (relatively) short. It involves a systematic investigation of the various possible patterns of failures and repairs, beginning with the simplest patterns that can cause system failure and progressing only as far as necessary to attain the accuracy required, calculating the contribution each makes to unreliability and the possible contributions of all the not-yet considered patterns. (Author in part)

REVIEW: This paper constitutes a brief and clear presentation of a method of analysis which can be quite useful for the types of systems to which it is applicable. It should be noted that the method applies to time periods which are short relative to the component mean lives. It is also essential that the user have a clear picture of the failure patterns which are possible, together with adequate information on their probabilities of occurrence. Given these inputs, the method provides for relatively simple and straightforward calculations. However, even these can be tedious when the system is large and complex. ##

Serial Number 2430
ASQC Codes 414;433;821

TITLE: Bayesian decision models for system engineering

AUTHOR: Ronald A. Howard (Stanford University, Palo Alto, Calif.)

SOURCE: IEEE Transactions on Systems Science and Cybernetics, vol. SSC-1, Nov 65, p. 36-40

PURPOSE: To indicate the character of the Bayesian approach to decision problems by applying it to a problem in reliability.

ABSTRACT: This paper shows how modern developments in statistical decision theory can be applied to a typical systems engineering problem. The problem is how to design an experiment to evaluate a reliability parameter for a device and then make a decision about whether to accept a contract for the development and maintenance of a system of these devices. The concept of subjective probability distribution to permit encoding prior knowledge about the uncertainty in the process is introduced. The expected value of clairvoyance is computed as an upper bound to the value of any experimental program. The structure of decision trees serves as a means for establishing the optimum size and type of experimentation and for acting on the basis of experimental results. The subjective probability approach to decision processes allows one to consider and solve problems that previously could not be formulated. (Author in part)

REVIEW: The application of Bayesian decision models as discussed in this paper would be of particular interest to technical and management personnel involved in contract negotiations. The problem discussed is the desirability of accepting a fixed-price contract to build and maintain a system of N devices. A slight deviation from the proposed procedure which may be of interest is that of assuming a small probability of no profit as opposed to making the expected profit greater than zero. Bayesian models would also be helpful in estimating expected profits in incentive-type contracts. The use of expected profits as a guide to selecting the number of devices to be tested is a good decision tool.

There is some evidence in the recent literature to indicate that the Bayesian approach in reliability evaluation is receiving the increased attention that it deserves. See, for example, RATR 1125, 1287,2072,2268, and 2381. ##

Serial Number 2431
ASQC Code 800

TITLE: Space reliability and consumer products

AUTHOR: Catherine Dryden Hock (National Aeronautics and Space Administration, Office of Manned Space Flight, Washington, D. C.)

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 3, Mar 65, p. 9-18, 27 refs. (presented at a meeting of the Baltimore, Maryland Section of the American Society for Quality Control, Baltimore, Md., 21 May 65)

PURPOSE: To describe reliability engineering and give examples of consumer industries which use it.

ABSTRACT: While reliability engineering existed in a few industries prior to 1950, its lack caused serious problems in the early missile development in the 1950's. If a product or system, such as an automobile, is allowed to evolve slowly over the years, the traditional methods of engineering can handle the reliability problems. But when new systems such as missiles must be operational from scratch, within 5-10 years, then an organized attack on reliability problems is necessary.

Reliability engineering is generally required on DoD and NASA contracts, but has been slow to find its way into consumer industries. The lengthening of warranties by the automotive, typewriter, and home-appliance industries are examples of applications of reliability. Other industries such as computers and firearms also use reliability techniques.

REVIEW: As a general paper, this will be informative to those not in the field of reliability. It does provide reasonable background information. There are no details on how consumer industries have applied reliability techniques to their products. The lengthening of express-warranties is an excellent way for companies to separate the truth from "sales-talk." Reliability engineering can find much application by assisting in this area. ##

Serial Number 2432
ASQC Code 800

TITLE: Basic tools of reliability

AUTHOR: Alexander Sternberg (Radio Corporation of America, Astro-Electronics Div.)

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 3, Jun 65, p. 15-20

PURPOSE: To present the most frequently used methods utilized to implement a reliability program.

ABSTRACT: This report is directed toward Reliability Tasks, not toward the problem of who does them. Not all of the techniques mentioned in the paper are always used. The tasks are:

A. Reliability Requirements Study: Mission Goals, Mission Profile, Redundancy Requirements, Reliability Apportionment and Estimates, and Degradation Analysis.

B. Reliability Analysis and Prediction: Reliability Block Diagram, Mathematical Model, Design Analysis--Worst Case, Trade-offs, Preliminary Reliability Estimate and Reliability Allocation, Detailed Reliability Stress Analysis, and Failure Mode and Effects Analysis.

C. Parts Selection, Evaluation and Control: Parts Study and Application, Standard Parts, Nonstandard Parts, Screening--Pre-conditioning--Lot Identification, and Parts Derating.

D. Failure Reporting and Analysis.

E. Design Reviews: Preliminary Review, Major Review, and Final Review.

F. Testing Program: Test Monitoring, Reliability Measurements, Follow-up, Material Flow Charts, and Equipment Logbooks.

G. Reliability of Subcontractors and Vendors.

H. Documentation.

REVIEW: 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 task. There are no references. Managers and designers not familiar with all of these will find the review helpful. No one task is as simple as it may appear to the uninitiated from a one-paragraph description. ##

Serial Number 2433 -1
ASQC Codes 711;712;782

TITLE: Materials vs heat
a) How to protect materials from heat
b) How to test and evaluate the effects of heat
c) Properties of materials in a heat environment

AUTHORS: M. S. Howeth, H. R. Thornton and J. E. Burroughs (General Dynamics/ Fort Worth, Research and Engineering Dept.) (part a only)

SOURCE: Materials in Design Engineering, vol. 62, Dec 65, p. 99-134

PURPOSE: To help solve problems encountered when materials must function in a high-temperature environment (above $100^{o}F$).

ABSTRACT: The three sections of this report show how to protect materials from high-temperature environments, how to evaluate materials properties at high temperatures, and the influence of high temperature on materials properties. The four main classifications for controlling heat transfer are conduction, convection, radiation and change of state. Each is briefly described with examples. Tests for measuring thermal properties are briefly discussed and standard tests are referenced. The less familiar phenomena, such as creep, are explained. Nineteen pages are devoted to tables of melting point and to mechanical properties vs. temperature.

REVIEW: This type of information is valuable to designers. The specific treatment here is too superficial in many respects, and on occasion tries to be very fundamental but without imparting any real information. The tables themselves may well be useful to designers and the references to Standard Tests are good.

Designers should be aware that even though a test is Standard, it may not measure the property he is interested in very well. This is especially true for rubber and polymer materials, and is true even for some "high-strength" steels.

Examples of the inadequacies and ill-fated attempts at being too fundamental are the following.

1. "As electricity travels in pulses, heat travels and is transferred in waves whose length depends on temperature." This presumably alludes to the phonon concept and is completely (and properly) ignored in the rest of the paper.

2. Lip service is paid to problems at low-temperatures but no data or discussions are given. Not even the ductile-brittle transition of steels is mentioned.

3. In most cases, where "heat" is used, high-temperature environment is meant (relative to room temperature).

4. For fatigue and creep properties including the tables, no mention is made of the tremendous scatter in fatigue and creep lives at a given condition. The range of variability can easily be (max/min) 10 or more for a small sample. Neither is the fact mentioned that most curves are median curves. Very few designers are interested in having 50% failures. Several excellent ASTM publications exist on this topic.

5. The tensile strength discussion skirts around true vs. nominal stress near failure but does not mention the problem. No-

where is there a definition of yield strength, but a table of it is given.

6. Part of the discussion on heat transfer implies that liquids and gases do not support heat conduction.

7. The pictures on polymer linkages are reversed or not clear, or both.

8. Some of the discussions on fatigue limit seem to imply a non-zero value for materials at room temperature. The ferrous metals are one of the few construction materials that possess a non-zero fatigue limit (under constant amplitude loading). If any of the values of a spectrum load exceed the fatigue limit, further loads below the nominal fatigue limit may well cause damage.

9. Volume resistivity is given in a table for insulators, but no mention is made of surface leakage. In many situations, the surface currents will exceed currents through the bulk. ##

Serial Number 2434
ASQC Codes 814;816

TITLE: Today's reliability motto: cost effectiveness

AUTHOR: --

SOURCE: Electronic Procurement, vol. 5, Jul 65, p. 28-31

PURPOSE: To show how the elements of the procurement team organize for reliability.

ABSTRACT: Reliability begins with the allotment of the necessary tasks. While some people concentrate only on one phase, a good organization must include quantitative reliability requirements, design control, component selection and control, production evaluation, failure feedback, and a reliability testing program.

Proper specifications and standardization of parts go a long way toward improving reliability. They mean fewer part types with the resultant ability to get more information on them, to put more controls on them, and to purchase better parts at lower cost. In a complex system, these benefits go right on down to the subcontractors and their suppliers.

For those groups who purchase raw materials, it is essential to have give and take with suppliers. Many times a supplier can make suggestions for improved quality at lower prices by slight modification of the requirements. Vendor performance ratings are essential.

Value engineering can include reliability as one of the criteria for value. Weaknesses due to design should be smoked out at an early stage by carefully planned testing. Test-to-failure by increasing the stresses is an effective way to find weaknesses. It is wise to know how various environments (stresses) act on a product and to be able to make a scale of increasingly severe combined environments.

The customer should realize that experimental proof costs money and the more stringent the proof, the more it costs. Excessive confidence levels should be avoided because the supplier must make his product much better than the guarantee in order to pass the test easily. Paper work also is expensive and after assuring himself of the supplier's integrity, etc., the customer should be satisfied with certification rather than reams of paper.

REVIEW: This is a summary of several different papers. The first was covered by RATR 2061. In general this summary is reasonable and non-technical--directed primarily toward purchasing agents. For this purpose the article is quite satisfactory. The problem of testing to a confidence level and having to make the product of much higher quality than specified is quite serious. The source of the trouble lies in the fact that the usual statistical test has the implicit assumption of absolute ignorance about the product before the test begins. Since this is not so, usually, people fudge on confidence levels, etc. to bring the amount of testing into line with their "intuitive" feelings. There is no good solution to the problem at present, but Bayesian statistics is one approach which is receiving increased attention. ##

Serial Number 2435
ASQC Codes 813;817;844

TITLE: Detecting and correcting weakest reliability links

AUTHOR: John B. Ellison (Martin Orlando)

SOURCE: Electronic Procurement, vol. 5, Sep 65, p. 26-28

PURPOSE: To present a system for pinpointing the item most in need of reliability improvement.

ABSTRACT: The item with the highest failure rate may not be the one most in need of improvement. An index number given by

$$\frac{\text{number of functional failures}}{\text{significance factor x (1 + number of items tested)}}$$

is used to assign priorities. A suggested significance factor is $10^6(1\text{-}R)$ where R = allocated reliability. The higher the index number, the higher the priority for improving the reliability. Charts and tables are maintained to implement the program of allocating the priorities. Other tasks are associated with the same data which make it easier to visualize the subsystems which are causing the trouble.

REVIEW: Other papers have appeared on this topic (see, for example, RATR 1910). The suggested formula for the index number essentially reduces to

$$10^6\text{(actual failure probability)/(allocated failure probability)},$$

and in that form seems less mysterious. Contrary to the author's statement, this method will not necessarily "...net the largest system reliability improvement per corrective dollar spent," since costs are not a factor in the index. Other authors have more correctly treated that problem. ##

Serial Number 2436
ASQC Codes 816;833

TITLE: The '2N' reliability game--rules for spec-pricemanship

AUTHOR: Robert A. Bernay

SOURCE: Electronic Procurement, vol. 5, Sep 65, p. 30-32, 35 (from Reliability Digest, house organ of Melpar Inc., Falls Church, Va.)

PURPOSE: To show how the distribution of properties of transistors affects the reliability and the price.

ABSTRACT: Transistor properties, for a given family, i.e., before sorting, have wide-dispersion distributions. Since the spread in values is much too great for application, they are sorted into groups. The price of each group is adjusted so that the whole batch can be sold to bring in as much money as possible. The transistor properties are determined by geometry and the junction, surface, and bulk effects. The bulk and junction effects are likely to be stable throughout the family and thus groups within the family are all equally reliable with regard to properties which depend solely on these effects. On the other hand, surface effects can vary widely from unit to unit and cause the major differences in classification. By their nature, the surface effects are very likely to be quite time- and stress-dependent. These facts lead to two Reliability Laws for Semiconductors: For a given device family:

I. Differences in bulk-property dependent characteristics have no effect on reliability.

II. Characteristics which are very dependent on surface properties indicate a low reliability.

As far as distributions within groups are concerned, the user has virtually complete ignorance except for the end limits. It would be most unwise, certainly for any particular batch, to make any predictions about the distribution. It may be bunched at either or both ends, for example, and will depend on the batch and the manufacturer's other orders.

Some of the less expensive transistors might be "reliable enough" but since they are so cheap, no one wants to spend the money to find out. Consequently only the higher priced units, less likely to have poor surface-dependent parameters and thus more likely to be reliable, have reliability data.

REVIEW: The '2N' in the title apparently refers to the 2N___ transistor EIA numbers. On the whole, this article is good and most certainly the points about the distributions should be taken to heart. The generalities about reliability are effective as long as they remain generalities. We do not know enough about the implications of the phrase "...properly applied in their circuits" to give an exact meaning to the two laws. ##

Serial Number 2437
ASQC Code 815

TITLE: Implementing reliability with specifications

AUTHOR: L. G. Reynolds (Martin Company, Orlando, Fla.)

SOURCE: Presented at the AIAA Second Annual Meeting, San Francisco, Calif., 26-29 Jul 65, 26p, 36 refs., AIAA Paper No. 65-393 (American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N. Y. 10019); summarized in Electronic Procurement, vol. 5, Oct 65, p. 1-2

PURPOSE: To provide meaningful guidelines for the engineer who must generate specifications for aerospace hardware which must be reliable under many environments.

ABSTRACT: Existing guidelines for incorporating reliability requirements into specifications are presently scattered, incomplete, and to some extent obsolete. Several partial guidelines exist but these generally deal with other subjects which range from remotely connected to unassociated with reliability. The engineer who is assigned the task of writing the specification will scarcely be aware of all the partial guidelines that exist and will hardly have time to collect them to filter out the inapplicable material. Direction is particularly lacking in the quality-reliability interface, the safety margin concept, and success-failure criteria. These conclusions are based on a study of current specifications. While there is no single reliability format suitable for universal application, there are worthwhile specification guidelines that can provide firm reliability direction to the supplier. Two reasons for the current situation are that standards of reliability performance and demonstration have obtained only narrow acceptance, and that reliability requirements can rarely be measured, but rather are interpreted subjectively by the different backgrounds of the engineer, administrator, and statistician. Master reliability specifications are needed for the various major combinations of hardware type, use, and program constraints. (Author in part)

REVIEW: Guidelines provided here are mainly the identification of some typical problems found in specifications dealing with reliability, and a collection of background material, which includes complete reproduction, excerpts, and references. The problems are certainly appropriate, and the background material is a complete-looking package. Those persons writing system- and equipment-level specifications are usually faced with obstacles such as constantly changing management or customer directives, short time schedules, and a new program group which is under-manned and does not readily accept reliability notions. The specification writer may be inexperienced. Thus the master specifications which the author says are needed would indeed assist in the generation of improved reliability specifications. Reliability as dealt with in this paper is mainly from the viewpoint of a quantitative requirement and its measurement. Little is given on the tasks which comprise a typical reliability effort such as analysis, reviews, parts, or failure reporting. ##

Serial Number 2438
ASQC Code 811

TITLE: Survey reveals reliability profile--pinpoints organizational trends

AUTHOR: Marvin Freedberg (Belock Instrument Corp., College Point, N. Y.)

SOURCE: Electronic Procurement, vol. 5, Oct 65, p. 44-46

PURPOSE: To report on a survey and to tell how a reliability group should be organized.

ABSTRACT: Questionnaires about the organization, responsibilities and significant problems of reliability departments in electronics companies were circulated and responses were analyzed. The results from a 56% response are summarized. Most companies had separate reliability groups that reported to a top operating executive and had been in existence more than two years. Most groups felt that inadequate funds, lack of field data, lack of people and lack of management support were their reasons for not meeting goals. The recommendations for improvement centered on budgets, specifications, management and data collection.

REVIEW: The results are interesting, but little is known about how representative they are due to the low rate of response. There is an implication that Quality Control, Reliability, and Quality Assurance should not be associated with each other and that the reliability manager should be directly under a top-line executive. Many people are becoming very concerned that the engineering groups do not have the responsibility for reliability, etc. and are moving to put this responsibility squarely on the engineering groups, with the reliability groups offering assistance where needed. ##

Serial Number 2439
ASQC Code 815

TITLE: Standards for reliability--are you kidding?

AUTHOR: Gerald M. Walker

SOURCE: Electronic Procurement, vol. 5, Oct 65, p. 72

PURPOSE: To discuss the problems of standards for reliability.

ABSTRACT: Getting standards in the area of reliability is difficult because of the proliferation of requirements and their interpretations. If each reliability group had a standards man in it, he could help guide the group. System-wide standardization of parts is a big help. Finally, the various groups within a plant need coordination and cooperation.

REVIEW: The need for standardization is a recurrent theme. In general, it is thought to be what everyone else should have... our own special ways of doing things are vitally necessary. Standardization is a complex idea and has many different meanings. One of its major areas is the reduction in numbers of the same type of thing. Where this is done, more effort can be put on the few that are being used. Whether or not this can be applied to reliability specifications themselves is a question, but one that needs to be searched.

The author's points are good; we do need more standardization, commonality or whatever you want to call it. Perhaps the best thing it does for us (and this is in few reliability "theories") is to reduce the problem of "foolish failures" and human carelessness.
##

Serial Number 2440 -1
ASQC Code 832

TITLE: ZD: Momentary or momentous?

AUTHOR: Luther W. Rook (Litton Systems, Inc., College Park, Md.)

SOURCE: Quality Assurance, vol. 4, Oct 65, p. 24-28, 6 refs. (see also letters to the editor, Quality Assurance, vol. 4, Dec 65, p. 10, 40, 42, 44-47)

PURPOSE: To point out that ZD and other employee-motivation programs require realistic appraisal if they are to offer long-term gains.

ABSTRACT: There are really two aspects connected with error reduction programs. One concerns modifying people; the other concerns modifying situations. They may be described as motivational and situational. The amount of improvement which can be obtained from such error reduction programs is the result of both aspects. The amount of improvement to be gained through changing environmental situations is limited only by the time and money available. Such changes usually have relatively permanent effects. Permanence is not typically the case, however, with purely motivational efforts, and maximum performance gains effected thereby are usually about 30 percent or less.

The arguments presented by proponents of motivation programs contain fallacies. These include the selection of 95 percent accuracy as an appropriate estimate of average human reliability, and the comparison of totally divergent kinds of behavior. It is doubtful that participation in motivation programs is really voluntary on the part of most workers. Overmotivation can have negative effects on performance.

Better and more long-lasting effects can be obtained by considering human errors to be the results of interactions of persons with situations. The situationally-caused error (SCE) must be differentiated from the human-caused error (HCE) Most errors result from SCE's rather than from HCE's. However, typical motivation programs concentrate on HCE's, while paying little attention to SCE's. Management must assume its basic responsibility for creating SCE-free environments for workers. The big problem will be in getting management to accept this responsibility instead of following the easier course of blaming the human element. The more rational course is to use the capabilities of people as we find them, and to create situations in which the job at hand can be done by the people we can get, rather than only by the people we wish we had. (Author in part)

REVIEW: ZD and similar motivation programs have recently attracted a great deal of attention (see, for example, RATR 2219). There is evidence that they have produced results of importance in the production of reliable equipment. However, some questions have been raised as to the permanence of these results after the pressure and initial enthusiasm are off.

There existed in this field a need for a competent, expert appraisal of motivation programs, giving the outlook for permanent beneficial effects. The present paper has done an admirable job of filling that need. It should be read carefully by top and middle management in manufacturing concerns who have instituted or are contemplating an employee motivation program. Hopefully, blind enthusiasm will give way to objective appraisal, and some may even take up the challenge presented by the author (see the last sentence of the paper, which is also the last sentence of the above ABSTRACT). The thought should also be taken to heart by those who write papers on Reliability Organization and then fail to realize that, inevitably, the organization will be staffed with average people. A reading of the paper brings to mind these questions: "In a typical situation, how much does top management really know about how the workers on the line feel about their jobs?" and "How much does the design engineering group know about the ways in which jobs are actually done (relative to the drawings)?"

In the letters to the editor (see SOURCE) this paper received five strong votes of approval--they are worth reading also. Prominent among the points made are the following: (1) participation of workers in ZD programs is most generally not voluntary, in spite of propaganda to the contrary, (2) declining interest after the first period of enthusiasm is likely to be quite common, and (3) putting the onus on management for creating error-free environments is a good idea. ##

Serial Number 2441
ASQC Codes 833;844

TITLE: A reliability profile

AUTHOR: John Hepp (General Motors Corp., A.C. Spark Plug Div., Milwaukee, Wis.)

SOURCE: A.C. Spark Plug Div., General Motors Corp., Milwaukee, Wis., 15 Feb 62, 6p

PURPOSE: To show that proper reliability application data for parts are needed.

ABSTRACT: The Darnell report is a good first step toward obtaining reliability, but it is not enough. One-fifth of component failures are due to misapplication and could be prevented. The designer needs failure-rate curves for each important parameter in a component. These could be added together to give the overall failure rate for the component. The failures must be well defined and must include drift as well as catastrophic failures.

REVIEW: This is essentially a "thinking out loud" piece. There is good reason to want the extra failure-rate descriptions and there are cogent reasons for not supplying them due to the expense. The author has not concerned himself with the problems of non-statistical independence of the parameters of a single component. For example, the h parameters of a transistor are correlated as are BV_{CEO} and V_{CESAT}. When the parameters are correlated, one cannot just add the failure rates. If the distribution is not exponential (the author implicitly assumes a single-parameter distribution), then the accumulation of the reliability data is even more expensive.

The problem discussed here is a real one, even more so with integrated circuits coming on the scene, but the solutions to it are most difficult because of conflicting interests and tradeoffs.
##

Serial Number 2442
ASQC Code 824

TITLE: Estimating reliability as a function of stress/strength data

AUTHOR: J. E. Norman (Research and Development Operations, Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala.)

SOURCE: Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala., Nov 61, 6p

PURPOSE: To show how to estimate the reliability from stress-strength data.

ABSTRACT: If the stress and strength of a part are Normally distributed, the strength margin has a Normal distribution with variance equal to the sum of the variances of the stress and strength distributions. The probability of failure is then calculated from tables of the cumulative Normal distribution. For a given nominal stress margin, the failure probability decreases as the variance decreases.

REVIEW: The mathematics in this report appears to be quite correct. One appendix contains a long-drawn-out proof of the theorem asserted in the first sentence of the abstract above. The early cautions regarding behavior which is only approximately Normal were disregarded later when calculations were made. The introduction of the Poisson distribution early in the text is pointless. The discussion of the mortality curve mixes failure rates and hazard rates.

The useful essence of the article is contained in the abstract above. ##

Serial Number 2443
ASQC Codes 823;844

TITLE: Accelerated life tests of items with many modes of failure

AUTHOR: W. R. Allen (Statistical Techniques Research Group, Section of Mathematical Statistics, Department of Mathematics, Princeton University, Princeton, N. J.)

SOURCE: Technical Report No. 44, Statistical Techniques Research Group, Section of Mathematical Statistics, Department of Mathematics, Princeton University, Princeton, N. J., Contract No. DA-034-ORD-2297, Feb 62, 22p, 7 refs.

PURPOSE: To present a formal language for discussing accelerated life tests.

ABSTRACT: This paper uses the formal probability language to define absorption processes, accelerated life tests, and accelerated processes. Two formal models of failure probability are given in terms of the hazard functions of several competing failure processes. Irreversible and tree processes are defined as formal descriptions of failure behavior. The problems in accelerated testing, especially the pitfalls of non-equal acceleration of different failure modes, are briefly analyzed.

REVIEW: This paper is directed toward the mathematical analyst rather than to the design engineer. The formal concepts are adequately defined and should prove of use in developing further models. Little is done with the concepts in this paper. ##

Serial Number 2444
ASQC Code 844

TITLE: A theoretical technique for predicting the reliability of solenoid valves

AUTHORS: G. M. Eisenlohr and W. J. Willoughby (ARINC Research Corporation, 1700 K Street, N.W., Washington 6, D. C.)

SOURCE: Publication No. 173-4-278, Special Report prepared by ARINC Research Corporation for Advanced Research Projects Agency under Contract SD-77, Jan 62, 36p

PURPOSE: To describe an analysis of the reliability of the seat-poppet in a typical solenoid valve.

ABSTRACT: A simple non-pilot solenoid valve is modeled for reliability. The analysis is approximate. A simple system of magnetic force, spring force, poppet and seat is used. Elastic behavior is assumed for the metal in the poppet and seat. The main source of failure is considered to be a failure of the poppet and seat to seal properly and that this will happen because of metal fatigue. Energy considerations are used to estimate the maximum stress in the mating parts and the material S-N fatigue curves are used to estimate the life.

REVIEW: This is a "quick and dirty" analysis and unfortunately all the assumptions are not spelled out. It probably would have been more instructive if they were--especially as a help to a more complicated and exact model. The amount of scatter assumed in the fatigue curve is rather small, since a factor of 10 to 100 in life can exist for similar specimens at the same stress. Misalignment is not considered, nor is cold welding in the space environment. The exponential failure behavior assumed for the coil and spring is reasonable, although the actual failure rates are subject to wide variation depending on construction. ##

Serial Number 2445
ASQC Codes 814;872

TITLE: Study of maintenance cost optimization and reliability of shipboard machinery

AUTHORS: Igor Bazovsky, Neil R. MacFarlane, and Robert L. Wunderman (United Control Corporation, Seattle, Wash.)

SOURCE: Report prepared by United Control Corporation, Seattle, Wash. for Department of the Navy, Office of Naval Research, Contract No. Nonr-37400(00)(FBM), Washington, D. C., Jun 62, 158p, 23 refs.

PURPOSE: To report the results of a study on the development of equations to optimize predetermined parameters related to maintenance.

ABSTRACT: Mathematical models and equations are presented which interrelate reliability, maintenance, and costs. The presentation form is such that the models and equations can be used in practical situations. The philosophy applied is such that similar models and equations for specific situations different from those discussed can be constructed. A detailed description is given of the information required to conduct numerical studies. Three main feed pumps were used for sample analysis. Field investigations were conducted at BuShips, manufacturers' plants, shipyards, and in the fleet. Each source is then evaluated as to content, accuracy, and degree of coverage. Types of data included are operating conditions, failure mode analyses, failure frequency estimates, costs, and estimates of maintenance times. Numerical examples show how the collected data were processed to obtain specific answers. It was found that reliability techniques can be meaningfully applied in optimizing the operation of naval machinery when clearly defined objectives are set. However, the lack of information and data precludes the general application of the techniques proposed here, since the required parameters are generally lacking and can be obtained only by extensive field work. (Authors in part)

REVIEW: This study predates by several years the current emphasis on cost-effectiveness. Some features which enhance it are that it is mechanically oriented whereas so much similar work is on electronics, and that it was actually carried to the point of field applications. It is about one-half theory and models, and one-half data topics. Those interested in cost-effectiveness, particularly from the naval shipboard viewpoint, will want to see this report. ##

Serial Number 2446
ASQC Code 838

TITLE: Failsafe circuits

AUTHOR: John Hill (University of Illinois, Graduate College, Digital Computer Laboratory)

SOURCE: Report No. 120, University of Illinois, Graduate College, Digital Computer Laboratory, supported in part by the Office of Naval Research under Contract Nonr-1834(15), 22 Jun 62, 34p

PURPOSE: To describe and analyze a particular kind of redundancy for AC coupled logic circuits.

ABSTRACT: If a logic element is AC coupled, with positive and negative pulses for 0 and 1, it can be made redundant, component by component, so that failure of any one component will not cause failure of the element. These elements can be combined into complex logic circuits and still maintain the ability to operate with one failed component in each element. The mean life of the circuit is not much improved, but the failure rate in early life is much reduced. If the circuits can be repaired at reasonable intervals, the reliability can be much improved over a long period. Failure indicators are provided which operate from DC bias levels.

REVIEW: The title is somewhat misleading; it does not refer to the safety of the system when the system fails. In fact, the system per se does not "fail safe." How practical the system would be is not known, although the author does analyze the increased complexity to some extent. For example, circuits designed with wide tolerance allowances tend to dissipate more heat, weigh more, have less output capability, etc. In the analysis, inspection and repair is implicitly assumed to be perfect. ##

Serial Number 2447
ASQC Codes 711;712;837;
844

TITLE: Statistical evaluation of a limited number of fatigue test specimens including a factor of safety approach

AUTHOR: Carl O. Albrecht (The Boeing Company, Vertol Div., Morton, Pa.)

SOURCE: Presented at the Fourth Pacific Area National Meeting of the American Society for Testing and Materials (1916 Race Street, Philadelphia 3, Pa.), Los Angeles, Calif., Oct 62, 38p, 37 refs.

PURPOSE: To show how to design structures for a given probability of failure in fatigue.

ABSTRACT: If the probability distribution function (pdf) is known for the failure stress at a given number of cycles, if the standard deviation (σ) is known, and if the mean is known from a few tests, the safe working stress can be predicted for a certain confidence level. Generally, the endurance limit rather than a fixed life is estimated. Equations for both a Normal and log-Normal pdf are given. Tables and charts are shown for ease in calculations. Some estimates of σ are given for common materials.

REVIEW: The basic approach described in this paper is common enough and has much to recommend it over older and less sophisticated methods. But it has some difficulties of its own, and many of these are not easily solved. Some are conceptual in nature and need not bother the working engineer, especially since he will use much "engineering judgment" anyway. Some of the notation in the paper is confused, which makes the derivations rather hard to follow. The results were therefore not adequately checked. Lip service is paid to the problems of estimating σ from the data, but no estimates of required sample number are given; this number may be very large. At 0.01% probability of failure, even if the distribution is known to be exactly (log) Normal, the "Student's" correction for finite degrees of freedom is appreciable. For a sample of four compared to an infinitely large sample the ratio of probability factors (denoted by a's in the paper) is about 6:1; for a sample of seven, the ratio of a's is down to about 2:1. But in truth, the ignorance of the exact shape of the pdf in the tail region is more severe than the paper implies (a few words of caution notwithstanding). For example, the sample curves pretending to illustrate Normal and log-Normal behavior would, in fact, probably not pass a statistical test for either. Safety margins are an excellent idea, but calculating very low probabilities of failure associated therewith is at best an exercise in futility.

(The author also implies on p. 11 that the confidence level remains the same when reliabilities estimated from sample data are used to calculate a system reliability; it may not. Furthermore, the formula used for combining probabilities of failure implies statistical independence of the failure events which is quite unlikely to be the case.) ##

Serial Number 2448
ASQC Code 844

TITLE: Prediction of field reliability for airborne electronic systems

AUTHORS: H. Balaban and A. Drummond (ARINC Research Corporation, 1700 K Street, N.W., Washington 6, D. C., now located at the Annapolis Science Center, Annapolis, Md.)

SOURCE: ARINC Research Corporation Publication No. 203-1-344, prepared under Contract No. AF 33(657)-7382 by ARINC Research Corporation, 1700 K Street, N.W., Washington 6, D. C., 31 Dec 62, 74p

PURPOSE: To show how to predict the field reliability of average airborne equipment.

ABSTRACT: The usual exponential assumption is made for components, but the failure rates are those actually experienced in service in aircraft, rather than in laboratory life tests. The major effort of the study was the reliability analysis of over 200 million avionic part operating hours. Attention is called to the difference between a complaint and a malfunction, and to the possibility of inadequate maintenance. Tables, charts, and formulas are provided for estimating failure rates. If the operating conditions are average, no correction need be made for them. Methods for redundant systems are illustrated. The basic set of failure rates is used to predict the system malfunction rate which is then modified by factors relating to maintenance efficiency to yield an estimate of the probability of no in-flight complaint through an equation based on an assumption of a steady state condition.

REVIEW: The report presumably represents one of the first comprehensive approaches for quantitatively assessing the relative accuracy of a reliability prediction. This is a "quick and dirty" method of reliability estimation with all the good and bad properties implied by the name. However, if all the options are exercised, it is not very "quick" and somewhat less "dirty." Many of the points are quite pertinent, although care should be used not to split hairs about the results. Anyone who expects them to be good to 10% or so is bound to be misled; uncertainty of a factor of two or so in overall failure rate is probably minimum, especially if the design is at all unconventional. This uncertainty arises not only because of random errors in the estimates but also from very real biases inherent in any such method, no matter how sophisticated. ##

Serial Number 2449 -1
ASQC Code 844

TITLE: Failure rates and failure modes of small rotary electrical devices

AUTHORS: William H. von Alven, J. M. Evans, and W. B. Reese (ARINC Research Corporation, 1700 K Street, N.W., Washington 6, D. C.)

SOURCE: ARINC Research Corporation Publication No. 160-2-269R, a special report prepared for Aeronautical Systems Division, Wright-Patterson Air Force Base, O., under Contract AF 33(600)-42462 with Air Materiel Command, Aeronautical Systems Center, United States Air Force, Nov 61, 46p

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TITLE: Failure rates and failure modes of airborne rotary devices, relays, and other electrical parts

AUTHOR: J. M. Evans (ARINC Research Corporation, 1700 K Street, N.W., Washington 6, D. C.)

SOURCE: ARINC Research Corporation Publication No. 204-1-336, a special report prepared for Air Force Systems Command, Aeronautical Systems Division, United States Air Force, under Contract AF 33(657)-7382, 31 Dec 62, 97p

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PURPOSE: To present and discuss the failure behavior of electrical parts.

ABSTRACT: Part of the first report is included in the second. Failure rates and failure-mode distributions were determined for the following electrical parts employed in airborne equipments: small rotary devices (AC, DC, and servo motors; motor generators; resolvers; synchro transmitters; differential generators; transformers, and repeaters), relays, electrical connectors (plugs and jacks), frequency-control crystals, and diodes and transistor semiconductors. The failure rates varied widely within the same systems for different types of rotary devices. Variations in failure rate were also found among different systems for the same rotary device, relay, diode, or transistor. Specific applications having a high incidence of failure are noted along with suggested causes of failure. In airborne equipments, the average failure rates for AC motors, servo motors, motor generators, synchro transmitters and repeaters are not significantly different, averaging 80 x 10^{-6} failures per hour. In shipboard (or ground) equipments, the average failure rates for AC motors and synchros are lower than those of airborne equipments. The difference between these average rates is presumed to be caused by the more severe environments of airborne equipments, by the emphasis on high performance for weight and space requirements in the design of such equipments, and by specific problems peculiar to obtaining accuracy under the fluid conditions of high-speed and high-altitude flight.

A large proportion of airborne systems will have at least one outstanding problem which seriously limits the reliability of the system, and this problem should be corrected.

The dominant failure mode was mechanical for AC, DC, and servo motors, synchro transmitters, and differential generators. Electrical failures were the dominant failure mode for motor generators, resolvers, synchro transformers, and repeaters. Open and shorted windings plus tolerance and calibration difficulties due to changes in winding resistance created by relatively high ambient temperatures over long periods of time are among the problems. However, on laboratory examination, many slow-speed devices, which were ostensibly replaced for electrical deficiencies, yielded bearings displaying evidence of dryness, corrosion, and wear. (Authors in part)

REVIEW: The discussion of the reasons for failure is very informative. Even though the reports are several years old, many of these problems still exist. The analysis generally does as much with the data as possible without going overboard on reading into them patterns which are not really there. Designers would do well to read these reports--they are not really very long--and take them to heart. ##

Serial Number 2450
ASQC Codes 711;712;837;
844

TITLE: The application of reliability concepts to fatigue loaded helicopter structures

AUTHOR: Harry T. Jensen (Sikorsky Aircraft, Div. of United Aircraft Corp., Stratford, Conn.); Appendix by Carl E. Nord (Sikorsky Aircraft, Div. of United Aircraft Corp., Stratford, Conn.)

SOURCE: Presented at American Helicopter Society 18th Annual Forum, Washington, D. C., 3 May 62, 26p

PURPOSE: To introduce probabilistic concepts into fatigue of helicopter structures.

ABSTRACT: The concept of an absolute safe life is unfounded since part and environment characteristics are not known that well. The usual fatigue S/N curve is just a median and considerable scatter exists on either side. When the variability in fatigue resistance and environment are recognized, we realize the need for introducing probabilistic concepts in dealing with them. Having applied probabilistic methods, the importance and value of inspection - detection of cracks before failure occurs - becomes evident. Each fatigue failure in the field should be investigated to see what corrective action is necessary and then that action should be taken. The appendix suggests some formulas for describing the S/N curves for materials and components and for the probability function (log-Normal) describing the scatter. It also suggests a method of quantifying the increase in reliability gained by using inspection.

REVIEW: The tone of the paper is good; the only sad part is that it seems to be necessary; it is important to recognize that the occasion of fatigue failure cannot be predicted very accurately. The references and figures are all missing in the STAR copy of the document, which handicaps understanding. However, complete copies are available from the author.

The appendix is generally satisfactory although the use of one formula in preference to another is rather arbitrary. Some of the reasons for opposing the Weibull distribution are not legitimate, and, in fact, many people use it. (There is an inaccuracy in the reason for a probability statement, but the answer is correct.)

With no adverse reflections on the present paper, it should be emphasized that even when a lot of data are accumulated from field experience, the calculation of failure probabilities below 1% or so is at best a futile effort. Appropriate safety margins are essential, but a failure probability usually is not known. ##

Serial Number 2451
ASQC Codes 711;712;844

TITLE: Some statistical aspects of fatigue life variation

AUTHORS: D. G. Ford, D. G. Graff and A. O. Payne (Department of Supply, Australian Defence Scientific Service, Aeronautical Research Laboratories)

SOURCE: Structures and Materials Technical Memorandum 105, Department of Supply, Australian Defence Scientific Service, Aeronautical Research Laboratories, Jul 61, 48p (also "Fatigue of Aircraft Structures," Pergamon Press, 1963, p. 179-208)

PURPOSE: To give examples of the variation in fatigue life.

ABSTRACT: The log-Normal distribution of life is presumed to be reasonably accurate in the finite life range down to failure probabilities of 1%. If the standard deviation (σ) is known, failure probabilities vs. expected life can be calculated. Notched specimens and manufactured components seem to have the same σ which is lower than σ for smooth specimens. Spectrum loading will modify the σ to some extent.

REVIEW: The basic assertion, that σ is independent of mean life (μ) and is therefore a constant is belied by the data. The average σ may be independent of μ, but the actual standard deviation of samples varies from the average σ by 3:1 or more. It is also asserted that the log-Normal distribution inherently has σ/μ independent of μ. Not only is this not generally true, it contradicts the earlier assertion that σ is independent of μ. This is not to say, however, that some types of structures may not have a constant σ/μ. The cautions about calculating failure probabilities below 1% by extrapolating the log-Normal are well taken. In fact, below 10% they are highly uncertain.
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Serial Number 2452
ASQC Codes 711;714;716;
844

TITLE: Study of failure mechanisms

AUTHORS: S. M. Skinner and J. W. Dzimianski (Westinghouse Electric Corp., Air Arm Div., Baltimore, Md.)

SOURCE: Technical Documentary Report No. RADC-TDR-63-30, Rome Air Development Center, Research and Technology Div., AFSC, USAF, Griffiss Air Force Base, N. Y., Final Report prepared under Contract No. AF 30(602)2558 by Westinghouse Electric Corporation, Air Arm Div., Baltimore, Md., Dec 62, 282p, 38 refs.

PURPOSE: To summarize the diverse investigations of a broad physics of failure program.

ABSTRACT: Transistors may fail in use through: electrostatic charging of the passivating layer during manufacture or use; the effects of steep pulses of a magnitude less than overload; frictional effects of loose desiccant or other material within the case; major pressure changes resulting from environmental change or acceleration. High voltage turn-on pulsing, excessive power dissipation in the collector breakdown region, and continuous operation in the reverse breakdown region of the emitter-base junction appear to be the most severe stresses.

Even with careful processing, contiguous regions of solid state devices may be covered by quite different chemical compounds or be in quite different energy states. Routine and accepted processing techniques such as scribing, grinding, or bimetallic connection welding or attachment can create stresses sufficient to cause cracks. The effects of errors in processing procedures, and the presence of either chemical or structural defects in the material or device can be pictured precisely by the "electrical-frictional probe." Thin films passing over sharp edges of steps crack and separate primarily because of lack of adhesion, and secondarily because of any stresses maximizing at the edge of the step.

The result from the Mossbauer studies of high energy electron irradiation of ferrites confirms magnetic measurements that the total irradiation used (up to 10^{11} rads) produces little measurable change in the composition or chemical structure of the materials studied. The capacitance of silicon diodes increases significantly with the increase of high energy irradiation, for high resistivity base material, and remains approximately constant for low resistivity base material.

REVIEW: This document is a detailed description of the work previously presented at the 1962 Physics of Failure Symposium (see RATR 1342). The scope is more extensive in that several topics not reported then (such as the theoretical study of transient effects in semiconductors and the study of high-energy radiation effects in ferrites by use of the Mossbauer effect) are included in this report. By and large, however, the major import of the work has been captured in the Symposium presentation and this final report is of interest primarily to the reader who desires to follow the experiments in greater detail. ##

Serial Number 2453
ASQC Code 822

TITLE: The cumulative hazard rate in reliability studies

AUTHOR: Robert Blackburn Rutledge

SOURCE: Dissertation presented to the Faculty of the Graduate School of Saint Louis University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1962, 100p, 13 refs. (Xerographic copies may be purchased from University Microfilms, Inc., Ann Arbor, Mich., order no. 64-3766)

PURPOSE: To introduce the cumulative hazard rate and show its usefulness in reliability studies.

ABSTRACT: This dissertation generalizes the definition of the cumulative hazard rate given by earlier authors and uses the cumulative hazard rate to investigate the reliability of systems. The relationship of the cumulative hazard rate to the corresponding probability distribution permits many properties of distribution functions to be expressed more conveniently. A pair of operators is defined on the set of all distribution functions and the algebraic properties of the system are developed. A reliability model with two modes of failure is introduced and an analysis is made of series and parallel redundant systems of such components. Under certain conditions it is shown that an optimal number of such components exists. Some discussion is given of the generalized Poisson process.

REVIEW: It is not quite clear to whom this paper is directed, as the mathematician or mathematical statistician will find many errors and may very likely put the paper aside before finishing it. On the other hand, the engineer or practicing statistician may have a difficult time separating out the useful parts of the theory.

In a paper of this nature the errors in mathematics are most disturbing. For example the definition of a cumulative distribution function $F(x)$ is not complete. The condition that $F(x)$ be continuous from the right is omitted. A similar omission is made in defining the cumulative hazard rate. The meaning of $F(\infty)$ is not defined. If the usual interpretation is meant, then the "zero distribution function" introduced on page 19 is not a distribution function. Similarly the "unit distribution function" (page 20) is not continuous from the right. The implicit assumption that we are dealing with non-negative random variables, i.e. lifetimes, could better be stated as $F(0-) = 0$. Statements such as "all probability functions in this paper are assumed to be independently distributed" and "given a set of identically distributed and redundant components" should be completely reworded. The section on inverted distribution functions is superfluous since every distribution function is an inverted one and every cumulative hazard rate is an inverted one. "The mean for the inverted exponential is not easily calculated" since it does not exist. In fact the mean for the inverted Weibull distribution is $a^{-1/b}\Gamma[1-(1/b)]$ which is finite for $b > 1$. While most of the errors are easily corrected, their presence, along with many trivial details in the proofs of theorems, makes it very difficult to extract the results from the paper. ##

Serial Number 2454
ASQC Code 840

TITLE: An experience report: Step stress testing to failure for reliability analysis of electronic equipment

AUTHORS: J. J. Bussolini, M. J. Ciarlariello (Grumman Aircraft Engineering Corp., Bethpage, N. Y.)

SOURCE: Grumman Aircraft Engineering Corp., 17 Dec 63, 12p

PURPOSE: To discuss some accelerated tests.

ABSTRACT: Since proving high reliability by conventional means is virtually impossible, accelerated tests must be used. Different failure modes should be accounted for separately if a Weibull analysis is to be fruitful. The failure mechanisms to be considered have the "wear out" behavior. The situation should be investigated.

REVIEW: The authors' abstract given in the report is misleading since the report is a loose qualitative discussion of some points in connection with testing. No quantitative theory or experimental results are given. The grammar is poor which makes the report hard to read. The program itself may have been of value, but it does not show through in this report, except as noted in the ABSTRACT above. ##

Serial Number 2455
ASQC Codes 872;882

TITLE: The operational readiness of a system subject to a mixed maintenance policy

AUTHOR: N. Kaufman (Space Technology Laboratories, Inc., One Space Park, Redondo Beach, Calif.)

SOURCE: Report 6101-8131-TU-000, BSD-TDR-63-140 prepared for HQ Ballistic Systems Division, Air Force Systems Command, USAF under Contract AF 04(694)-3 by Space Technology Laboratories, Inc., Redondo Beach, Calif., 12 Jul 63, 17p, 6 refs.

PURPOSE: To present a model to analyze the availability behavior of a system which, upon repair, is replaced as a unit, but which is monitored partly continuously and partly periodically.

ABSTRACT: The relationship of the various parts of the system represented by the model and the assumptions of the model are described. A three-box system is considered; it is repaired as a unit, but a box is monitored either continuously, periodically, or not at all. An example of such a system is the Atlas inertial guidance system. Symbols are defined, and the formula for the availability is given. A discussion of the data requirements necessary to estimate the parameters of the model is presented. Some of the parameters will present no problem, some can be obtained from a chronological history, and some require that nominal operational maintenance policies must be varied. If the model is valid it should be useful for determining best periodic checkout intervals and for estimating the effect of proposed hardware changes. (Author in part)

REVIEW: This report is largely a presentation of results, and further details are apparently contained in the references which are mainly company reports. The material is applications-oriented and its concise presentation allows it to be read quickly with a feeling that the essentials are being conveyed. The model is a rather formidable-looking equation containing 14 basic probability parameters. It would be interesting to learn of further results with respect to its validity and usefulness. ##

Serial Number 2456
ASQC Codes 431;821

TITLE: Signal flow theory applied to probability and reliability problems

AUTHOR: R. F. Hynes (Raytheon Co., Wayland, Mass.)

SOURCE: Report RFH-5, Raytheon Co., Wayland, Mass., 21 Feb 63, 8p

PURPOSE: To show how signal flow theory may be used in reliability problems.

ABSTRACT: This report is a brief introduction to the use of signal flow theory as applied to probability and reliability problems. Previously, signal flow theory has been used mainly in the analysis and synthesis of electro-mechanical control devices--especially in the design of servomechanisms. In recent years, however, this theory has been extended to many diverse areas, including reliability, where the control aspects of the process are not apparent. Herein two examples are presented, one for a discrete-time Markov process and the other for a continuous-time Markov process, to clarify the definitions used and to serve as a guide in the solution of similar problems. (Author in part)

REVIEW: This report is of the "cookbook" variety in that it gives a set of "rules" for calculating certain probability generating functions (discrete-time case) or the Laplace transform of the time to failure density function (continuous-time case) when the basic process is of the Markov type with a finite number of possible states. The rules are clearly written and should be of help in evaluating systems of this type if the number of states and number of possible transitions are not too large. Two good examples are given to illustrate the use of the rules. ##

Serial Number 2457
ASQC Code 872

TITLE: Validating maintenance policies and estimating launch capability for ballistic missiles

AUTHOR: Milton Kamins (The RAND Corporation, Santa Monica, Calif.)

SOURCE: Memorandum RM-3645-PR (abridged), prepared for USAF Project RAND, The RAND Corporation, Santa Monica, Calif., Jul 63, 29p

PURPOSE: To present a methodology for determining the frequency of scheduled maintenance on large missiles which spend long periods in an inert condition and where defects can only be found by a test.

ABSTRACT: Since large, complex missiles are normally inert, critical defects may remain hidden for inacceptably long periods of time unless appropriate means for identifying them are developed and applied. Determination of the best test interval is a tradeoff between exercising too frequently, with the consequences of time off alert and of repair time for failures caused by the exercise, and exercising too infrequently to catch the undiscovered failures. Generation of the data which can be used with previously developed techniques is of principal concern in this report. The four required inputs are: (1) failure rate while standing, (2) the probability that a test will trigger a failure, (3) test time, and (4) repair time. The first two inputs are reliability parameters and are ordinarily observed together with no practical way of separating them unless one runs a statistical experiment to do so. An approach to this experiment is presented which is based on back-to-back tests. Simulation of the back-to-back tests was used to assist in planning the tests. The simulation also resulted in a by-product of a confidence map which is associated with the lift-off capability. An appendix illustrates a specific procedural approach of the principles which are presented in this report. (Author in part)

REVIEW: As this is an abridgment of a report containing classified data, not all detail is presented. Rather, it is mainly a discussion of the approaches in uncomplicated terms. Not too much is presented on developing the model, which was done on pp. 238-243 of the book referenced in RATR 2312. Several points about this work are worth noting. One is that models which are widely presented in the popular literature are often not directly applicable to the situation at hand, but rather a model must be developed. Here the thought is about the many times in the literature that formulas are seen for availability as a function of failure and repair rate only, but which are not applicable to this practical situation. Another is recognition that some field experimenting or sampling is required to obtain data for accurately estimating parameters on even relatively simple models. ##

Serial Number 2458
ASQC Codes 802;830

TITLE: Bureau of Ships Reliability Design Handbook

AUTHORS: Staff members of the Equipment and Systems Evaluation Department, Engineering Division, Federal Electric Corporation, Paramus Industrial Park, Paramus, N. J.

SOURCE: NAVSHIPS 94501, prepared for Fleet Electronics Effectiveness Branch, Bureau of Ships, Department of the Navy by Equipment and Systems Evaluation Department, Engineering Division, Federal Electric Corporation, Paramus Industrial Park, Paramus, N. J., under Contract NObsr 87433, 29 Mar 63, 591p, 82 refs. (for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20302)

PURPOSE: To provide the design engineer with information and guidance that will help him engineer reliability into an equipment during its basic design stage.

ABSTRACT: Quantitative evaluation determines design progress toward reliability goals and design objectives. The quantitative evaluation techniques which are presented include reliability prediction, thermal design and evaluation, and tolerance evaluation. Reliability prediction must be applied during the design stage to insure that contractual requirements are met, and thermal and tolerance evaluations point the way to potential trouble spots. Several design techniques which will lead to more reliable designs include guidelines for derating, the application of redundancy, network synthesis procedures, and minimizing radio-frequency interference. Reliability information is presented for selected electronic parts and special designs, such as semiconductors, encapsulation, printed wiring, microelectronics, and tubes. Often equipment reliability is affected by activities outside those of the designer. The handbook covers information on such topics, including shock and vibration, reliability programs, parts testing, and human factors.

REVIEW: An electronic design viewpoint mainly at the circuit level is emphasized in this handbook. Much of the orientation is in terms of why failures occur and how to reduce them. However, for some of the material--such as that for network synthesis and for displays--the tie-in to reliability is not very strong. The brief treatment of the fringe areas such as reliability prediction or programs is appropriate for the circuit reliability viewpoint, particularly since other reliability handbooks dwell on these topics. An elementary viewpoint is maintained throughout. As with most handbooks, this one is primarily a handy reference for experienced designers, and will convey fresh information mainly to newcomers who are designing circuits with an explicit reliability emphasis.
##

Serial Number 2459
ASQC Codes 711;712;833;
844

TITLE: Applying new gear strength and durability formulas to design

AUTHOR: E. J. Wellauer (The Falk Corporation, Milwaukee, Wis.)

SOURCE: Presented at the ASME Design Engineering Conference, Chicago, Ill., 11-14 May 64, 16p, 17 refs., Paper No. 64-MD-34 (The American Society of Mechanical Engineers, 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To discuss the derivation, development, and design application of new gear strength and rating formulas.

ABSTRACT: A ten-year project by the American Gear Manufacturers Association (AGMA) has resulted in the development of new rating procedures which take advantage of modern knowledge and technology. Theoretical formulas have been derived which are modified by factors and coefficients to fit operating conditions. The new rating methods correlate all sizes and applications of spur, helical, herringbone, and bevel gears. The revision and additions to older methods have resulted from: (1) more accurate analysis of gear tooth strength, (2) evaluation of factors and coefficients to modify theoretical formulas, (3) practical methods for computing the effect of load distribution across the tooth face, (4) the consideration of dynamic effects, (5) means of correlating loads with fatigue life, (6) reliable information on the load carrying capacity for various metals and heat treatments, and (7) the use of statistics.

The difference between actual, estimated, and rated capacity is defined. A gear rating system is used to evaluate differences in life due to mounting, material quality, and variations in speed and load. This rating system is based on separate master information sheets for strength and durability. These sheets provide the basic formulas and modifying factors and allow the designer to translate his experience from one type of gear design to another. Gear rating standards and design practices are developed from the master information sheet for spur, helical, herringbone and bevel gears.

The AGMA rating formulas for both strength and durability are shown. Also listed are the factors used for rating gears. The effect of non-uniform load distribution, dynamic load effects, finite life and statistical reliability are also discussed.

REVIEW: The paper definitely serves its purpose in reporting the manner in which the latest developments in technology are used to establish new gear ratings. It is well written and adequately documented, and should be of great value to those engaged in gear application.

For other papers pertaining to gear life and gear strength, see RATR 829,2460, and 2462. ##

Serial Number 2460 -1
ASQC Codes 711;712;844

TITLE: Results of a fifteen-year program of flexural fatigue testing of gear teeth

AUTHORS: John B. Seabrook and Darle W. Dudley (General Electric Co., Lynn, Mass.)

SOURCE: Transactions of the ASME, Series B, Journal of Engineering for Industry, vol. 86, Aug 64, p. 221-239, 7 refs., Paper No. 63-WA-199

PURPOSE: To describe a test program designed to measure gear-tooth flexural fatigue strength as a function of tooth shape and material.

ABSTRACT: A continuous program has been in operation since 1946 to fatigue test gear teeth for the effect of materials, tooth designs, and number of teeth. Also explored was the effect of such variables as case depth, cleanliness of steel, and shot peening.

Since only tooth shapes and materials and their treatments were evaluated, the damaging effects of misalignment and dynamic overload were avoided by making nonrotating gear tests on a Sonntag universal fatigue testing machine which permitted accurately measurable loads and alignment. The results are given in terms of unit load which is defined as the load in pounds per inch of face on a tooth of one diametral pitch in the normal plane.

Unit load can be related to root stress by means of gear tooth stress formulae. Unit loads are referred to the "worst position" which is the highest point of single tooth contact. The test results are listed in tabular form which shows the type of fatigue test (standard or staircase); treatment, hardness values, and fatigue limit in terms of unit load for 10% and 50% failure probability. These results are further condensed in a table which gives the fatigue-limit values for optimum materials, treatments and manufacture.

In general it was found that (1) dirty or defective material, poor heat treatment, and poor machining can reduce fatigue strength values considerably; (2) the highest fatigue strengths were obtained with case and core processes of heat treatment; (3) nitrided and carburized teeth have the greatest strength, next was induction hardened teeth, and furnace hardened teeth were last; (4) chemical composition except as it affects case or core hardness has little effect; (5) shot peening is significantly beneficial in all cases except when applied to a nitrided steel surface; (6) nitriding was associated with the strongest teeth attained at both room and elevated temperatures; (7) decarburization results in a strength reduction of as much as 40% of that expected without it. Tempering served to increase the life of decarburized teeth. This may have been the result of relieving detrimental residual stress that is associated with this condition.

The original premise was that nonrotating gear test results could be correlated with results from actual running tests. Running test unit load values were found to be equivalent to about 77% of those for the nonrotating fatigue tests. Comparison of the results from the fatigue tests with design practice shows that

design loads are somewhat lower, 1/5 to 1/2 the loads at which 10% failure was obtained in the fatigue tests.

REVIEW: Because of the large number and types of specimens tested, this paper should unqualifiedly be listed as one of tremendous value to the gear industry. One cannot disagree that such tests are better than theoretical opinions because of the complexities and interactions that exist as a result of the many variables. As to whether or not nonrotating tests can be used as a criterion for design does not seem to be as significant as the importance of the data obtained in allowing comparisons between materials, heat treatments, and tooth shapes. There can be no doubt that the paper is also of great value to those engaged in other fields to which the results have pertinence.

For other papers pertaining to gear life and gear strength, see RATR 829, 2459, and 2462. ##

Serial Number 2461 -1
ASQC Codes 711;712;844

TITLE: A set of fatigue failure criteria

AUTHOR: H. O. Fuchs (University of California, Los Angeles, Calif.)

SOURCE: Presented at the AWS-ASME Metals Engineering Conference, Detroit, Mich., 4-8 May 64, 10p, 77 refs., Paper No. 64-Met-1

PURPOSE: To show that a set of three criteria can explain and predict fatigue phenomena more correctly than any one or combination of two of the three criteria discussed.

ABSTRACT: The use of three separate criteria can be used to predict the endurance behavior of structures by taking into account the variation in notch sensitivity with mean stress, the existence of cracks which do not propagate or propagate slowly, and the dependence of cumulative fatigue on mean stress and stress sequence. The criteria are:

1. The alternating local shear stress modified by the mean local stress modified by the mean local normal stress for crack nucleation.
2. The alternating nominal tensile stress for crack propagation.
3. The maximum nominal shear stress for yielding.

The following four constants of the material are considered for this type of analysis: (1) the reversed bending fatigue limit, (2) the coefficient of mean stress influence, (3) the critical alternating stress, and (4) the static yield strength. The three criteria are reviewed separately.

The first of these is the Crack Nucleation Criterion. This is based on the alternating octahedral shear stress and modified by the mean octahedral stress. For smooth specimens, crack nucleation will not occur if

$$\tau < 0.5\ (S_E - 0.5\ \sigma) \qquad (1)$$

where τ = alternating octahedral shear stress
S_E = endurance limit, and
σ = normal steady octahedral stress

For notched specimens, τ in (1) is modified by the fatigue notch factor K so that

$$K\ \tau < 0.5\ (S_E - 0.5\ \sigma) \qquad (2)$$

The second criterion discussed is Crack Propagation and is concerned with the amount of alternating stress necessary to propagate a fatigue crack and with correlating the rate of crack growth with the amount of stress. The alternating tensile stress must be less than some critical stress; some values for this critical stress are 10 ksi for hard steel, 4 ksi for mild steel, and 3 ksi for high strength aluminum.

The third and last criterion is Yield which is important for two reasons: (a) it may mean failure even though fracture does not occur (for example sagging springs due to yielding), and (b) the effect of yielding on beneficial residual stresses. Here one can

use for a first approximation:

$$\tau_{max} < 0.5\ S_y$$

where τ = shear stress
S_y = yield stress

These three criteria can be combined graphically so that an area of allowable stress is established.

In an example, the three criteria are applied to a rotating bending test on a notched shot-peened part. Test results showed good correlation with smooth polished parts subject to the same loads as predicted by the application of the three criteria which took into account residual stresses and stress concentrations. Also illustrated in the paper is the application of the criteria to biaxial states of stress.

REVIEW: This paper requires a knowledge of fatigue nomenclature and types of stresses to fully appreciate its value. If one is familiar with the Goodman or Gerber diagram, the paper will shed light on the probable explanation for the variation in life that results from changes in mean and alternating stress which have been related by the three criteria discussed in the paper. The author has done a creditable analysis which deserves considerable attention.

The treatment apparently deals with median life; no effort is made to extend it to low probabilities of failure. Such an extension would be worthwhile. ##

Serial Number 2462
ASQC Codes 711;712

TITLE: Predicting the life of gears, shafts and bearings--a systems approach

AUTHOR: E. J. Wellauer (The Falk Corporation, Milwaukee, Wis.)

SOURCE: Presented at the ASME Design Engineering Conference, New York, N. Y., 17-20 May 65, Paper 65-MD-6, 12p, 9 refs. (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To discuss the prediction of the life of geared systems.

ABSTRACT: Gear tooth failures fall into four general classes: wear, surface fatigue, plastic flow, and breakage. This paper deals specifically with predicting the strength and profile durability of spur and helical gears having involute profiles. Gear tooth strength failure is said to occur when a full tooth or portion of a tooth breaks from the rim. Such a failure may result from high shock loads which bend a tooth and result in excessive stresses due to geometric interference. Gear tooth profile failures are the result of pitting and other types of surface deterioration which may not immediately impair the load transmission. In this case damage is measured by the degree of pitting severity.

The life prediction for both strength and profile failure is based on estimating the stress level and cycles as well as mortality statistics. Life can be predicted without fatigue and mortality tests through the use of AGMA Gear Rating Standards and Design Procedures. The term failure when used in conjunction with AGMA formulas implies a gear life shorter than stated. The allowable bending stresses and surface stresses may be calculated for a desired life with the use of the bending stress and surface stress formula, taking into account geometry, load distribution, dynamics, hardness, overload, surface condition, temperature, life, and safety. Gear teeth that are designed by these equations with stresses below the endurance limit should last indefinitely, if used within the design assumptions. The AGMA basic ratings are adjusted by "service factors," based on type of service application, in order to obtain "service ratings." AGMA Standards and Design Procedures have been based on 30 years of research and field data and should be reliable.

REVIEW: Obviously where fatigue data can be obtained under simulated operating conditions it should be preferred in design work; however in lieu of such data the use of the AGMA Design Procedures outlined appears to offer a satisfactory method for design and predicting the life of gears. This paper is well written and well documented.

For other papers pertaining to gear life and gear strength, see RATR 829, 2459, and 2460. ##

Serial Number 2463
ASQC Codes 711;712;830

TITLE: Designing to prevent fatigue failures

AUTHOR: Lloyd Kaechele (The RAND Corporation, Aero-Astronautics Dept., Santa Monica, Calif.)

SOURCE: Presented at the ASME Design Engineering Conference, New York, N. Y., 17-20 May 65, Paper 65-MD-15, 8p (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017); also AD-611 267; see also Design Abstract in Machine Design, vol. 37, 22 Jul 65, p. 188, 190, 193

PURPOSE: To present ideas for use in designing to prevent fatigue failure.

ABSTRACT: The prevention of fatigue failure is primarily the responsibility of the designer. Problems that arise during the design stage include: (a) predicting service stresses, (b) evaluating fatigue behavior and cumulative damage, and (c) accounting for scatter. The prediction of service stresses is simplified considerably if similar structures are already in service, since it may be possible to obtain existing stress records. The problem becomes more difficult, however, when dealing with new designs under unpredictable usage. The designer must then obtain stress information as soon as possible after the design has been put into operation, in order to check assumptions, so that the design may be certified or modified as necessary. The possibility of harmful residual stresses, surface defects resulting from manufacturing process, and unexpected corrosive atmospheres should also be taken into account. Load spectrum patterns such as those experienced by an aircraft wing require analysis using cumulative damage theory.

It is shown that when the probability of failure is taken in terms of design weight, antifatigue design is not too different from constant load design work, where scatter in the yield strength is a criterion. The limited number of fatigue tests that are practical necessitates that confidence levels be applied to the results. The assumption of a log-Normal distribution allows the use of a K factor that can be applied to the estimate of the standard deviation which then establishes the confidence level for a specified probability of any specimen's failing before a given number of cycles. The use of a "canonical damage rate" is also outlined for a more simplified handling of the problem of scatter. By using S-N curves with prescribed values of failure probability and confidence levels, along with stress histories of similar existing equipment already in use, a number of cumulative fatigue values (from each stress history) may be obtained for a given life expectancy.

REVIEW: The ideas expressed in this paper offer interesting possibilities if one could obtain adequate stress histories. Perhaps various stress histories could be assumed and the results analyzed in terms of these methods in order to determine their validity. The paper does point out a need for a standardized procedure for making cumulative damage calculations. The problem of predicting stress history prior to usage appears to be insurmountable. Safe methods for making assumptions of stress history are of greater importance than ways of dealing with fatigue scatter. ##

Serial Number 2464
ASQC Code 800

TITLE: Material reliability as related to aircraft accidents

AUTHOR: N. R. Quiel (Commander, USN, U. S. Naval Aviation Safety Center, Naval Air Station, Norfolk, Va.)

SOURCE: Presented at the Sixth Navy-Industry Conference on Material Reliability, Washington, D. C., 31 Oct, 1 Nov 62, 51p

PURPOSE: To relate the effects of aircraft component failures on the Navy.

ABSTRACT: In fiscal 1962, the cost of aircraft accidents was the same as the cost of a Forrestal-class carrier or as 10% of Naval Aviation operating combat potential. The number of pilots killed amounts to almost 10% of the number trained each year. Aircraft failures are caused largely by the failure of components. The same mistakes persist in design, year after year. In two similar cases the oil system sprung a leak due to component fatigue; one was on a new jet fighter, the other over 40 years ago on a Navy NC. It takes too long for fixes to find their way into the field and it is taking too long for reliability to be given equal weight with more traditional measures of performance.

REVIEW: This tends to be more of a case history outline of what is wrong, rather than specific suggestions to remedy particular types of failure. The case history approach makes it more personal and thus perhaps more effective in motivating people to get on the ball and do the job right. While too many papers such as this can easily be published, it is important for designers to read them occasionally and thus to be jolted out of their complacency or whatever it is.
##

Serial Number 2465
ASQC Codes 412;824

800

817

120

TITLE: Approximate confidence limits for the reliability of series and parallel systems

AUTHOR: Albert Madansky (RAND Corporation)

SOURCE: Technometrics, vol. 7, p. 495-503, 6 refs., Nov 65

The text of this paper is essentially the same as that of the report covered by RATR 2235.

TITLE: Warranty analysis: industrial and commercial product reliability

AUTHORS: Paul Gottfried and Ralph L. Madison (Booz-Allen Applied Research Inc., Bethesda, Md.)

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 3, Mar 65, p. 3-8

This paper is identical to the one covered by RATR 2108.

TITLE: A trade-off history for a high reliability program

AUTHOR: W. R. Burkhalter (Electro-Mechanical Research, Inc., Sarasota, Fla.)

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 3, Jun 65, p. 3-14

This paper is identical to the one covered by RATR 2101.

TITLE: Reliability in soldering--not a myth

AUTHOR: Howard H. Manko (Alpha Metals, Inc., Jersey City, N. J.)

SOURCE: Insulation, vol. 12, Jan 66, p. 34-38

This paper is essentially the same as the one covered by RATR 2105.
##

Serial Number 2466
ASQC Codes 711;712

TITLE: Fatigue: a complex subject--some simple approximations

AUTHOR: S. S. Manson (Lewis Research Center, National Aeronautics and Space Administration, Cleveland, O.)

SOURCE: William M. Murray Lecture, presented to the Society for Experimental Stress Analysis, Cleveland, O., 30 Oct 64 (NASA Technical Memorandum X-52084, 1965), 73p, 44 refs.

PURPOSE: To illustrate methods of approximating the fatigue curve based on plastic and elastic strain.

ABSTRACT: Recent experimental tools for the study of crack propagation (photoelastic coatings, phase interference methods, use of polycarbonate resin, electron microscopy, X-ray techniques, and ultrasonic techniques) are described. The paper deals primarily with the concept that cyclic life is related to total strain range, but that the data can best be interpreted when the total strain range is divided into its elastic and plastic components. When this is done, two straight lines result on logarithmic plots of strain range versus cyclic life. The total strain range, which is the sum of the elastic and plastic components is not a straight line but a curve which is asymptotic to the elastic line in the high cyclic life range and to the plastic line in the low cyclic life range. Several methods are discussed for predicting the lines of the elastic and plastic strain ranges from a knowledge of the static tensile properties of the material, and comparisons of predictions with actual tests are presented for 29 materials representing various physical properties including different crystalline structures.

This report extends concepts previously presented by the author relating life to strain range by separating the period of crack initiation from that of crack propagation, and a simple approximate formula is presented relating these periods to total life. Application of the relative proportions of the total life devoted to crack initiation and crack propagation are made to interpret reasons why low cycle fatigue properties do not depend strongly on yield strength and notch sensitivity, but rather on ductility, ultimate tensile strength and elastic modules. Deviations from the linear damage theories (Palmgren and Miner) are also discussed in relation to the question of crack initiation and propagation, and found to be consistent with experimental findings.

An outline is presented of a method developed for estimating the flexure and rotating bending fatigue properties of materials from a knowledge of their axial fatigue characteristics or simple static tensile properties.

The fundamental mechanism of fatigue is outlined briefly.

REVIEW: This paper should be read by everyone interested in the subject of fatigue. It discusses the latest theory and concepts of fatigue failure. The contents and the manner in which the material is presented are consistent with the fact that the author is a leading authority in this field. ##

Serial Number 2467 -1
ASQC Codes 833;844

TITLES: a) Progress report of attainable reliability of integrated circuits for systems application
b) The application of failure analysis in procuring and screening of integrated circuits

AUTHORS: a) Jayne Partridge, L. David Hanley, and Eldon C. Hall (MIT Instrumentation Laboratory, Cambridge 39, Mass.)
b) L. David Hanley, Jayne Partridge, and Eldon C. Hall (MIT Instrumentation Laboratory, Cambridge 39, Mass.)

SOURCE: a) Presented at the Symposium on Microelectronics and Large Systems, cosponsored by ONR and UNIVAC, 17-18 Nov 64, Washington, D. C., Report E-1679, Massachusetts Institute of Technology Instrumentation Laboratory, Nov 64, 40p, 10 refs.
b) Presented at the Physics of Failure in Electronics Symposium, cosponsored by IITRI and RADC, 16 Nov 65, Chicago, Ill., Report E-1838, Massachusetts Institute of Technology Instrumentation Laboratory, Oct 65, 50p

PURPOSE: a) To present an approach for the design of a reliable computer.
b) To discuss in detail the procedures for insuring highly reliable integrated circuits for a computer.

ABSTRACT: A computer can be designed which uses virtually only one type of a simple integrated circuit. In this case, a three-input NOR gate was chosen. This approach allows tremendous concentration on the reliability and performance of just one item. Consequently a great thoroughness is achieved and chances for mistakes in production, inspection, handling, etc. are greatly reduced. The failure modes were exhaustively sought and studied; prequalification tests and screening tests were developed. The result was, for one manufacturer at least, that all potential failures could be removed prior to service with an enormous confidence. This allows a computer to be so reliable that redundancy is unnecessary.

The procedure for the testing, screening, and lot rejection of integrated circuits (for the Apollo Guidance and Navigation computer) is based on a knowledge of failure modes, failure mechanisms and contributing causes of failures in the manufacturing of devices. The generated data are used to assess the lot for acceptance, rework or rejection. The technique is applicable to high-usage devices and was developed after extensive testing of many tens of thousands of integrated circuits. To emphasize the need for the described technique, data are presented which show variations among vendors and among procurement lots shipped from a single vendor. The contributing factors to the variations are discussed. The process documents are included in the appendix; they contain stress test procedures, classification of failure modes, numerical rejection limits per class of failure modes, internal visual rejection criteria and leak test procedures. The ultimate goal of the documents is the elimination of detected failure modes. Failure studies have shown that some failure modes are screenable with high confidence whereas attempts to screen other types of failure modes merely decrease the life of the device. After 100% nondestructive testing, sample destructive testing, failure analysis and failure mode grouping,

the classes of failure modes in a lot are weighted in accordance with screenability and detectability. Failure of a lot to fall within the acceptable limits will instigate action as to whether the lot will be rescreened, resubmitted to tighter acceptable limits, or whether a portion of the lot or the entire lot will be rejected. The decision for lot or sublot rejection is based on the traceability of the nonscreenable failure modes to a critical manufacturing process. The approach presents a continuous monitoring procedure for qualification of parts and vendors, and creates an incentive on the part of the vendor to eliminate causes of failures. (Authors in part)

REVIEW: This approach is not a common one, judging by the literature, and its apparent success makes it command all the more attention. The report is important and any who have responsibility for design of similar equipments ought to be familiar with it. No estimate of overall system cost using this approach as compared to another is given; but the advantages of this one are so great, especially when standardization can be achieved on a broader base, that it should be investigated thoroughly and optimistically. In work as important as this, it is unfortunate that the vendors A,B,C "cannot" be identified.

The second report (b) is a sequel to the first. It presents the philosophy and some of the specifics in more detail. ##

Serial Number 2468
ASQC Codes 431;711;712;
821

TITLE: On upper and lower bounds of the probability of failure of simple structures under random excitation

AUTHOR: M. Shinozuka (Columbia University in the City of New York, Dept. of Civil Engineering and Engineering Mechanics)

SOURCE: Technical Report No. 01, Institute for the Study of Fatigue and Reliability, Department of Civil Engineering and Engineering Mechanics, Columbia University in the City of New York, sponsored by the Office of Naval Research, Air Force Materials Laboratory, and Advanced Research Projects Agency, Dec 63, 17p, 20 refs. (AD-602 528; OTS $2.00)

PURPOSE: To obtain upper and lower bounds on the probability of failure of simple structures under random excitation.

ABSTRACT: Upper and lower bounds are given for the probability $P(T; -\lambda_1, \lambda_2)$ that a random process $x(t)$ crosses barriers at $-\lambda_1$ and λ_2 in the interval (0, T) under zero initial condition $x(0) = 0$.

The displacement of a damped oscillator with one degree of freedom due to a nonstationary Gaussian random input is investigated as an illustration of an analysis that does not require the input to be white noise. If failure of the system is assumed to occur when the absolute value of the displacement exceeds a critical value λ, then $P(\infty; -\lambda, \lambda)$ is the probability of failure of the system. Under certain conditions, approximations for lower and upper bounds of $P(\infty; -\lambda, \lambda)$ are numerically evaluated with the aid of a digital computer. The result shows that the present method estimates $P(\infty; -\lambda, \lambda)$ in a sufficiently narrow interval and over a sufficiently wide range of the probability values as required in reliability analysis.

Applications to air and spacecraft subject to infrequent severe atmospheric turbulence and to structures subject to earthquake accelerations are suggested. (Author in part)

REVIEW: This is a theoretical paper and presumes familiarity with many mathematical concepts not ordinarily in the repertoire of design engineers. From the point of view of the theorist, it is a good paper on the whole and certainly sheds more light on a very difficult problem. It should be pointed out, however, that the work on average numbers of crossings on which the upper bounds are based is valid only under certain assumptions which were not made in the original work referred to in the paper. Fortunately the necessary assumptions are such that they will have negligible effect on applying the present results. A few small errors were noted. On page 4 "initial values" of $P_x(T;-\infty,\lambda)$ and $P_x(T;-\lambda,\infty)$ should be added to the right-hand sides of Equations 8 and 9 respectively. We must also assume that $x(T)$ and $\dot{x}(T)$ are jointly Gaussian. It might be noted here that if $x(T)$ is stationary, then necessarily $\rho = \text{corr}\,[x(T), \dot{x}(T)] = 0$. On page 7, the right side of equation (21) should be multiplied by H(s). ##

Serial Number 2469
ASQC Codes 822;824

TITLE: Two notes on the lognormal distribution

AUTHOR: Milton Kamins (The RAND Corporation, 1700 Main St., Santa Monica, Calif.)

SOURCE: Memorandum RM-3781-PR, prepared for USAF Project RAND, The RAND Corporation, Santa Monica, Calif., Aug 63, 26p, 16 refs.

PURPOSE: To discuss generating lognormal variables and certain properties of the hazard function associated with the lognormal distribution.

ABSTRACT: This report is divided into two distinct parts, the first of which is concerned with the artificial generation of lognormal variables for use in digital computer simulation studies. The method is straightforward in that normal variables are first obtained by "inverting" a uniform variable and then exponentiating the normal variable. A brief discussion is also given for a second method which appeals to the Central Limit Theorem. A simple FORTRAN subroutine for the required calculations and some illustrative examples are given. The second part deals with the hazard function of the lognormal distribution. In particular the maximum of this hazard function is studied. Information is provided concerning the "age" at which the peak occurs, its magnitude, and certain related asymptotic properties. Several graphs are provided in this connection.

REVIEW: The first part of this report is rather obvious theoretically but nonetheless useful since it is usable by someone not too theoretically-inclined. It should be pointed out however that the methods assume that a generator of "uniformly distributed" numbers is available. The second part is quite useful since many relationships between the "age" at which the peak in the lognormal hazard function and the parameters of the time-to-failure distribution are derived and plotted. ##

Serial Number 2470
ASQC Codes 431;615;872

TITLE: Optimal procedures for the installation of a unit subject to stochastic failures

AUTHOR: Sidney C. Port (The RAND Corporation, 1700 Main Street, Santa Monica, Calif.)

SOURCE: Memorandum RM-3910-PR, prepared for USAF Project RAND, The RAND Corporation, Santa Monica, Calif., Nov 63, 12p

PURPOSE: To derive optimal procedures for a specific replacement situation.

ABSTRACT: Suppose we have a unit which we observe at discrete periods of time and which at any given moment may be in one of three possible states 0, 1, or 2, where 0 is the "failed" state, 1 the "turned-off" state, and 2 the "good" state. If a unit is in state 0 we may either leave it in state 0 or we may replace it by a new unit, which will take a time X. A unit in state 2 may be transformed to one in state 1 by turning it off which we assume takes no time, or it may be left on, in which case the probability that it survives for k time periods will be $(1 - \beta)\beta^k$. Finally, a unit in state 1 may be left in that state or it may be "restarted." The restart operation takes 1 time period at the end of which the restarted unit will be in state 2 with probability α or in state 0 with probability $1 - \alpha$.

In this Memorandum we consider the case when X = m with probability one. For this case we explicitly determine the probability that, using an optimal policy, we have a unit in state 2 at some specified time n, and we explicitly find this optimal policy. (Author)

REVIEW: This Memorandum is devoted completely to the detailed solution of the above stated problem. The approach is via dynamic programming and the results are explicit. As is many times the case, the direct applicability of the procedures will depend on whether or not the assumptions of the model are valid. ##

Serial Number 2471
ASQC Codes 833;844

TITLE: National Association of Relay Manufacturers Relay Conference Papers, 1965

SOURCE: Proceedings of the Thirteenth Annual National Relay Conference cosponsored by the National Association of Relay Manufacturers and the School of Electrical Engineering, Oklahoma State University, Stillwater, Okla., 27-29 Apr 65 (Copies available from National Association of Relay Manufacturers, P. O. Box 7765, Phoenix, Ariz. 85011; price $5.00)

PURPOSE: To present the 34 papers given at the conference.

ABSTRACT: The papers range from those on basic physics of failure and operation of relay parts to application information. About one-third of the papers are in each of the classifications:

Design and manufacturing of relays,
Physics of failure and operation,
Circuit applications.

A very few are in the classifications: Theory, Testing.

REVIEW: This is a worthwhile proceedings on the subject of relays. While reliability/life is the primary topic of very few of the papers, most of them have at least an indirect bearing on considerations affecting reliable operation. Consequently the Proceedings will be of interest to designers of equipment in which relays are applied, as well as to those concerned with the manufacture of relays.

It is difficult for a reviewer to assess the validity of a paper which reports results of a development process. One can only remark that if relays were as good as they appear to be from the many descriptions of their development (not to mention some of the advertising), there should be vastly fewer problems with relay applications. This is not to minimize the importance of good circuit engineering and production which is also stressed in several of the papers.

Papers of a mathematical or reasoning nature are easier to review, since the work is in full view; the author is then at a greater "disadvantage." For example, in Paper 15 on a heat transfer analysis of a coil, it is readily ascertained that the author has an incorrect justification of a correct step and that his analysis implicitly assumes no winding irregularities, no wire imperfections, no heat transfer irregularities at the surface, that wire resistivity is independent of temperature, etc.

The order of the papers has little to do with their content; for example the two papers on bifilar windings for transient suppression are not put together.

See RATR 1078, 1309, and 1717 for other worthwhile papers on applications information for relays. The following publications of the National Association of Relay Manufacturers (see SOURCE for address) should also be very useful:

Recommended Specifications for High Reliability Relays
Reliability Guidelines for Relays. ##

Serial Number 2472
ASQC Codes 802;820

TITLE: Reliability: Basic concepts

AUTHOR: --

SOURCE: Report No. 2889, Aerojet-General Corporation, Von Karman Center, Production Projects Div., Jul 64, 34p, 11 refs.

PURPOSE: To explain the statistical concepts basic to reliability analysis.

ABSTRACT: Reliability, frequency distribution, failure rate, and survival probability are defined. The product law is given and simple redundancy is explained. The distribution of times between failures is discussed with special attention to infant mortality, wearout, and the period of constant failure rate (hazard), and to the concept of MTBF and the exponential reliability formula. Confidence limits are derived for MTBF estimates and the concept of testing hypotheses is explained. A glossary of terms is provided at the end.

REVIEW: Generally, this brief introduction gives a favorable impression, but there are several deficiencies--some of which may well be due to poor editing. Some examples are the following.

1. The definition of failure rate is not one of the better ones, largely because of the indefinite time period. Usually, either the plain or logarithmic derivative (yielding the plain failure rate or the hazard, respectively) is easier to visualize.

2. The probability of survival definition is actually that for an estimate of the survival probability. Later on the concept is used synonymously with reliability.

3. No distinction is made between physical and statistical independence. Failure events can be statistically dependent even though they are physically independent.

4. The formula associated with redundancy holds for parts with the same failure probability, connected and operated so that the failure events are statistically independent (which implies at least that the failure of one does not affect the probability of failure of another).

5. It is implied that a constant failure rate (hazard) is a desirable design goal. This is not necessarily so.

6. The effect of MTBF changes on reliability is given properly, but is incomplete. Even though (for $R \approx 1$) large changes in MTBF produce only small changes in R, there are useful performance indices that are roughly proportional (inversely) to MTBF. For example, $F = 1-R \approx t/MTBF$ for $R \approx 1$. Neither index, R or F, is innately superior to the other. It should also be pointed out that R (and F) are uniquely determined by MTBF only for one-parameter failure distributions--the most common of which is the exponential.

7. The formulas for confidence limits are quite wrong--and virtually unintelligible, undoubtedly due to poor editing. The correct ones apply only to the exponential distribution. Furthermore, different formulas apply depending on whether testing is stopped after a fixed time or after a fixed number of failures.

8. The glossary of terms is generally adequate except for: chance failure, failure rate, independent failures, random failure, randomness, redundancy, inherent equipment reliability, manufacturing reliability, operational reliability, and safety margin. ##

Serial Number 2473
ASQC Codes 431;863;872

720;740

TITLE: To determine reserves for systems of repeated action

AUTHOR: A. D. Solov'yev

SOURCE: Izvestiya, AN SSSR. OTN. Energetika i Avtomatika (Russian), No. 2, 1962, pp. 124-129, Translation prepared by Translation Div., Foreign Technology Div., WP-AFB, O., FTD-TT-65-13/1, 12 May 65, 8p (AD-617 097)

PURPOSE: To determine the proper number of spare parts.

ABSTRACT: If there are many identical items in service with constant failure rate (hazard) λ, and constant repair rate μ, and if the total number of units and the number required in service are given, one can find the probability that there will be a failure of the system. This is a Markov process. The answers are generally obtainable in closed form only asymptotically. Several expressions are given.

REVIEW: This kind of analysis is readily available in the American literature. There is no need to try to read a poorly translated (by machine, without editing) Russian paper to get it.

TITLE: Introduction of a system of defectless manufacture in industrial production

AUTHOR: A. S. Nefedov

SOURCE: Byulleten' Tekhniko-Ekonomicheskoy Informatsii. (Russian), No. 2, 1965, pp. 10-12, Translation prepared by Translation Div., Foreign Technology Div., WP-AFB, O., FTD-TT-65-549/1, 10 Jun 65, 6p (AD-620 098)

PURPOSE: To show the advantages of intelligent automation.

ABSTRACT: The industrial economy can be greatly improved if information is readily available to plants on the latest and best methods of manufacture and design. Examples are given of redesign of parts and of automation of processes which produced great economies.

REVIEW: This is a very qualitative document and a machine translation. It is not worth reading except to satisfy idle curiosity. ##

Serial Number 2474
ASQC Codes 552;844

TITLE: Progressive reliability functions

AUTHORS: Nathan Grier Parke, III and C. Robert Montgomery (Parke Mathematical Laboratories, Inc., One River Road, Carlisle, Mass.)

SOURCE: AFCRL-63-163, Scientific Report No. 1 prepared for Air Force Cambridge Research Laboratories, Office of Aerospace Research, USAF, Bedford, Mass., under Contract No. AF19(628)-2417 by Parke Mathematical Laboratories, Inc., One River Road, Carlisle, Mass., Jan 63, 32p

PURPOSE: To demonstrate a particular reliability calculation.

ABSTRACT: The cumulative failure probability is F(t). The function F(t + T) - F(t) will give the fractional number of failures in time T, beginning at time t. If the function F is tractable, the calculation is straightforward; if not, a graphical solution is appropriate. The graphical solution is explained.

REVIEW: As an explanation of the graphical technique, this paper is satisfactory. It should be emphasized that the applicability of this model may be severely hampered by F's being almost impossible to define if repairs are allowed and the equipment returned to service. In that circumstance, the only known tractable distribution is the exponential, and of course the problem is trivial in that case. ##

Serial Number 2475
ASQC Codes 424;612;824;
831;837;844

TITLE: Transfer functions in mathematical simulation for reliability prediction

AUTHOR: --

SOURCE: RADC-TDR-63-87, prepared for Reliability Techniques Group, Applied Research Laboratory, Rome Air Development Center, Research and Technology Division, AFSC, USAF, Griffiss Air Force Base, N. Y. under Contract No. AF 30(602)-2376 by Sylvania Electronic Systems-East, 100 First Ave., Waltham 54, Mass., 30 Jan 63, 146p, 27 refs.

PURPOSE: To describe some techniques for predicting the reliability of electronic systems from information about the components.

ABSTRACT: The first step is to hypothesize a circuit to perform a particular function. Then it should be analyzed. This is done by writing the equivalent circuit, next writing the equations implied by that circuit, and then solving these equations. Any one circuit may have several equivalent circuits depending on the number of performance parameters and the ease of handling components for which several equivalent networks must be drawn in order to be tractable. These equations are then solved. Component parameters and inputs may be varied to determine the effects on the measure of performance. For solving the equations, high speed digital computers are a virtual necessity.

REVIEW: There is little here that was new even ten years ago except the admonition to use high-speed computers and Monte Carlo techniques. The use of the term "transfer function" in the text will merely serve to confuse those who are expecting something different from what has generally been taught in straightforward analysis courses for at least twenty years. It should be mentioned that the construction of useful tractable equivalent circuits can be exceedingly expensive and time consuming. See also RATR 996 on the same topic.
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Serial Number 2476
ASQC Codes 412;824;831

TITLE: Reliability growth during a development testing program

AUTHORS: Richard E. Barlow and Ernest M. Scheuer (The RAND Corporation, 1700 Main St., Santa Monica, Calif. 90406)

SOURCE: Memorandum RM-4317-1-NASA, The RAND Corporation, 1700 Main St., Santa Monica, Calif. 90406, sponsored by the National Aeronautics and Space Administration under Contract No. NASr-21, Oct 65, 17p, 8 refs.

PURPOSE: To describe techniques for estimating reliability growth during a development testing program.

ABSTRACT: This study examines the problem of estimating the reliability of a system that is undergoing development testing. In such a program, changes are made to the system from time to time in order to increase its reliability. This study assumes that these changes are at least not deleterious, but, unlike some previous work in this area, it does not assume that system modifications cause reliability growth according to a prescribed functional form. The method described herein does, however, require that each failure be classified either as inherent or as reflecting a correctable cause. (Inherent failures are defined as failures which reflect the state-of-the-art and the elimination of which would require an advancement thereof. Failures reflecting a correctable cause are those which can be corrected by equipment or operational modifications.)

The study proceeds on the supposition that the test program is conducted in K stages, with similar items being tested within each stage. For each stage, the number of inherent failures, of assignable cause failures, and of successes is recorded. It is supposed that the probability of an inherent failure, q_o, remains the same throughout the test program and that the probability of an assignable cause failure in the i-th stage, q_i, does not increase from stage to stage of testing. This Memorandum obtains maximum likelihood estimates of q_o and of the q_i's subject to the condition that they be non-increasing, and also obtains a conservative lower confidence bound for r_K, the reliability of the system in its final configuration of the test program. Numerical examples to illustrate these methods are given. (Authors)

REVIEW: The results in this Memorandum would be of interest to statisticians and engineers concerned with assessing a system's reliability. The reliability growth models provide useful procedures for combining past experience with present test results in order to assess system reliability. The applicability of the proposed model should be determined by appropriate tests of the assumptions on real systems. The techniques are easy to apply and the concepts introduced should be helpful in reliability assessment. ##

Serial Number 2477
ASQC Codes 414;433;615;
872

TITLES: a) An adaptive age replacement policy
b) Age replacement with discounting

AUTHOR: Bennett L. Fox (The RAND Corporation, Santa Monica, California and Operations Research Center, University of California, Berkeley)

SOURCE: Reports ORC 65-17 and ORC 65-22, Operations Research Center, University of California, Berkeley, partially supported by the Office of Naval Research under Contract Nonr-3656(18), Aug 65, 45p, 14 refs. (a); 10p, 4 refs. (b)

PURPOSE: To derive optimal replacement policies (a) assuming a Weibull failure distribution, and (b) for age replacement with discounting.

ABSTRACT: a) Under an age replacement policy replacements are made at failure or at the end of a specified time interval, whichever occurs first. This makes sense if a failure replacement costs more than a planned replacement and the failure rate is strictly increasing. The failure distribution is assumed to be a Weibull with known shape parameter (>1) and unknown scale parameter. A natural conjugate prior distribution with specified parameters is assumed to be at hand, which is modified after each stage according to Bayes' rule. The policy adapts to the changing prior. The larger the replacement interval set, the more the information which can be obtained. This is taken into account through dynamic programming. The optimal policy is partially characterized and various limiting results are obtained.

b) It is assumed that continuous discounting is used and that the cost of a planned (failure) replacement is c_1 (c_2), where $0 < c_1 < c_2$. That is, if a denotes the fixed replacement interval then the loss incurred at time t (up to the first replacement) is given by $c_1 \exp(-\alpha t)$ if $t = a$ and is $c_2 \exp(-\alpha t)$ if $t < a$, where α is the discount rate. The problem is to choose a so as to minimize expected discounted cost over an infinite horizon. If the failure distribution is known then several results can be obtained. In particular if the failure rate is continuous and strictly increasing to infinity, then a*, the optimal replacement interval, is finite, unique and obtainable computationally by an increasing sequence of better approximations. Asymptotic results are also given as α tends to zero. If the failure distribution is unknown, the minimax strategy over an appropriate class of distributions is obtained; viz., replace only at failure.

REVIEW: The first paper is quite theoretical and an elementary knowledge of dynamic programming and of Bayesian statistics is required for the understanding of the proofs. However, computational aspects are discussed to some extent. Most of the results of the second paper pertain to the case of a known time-to-failure distribution and as such their usefulness depends on having a policy that is fairly insensitive to small changes in the assumed distribution. In any particular problem, this could be investigated numerically. A knowledge of Chapter Four of Barlow and Proschan (see RATR 2062) is necessary for a complete understanding of the proofs. ##

Serial Number 2478
ASQC Codes 720;815

TITLE: Quality assurance pamphlet: Standards of workmanship for wired equipment

AUTHOR: --

SOURCE: AMSEL-P-715-600, U. S. Army Electronics Labs., Fort Monmouth, N. J., Feb 64, 80p (AD-612 054)

PURPOSE: To provide a guide to the standards of workmanship desired by the U. S. Army Electronics Command in wired equipment procured for the military arms.

ABSTRACT: Proper production methods of joining and soldering are explained. The appearances of acceptable and unacceptable soldered connections are described. Solderless electrical connections are cited; they will be inspected for fracture, size, proper crimping, and tight wire. Some of the cabling and wiring standards include insulation, sleeving, coding, protection, and termination. Potential short classification covers instances where there are bare conducting members inadequately separated due to irregularities of workmanship during the manufacturing process, such as damaged insulation, excess solder or projecting wire ends. Minimum clearance requirements are given. A classification of defects for printed wiring boards is presented, in addition to board requirements. Other areas are also included, such as fastening hardware, fungus-proofing, and marking. Deviations from the provisions of this pamphlet where the words "shall" or "must" are used can be made within the U. S. Army Electronics Command only with approval by the Quality Assurance Element.

REVIEW: Workmanship standards is not an elegant topic, but it is an important one, since so many equipment failures are caused by poor workmanship. This standard will help to provide uniformity and to minimize customer-contractor differences on what is acceptable. The pamphlet is nicely illustrated with many sketches, and it uses simple language. Thus it is also suitable for use in the training of assembly and inspection personnel.

A paper discussing the NASA hand soldering program with emphasis on the associated specifications was covered by RATR 1494. ##

Serial Number 2479
ASQC Codes 773;813;841;
872

TITLE: Electronics equipment reliability study

AUTHORS: Howard Musoff and Charles L. Gagnebin (Instrumentation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass. 02139)

SOURCE: Technical Report MDC-TR-65-21, Air Force Missile Development Center, Holloman Air Force Base, N. Mex., prepared by Instrumentation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass. 02139 under Contract AF 29(600)-3916, Jun 65, 55p, 24 refs.

PURPOSE: To investigate the establishment of a reliability program pertinent to the peculiar problems associated with electronic gyro test equipment.

ABSTRACT: Gyro tests are divided into interruptible and noninterruptible tests; in the former the part of the test which preceded a test equipment failure is not repeated, but in the latter the test is repeated in its entirety after failed test equipment has been repaired. A reliability analysis model is developed for the noninterruptible testing, and is extended to a model for determining the mean expected number of extra days which should be planned. The length of time used by each of the various units for the two test types (line-voltage regulator, master oscillator, etc.) is considered in selecting allowable unit failure rates. A ten-year maintenance record of an inertial gyro test laboratory is examined for reliability problems, resulting in a list of wiring and mechanical recommendations for improving reliability. The area of equipment use and maintenance is discussed where a data-collection system can predict test-station reliability and spotlight needed improvements. The method proposed to collect failure data is given in detail. A system utilizing elapsed-time meters and punch-card records is recommended and outlined.

REVIEW: The perspective here is mainly one of the development of an operational analysis with emphasis on reliability, and touching on such related requirements as maintainability and cost. Both the initial specification and the later measurement of reliability are treated. An impression is given that the investigation was a first effort at an explicit reliability program. The examination of past problems of similar equipment resulted in recommendations which are relevant to the design and fabrication of an equipment in order to improve reliability. The list is rather short, and someone interested in pursuing this area would want to seek out similar check-off lists and reliability program tasks which are sprinkled throughout the reliability literature. This report could be of interest to those involved with the reliability of similar test equipment, but it is not of general interest. ##

Serial Number 2480
ASQC Codes 414;640;814;
824;844

TITLE: Some economic aspects of reliability and project management

AUTHOR: David C. Dellinger (Applied Mathematics and Statistics Laboratories, Stanford University, Stanford, Calif.)

SOURCE: Technical Report No. 67, Applied Mathematics and Statistics Laboratories, Stanford University, Stanford, Calif., supported by the Army, Navy and Air Force under Contract Nonr-225(53) (NR-042-002) with the Office of Naval Research, 31 May 63, 194p, 52 refs.

PURPOSE: To examine some reliability testing, estimating and prediction techniques in order to determine their usefulness and limitations in practical applications.

ABSTRACT: A brief summary of the general theory applicable to reliability tests and a review of the principal test procedures generally available are presented. Emphasis is on the form of the test, the underlying assumptions, and the decisions (implicit or otherwise) made by the user in drawing a conclusion. Available procedures are generally expressed in step-by-step format, but without adequate guidance in the proper application of the procedure. Parametric test procedures are based on an assumed underlying distribution. Methods are examined for estimating the true distribution, and the effects of misapplications are discussed. Economic test plan selection can be viewed as a problem of achieving a balance between the value of better differentiating ability and the cost of more testing. Decision theory is shown to provide a general approach to the problem. Two means are investigated for estimating system reliability. One is to make inferences about the system reliability from data on component reliability tests and the other is reliability growth. The PERT system is described, and a critical review is made with emphasis on the procedure for quantifying the uncertainty of the activity-time estimates.

REVIEW: The emphasis in this report on the indiscriminate use of reliability testing techniques and associated mathematical models is very timely. The author points the finger at the sophisticated model- and technique-builder for proliferating approaches which make little contribution toward the solution of practical problems. The plea is for approaches which explicitly include underlying assumptions, guidance for applications, and consequences of misapplication. This report is almost a book and it assumes that the reader is quite familiar with basic probability and statistics. The investigation emphasizes the statistical aspects of reliability testing, and does not treat other pertinent facets such as the technical and administrative problems. Examples of these are the definition of failure and test environment, or the effects on production flow and stock control. Also the bulk of this investigation shows that most of the statistical material on the subject does not tackle the general repairable system, but rather is oriented toward single life distributions. Yet the problem of repairable equipment reliability testing is probably more practical than that involving a single life distribution. No data or examples are used in examining the techniques. Coverage of PERT does not blend in, but it is a sound critique. All in all, this investigation is potentially very useful, and those interested in reliability testing should read it. ##

Serial Number 2481
ASQC Code 838

TITLE: Advanced development of satellite communication systems

AUTHOR: John Kemp (General Electric Company, Advanced Electronics Center, Light Military Electronics Department, Ithaca, N. Y.)

SOURCE: Special Report, Task II: Reliability, prepared for U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J. under Contract No. DA-36-039-SC-85236 by General Electric Company, Light Military Electronics Department, Advanced Electronics Center, Ithaca, N. Y., 18p

PURPOSE: To report on a study for determining design criteria and procedures for synthesizing digital systems to a given reliability specification using presently-available components in redundant digital circuits.

ABSTRACT: The approach to redundancy reported in this paper is that in which all components are wired into the system and component failures are forced to appear as errors which may be corrected by a majority decision on the outputs of redundant circuits. The problem of a very reliable monitor-switching arrangement is thus avoided. Computation of the reliabilities in this report is based on the probabilities of catastrophic semiconductor failures. Assumptions have been made concerning the relative probability of various types of failures. Two terms are defined in order to compare the various redundant approaches; these are called the figure of merit and the error reduction factor. These terms are used to compare the reliability of various redundant digital circuits, including error correcting, flip flop memory, adder, and sequence generator. The material appearing in this unclassified report was extracted from classified reports in order to make it more readily available.

REVIEW: A circuit engineering orientation is taken in this report, with little given of the details of the analysis. It is mainly a presentation of results, and is well illustrated with figures and graphs. Sufficient background is given in order to reconstruct the analysis. The assumptions which are made appear reasonable and are probably necessary in order to actually perform the analysis. An investigation of the sensitivity of the results to the probabilities of opens and shorts may be appropriate, depending on how accurately these probabilities are known. Usually there is some doubt as to what the relative probabilities of opens and shorts will be. The subject covered here is solely redundant digital circuits and thus is much narrower than the title implies. ##

Serial Number 2482
ASQC Codes 766;814;870

TITLE: A new concept of planned inspections

AUTHOR: Irving Katz (Operations Analysis Office, Directorate of Operations, Headquarters, Air Force Logistics Command, W-P AFB, O.)

SOURCE: Operations Analysis Working Paper Nr. 13, Operations Analysis Office, Directorate of Operations, Headquarters, Air Force Logistics Command, Jul 65, 15p (AD-619 944)

PURPOSE: To examine the planned inspection portion of preventive maintenance in conceptual terms in order to evoke responses which will lead to a consensus on fundamental concepts.

ABSTRACT: The frequency of inspections is an extremely important problem for Air Force logistics because a large portion of the Air Force resources are expended as planned inspections and as a consequence of inadequacies in these inspections. The purpose of preventive maintenance is to take action which will preclude failure from occurring at a subsequent time, when the total penalty (cost) for the failure could be substantially greater than the total cost of the preventive maintenance effort. The heart of preventive maintenance is the prediction of future failures. A key consideration in determining whether to inspect a particular item, and how often to inspect it, must be the amount of warning that is given concerning a future failure. Analysis of warning intervals is considered to be an essential feature of setting inspection intervals. Before determining an inspection interval, estimates should be made of the costs and the benefits which would be derived from such an inspection practice. An optimal inspection frequency would yield a minimal total cost, including the costs of scheduled and unscheduled maintenance, weapon downtime, penalties for operational failures, and associated logistic support such as replacement spares. The determination of the inspection interval would include individual line items and aggregations of them. The Operations Analysis Office of HQ AFLC is proceeding with related analytical studies.

REVIEW: Analysis of warning intervals seems quite appropriate conceptually, but there is divergence of opinion as to whether it can be handled in detail with data ordinarily obtainable. The cost effectiveness viewpoint is heavily relied upon. No references are cited.

In a private communication the author notes that the warning interval analysis is controversial, and the existing literature does not cover it adequately. It would seem that rather than being controversial, warning interval analysis is an approach which just has not been formally developed. The idea is probably used informally by operators of equipment and maintenance personnel who learn to predict incipient failures with some accuracy by observing the change or rate of change of certain parameters of the system. An instance of a formal use is the automatic recording of certain aircraft parameters while in flight, and the subsequent analysis of the recordings for warnings of incipient failures. The analysis of warning intervals would seem to have possibilities not as yet fully explored. ##

Serial Number 2483 -1
ASQC Code 813

TITLE: Reliability implementation in one electronic system

AUTHOR: Richard E. Worthey

SOURCE: Thesis presented to the Faculty of the School of Engineering of the Air Force Institute of Technology, Air University in partial fulfillment of the requirements for the Degree of Master of Science, Nov 64, 87p, 30 refs. (AD-609 933)

PURPOSE: To determine the factors which resulted in a reliability program being initiated for the AN/ARC-34 and to analyze the important aspects of this program.

ABSTRACT: The AN/ARC-34 was initially developed with no reliability requirements. Reports of low MTBF from using commands and the advent of the AGREE report resulted in a reliability program on later procurements. Redesign of circuits which had high failure rates and a manufacturing reliability program resulted in a significant reliability improvement. AGREE-type tests were used to measure reliability. The elements of the AN/ARC-34 program are compared with elements of present reliability programs under MIL-R-27542, with the conclusion that MIL-R-27542 should be included for future AN/ARC-34 procurement. Also provisions are needed to determine if operational reliability goals are met. An analysis is made of the reliability demonstration tests conducted on the AN/ARC-34 subsystems. Failure distributions of the subsystems were tested for goodness of fit, and the hypothesis could not be rejected that the exponential distribution could be the distribution of failures. The requirements for and contents of the reliability reports were investigated. Compliance was excellent and the reports were useful to the procuring agency. The contractor's reliability department is fully capable of conducting a comprehensive reliability program. However, the program has been hampered due to the lack of active management participation within the Air Force. Recommendations are given for improving the AN/ARC-34 program.

REVIEW: The historical review in this thesis reads like a novel with "reliability" the hero, and should give encouragement to proponents of an explicit reliability approach. Conclusions and recommendations are primarily a call for extensions of the reliability program to field operation and for up-dating the approach if initiation occurs for production or solid-state redesign. Some pointers are given which should be useful to those involved in the reliability aspects of procuring equipment for a government agency, although everything here should not be literally accepted.

Some of the common ambiguities which plague reliability are found here. The usual assumption of a Poisson failure distribution is made, which leads to the statement on page 74: "Physically this means that the failures encountered could not have been prevented through any debugging, preventive maintenance, or replacement procedure." This is not necessarily correct for repairable equipment, as even though failure data might indicate that the equipment follows a Poisson distribution, various parts which comprise it may

not have a constant hazard rate. Vacuum tubes and moving parts are the likeliest candidates, and their proper replacement could improve equipment reliability. Further, there could well be incipient failure indications, such as the value or rate of change of value of certain characteristics. A correct statement would be, "physically this means that the failures encountered could not have been prevented through the mere replacement of the equipment with an identical equipment." Another misconception lies in considering that the validity of the assumption of the Poisson process has been satisfactorily tested only by testing the times-between-failures for an exponential goodness of fit (pages 40-62). Just using this test does not assure that no time-ordering exists, as would occur if the successive time-between-failure intervals were tending to decrease or increase. The point here is not necessarily that some formal statistical test is always necessary, but rather that some explicit recognition is desirable as to the implications and omissions of "Poisson processes" and "goodness-of-fit tests." Actually, the "longevity test" which was discussed on pages 32-35 is relevant here, but it was illustrated with hypothetical data and was not shown as being applied to the AN/ARC-34 data for which the Poisson process was verified by an exponential goodness-of-fit test. On page 34 the implication is made that the reference which is given there is about the "time-between-failure averaging technique." The reference says nothing about this; the AGREE report, pages 183-190, actually discusses the "longevity test." Some other ambiguities and misconceptions which readily catch the eye were the use of unclear terms such as "inherent reliability" and "chance failure."
##

Serial Number 2484
ASQC Codes 612;824;882

TITLE: Numerical analysis of system availability and of parameter estimation methods

AUTHORS: W. J. Howard and N. Kaufman (Space Technology Laboratories, Inc., Redondo Beach, Calif.)

SOURCE: Report 6101-8161-TU000, prepared for HQ Ballistic Systems Division, AFSC, USAF, Air Force Unit Post Office, Redondo Beach, Calif., by Space Technology Laboratories, Inc., Redondo Beach, Calif., under Contract No. AF 04(694)-3, Aug 63, 105p, 8 refs.

PURPOSE: To check the potential usefulness of methods for estimating some parameters in an availability equation and to investigate the effects of various parameters on system availability.

ABSTRACT: Availability models for a ballistic missile weapon system should include the possible effects of checkout error, incomplete test coverage, and imperfect repair. These effects cannot be measured directly by means of routine failure and maintenance data, as the data themselves include these errors to an unknown extent. A surveillance program to obtain these data is costly and is not contemplated. Methods have been proposed for estimating the unknown parameters by inferential or indirect methods. A series of Monte Carlo trials was run on the 7090 computer in order to check these methods. The trials were conducted using various input parameter values and sample sizes, and estimated parameter values were computed using the estimating equations, in the same manner as if actual field data were available. The results of numerous trials are discussed, including the effects of true parameter values, sample sizes and type of data available. The second project was a parametric analysis of system availability using a curve plotting machine to aid in revealing the sensitivity of availability to the various system operational and maintenance parameters. The computer program is described, and sensitivity and interaction effects are presented which resulted from the numerical analysis. Appendices contain tables of estimates from the Monte Carlo runs and a selection of graphs from the parametric study of availability.

REVIEW: The end objective of this sort of analysis is mainly to aid in establishing actual field operational and maintenance procedures of very costly systems. Hence there is justification for the significant amount of effort which apparently went into obtaining the results presented in this report. It is readable, contains an expanded summary, and reflects work of high quality.

Much lamenting currently occurs on the lack of data for estimating parameters. Thus, the approach used here, estimating needed parameters from other data which are available, is worth noting. The results presented here are interrelated with material contained in the references which are other company reports. Apparently they contain the background of the inferential methods, the availability model, and the computer programs. ##

Serial Number 2485 -1
ASQC Codes 831;844

TITLE: Reliability assessment of the 1964 Mariner Mars spacecraft

AUTHORS: J. D. Andrew, E. E. Bean, and N. E. Chudacoff (Planning Research Corporation, Los Angeles, Calif.; Washington, D. C.)

SOURCE: PRC R-362, prepared for Jet Propulsion Laboratory, Pasadena, Calif., by Planning Research Corporation, Los Angeles, Calif., Washington, D. C., 22 Jul 63, 248p, 7 refs.

PURPOSE: To describe an independent reliability assessment for the prediction of the probability of success of the Mariner Mars planetary spacecraft system and the individual subsystems.

ABSTRACT: The mathematical model was based on a study of the available spacecraft design documents and a limited number of conferences with the cognizant design personnel. The application of the model includes the computation of the probability of success or failure of any desired functional subsystem that effects the occurrence of a significant mission event. A predicted reliability is given for each significant function. The model was developed in such a manner that it would afford a means of accounting for the partial success that might be achieved where some degradation of performance has occurred because of an impairment which is not catastrophic. The primary mission objectives are ranked, and an assignment of worth is made to each of them. Certain general assumptions which apply to the entire study are listed. Model representations of each of the spacecraft subsystems are discussed, and full details of the numerical exercise are given. Complete failure rate and parts count information are given in the appendices.

REVIEW: A reliability prediction is presented in this report which represents the practical application of state-of-the-art techniques. The objective, to obtain probability of success numbers from a systems viewpoint, was achieved and reported in a reasonable and competent manner. In particular, the assumptions are clearly stated and the value of reduced performance is recognized. The prediction was made by one organization on a system which was engineered by another; hence the prediction is an independent reliability assessment.

The following remarks are pertinent to the topic of this report and the typical practices used in reliability assessment. They are not meant to detract from the report per se, which is of high quality. Independent reliability assessments apparently consist, in some cases, of independent predictions of probability of success numbers. Yet the discipline of reliability consists of a number of tasks such as specification review, failure mode analyses, design review, parts program and testing review. Why is the independent reliability assessment restricted to prediction of probability of success numbers? Such predictions probably have the lowest pay-off of the various reliability tasks. A return to the reliability prediction of the Mariner Mars spacecraft which is abstracted above will illustrate the frustrations of a numerical reliability prediction. The solar panel deployment subsystem had a predicted reliability of

0.999996 and the attitude control subsystem had a predicted reliability of 0.9995 for the initial acquisition of Canopus. These two subsystem-functions had the highest predicted reliability by a large measure, as indicated by the total spacecraft predicted reliability of 0.111 for accomplishing all objectives. Two Mariner Mars spacecraft were launched in 1964 for which these predictions apparently were made. The first spacecraft ceased transmissions nine hours after launch, failing to deploy its solar panels and to acquire Canopus, with the failed panel deployment apparently caused by a fiberglass shroud's inner-layer separation preventing the shroud from jettisoning. The second spacecraft (with a new magnesium shroud), after some difficulty in locking on Canopus, ultimately went on to return the spectacular photographs of Mars. Thus the two subsystem-functions with by far the longest strings of reliability prediction "nines" gave the trouble. Also, the report on the Mariner Mars reliability prediction does not indicate that any action was taken as a result of the prediction. Somehow, this does not contribute to a satisfactory feeling concerning useful practices in reliability predictions and reliability assessments.

In a private communication, an officer of Planning Research Corporation has made the comments quoted below.

"To the greatest extent permitted by the clients' wishes, we emphasize failure mode, effect and criticality analyses, design reviews, parts program studies, and testing reviews in our independent assessment work.... Insofar as possible, we limit the use of predictive numerics to comparative evaluations because the results are more meaningful than are absolute reliability predictions."

"We have observed that more recently, our independent reliability assessment contracts do provide for functions other than predictions of probability of success numbers. We believe that this increased scope stems from two factors: (1) our customers have realized the futility of single numerical predictions and are not procuring these; and (2) the reliability assessment contractors have been able to demonstrate their 'worth' in improving reliability through independent reviews of designs, parts programs, testing, etc."

"... we are particularly anxious to have your readers know that the conventional 'numbers game' is decidedly losing popularity, at least as far as PRC's work with NASA and the U. S. Army is concerned." ##

Serial Number 2486
ASQC Codes 821;863;872

TITLE: Reliability of spare part support for a complex system with repair

AUTHORS: James M. Goodwin (The University of Washington) and Erich W. Giese (General Electric Co.)

SOURCE: Operations Research, vol. 13, p. 413-423, May-Jun 65, 9 refs. (*Operations Research Society of America, Mount Royal and Guilford Avenues, Baltimore, Maryland 21202)

PURPOSE: To consider the problem of adequate spare-part support at reasonable cost for a modularized complex system with repair.

ABSTRACT: In this paper an expression is derived for the probability that a given number of spares for each element of a complex system will be sufficient to ensure continued operation. Each part of the system being considered is subject to failure according to Poisson statistics, and may be subject to repair in some fixed time. The probability (that the number of spares will be sufficient) for non-reparable parts is obtained as a special case of the result for reparable parts. The probabilities are obtained for a single part by the construction of an artificial model, which differs from the case being considered through the division of the time period into an integral number of intervals. A part which fails at any time during an interval is replaced immediately with a spare part, and held until the end of the interval before repair is begun. The specified model is obtained by taking the limit as the 'holding time' approaches zero. Samples of the results obtained are included for several values of the various parameters. The results are generalized to include a variety of parts, both identical and different, and to include the effects of passive redundancy. (Authors in part)

REVIEW: This is a mathematical paper in which the problem, the procedure, underlying assumptions, and results are clearly set forth. Problems of a similar nature studied by other authors are mentioned and referenced. While the treatment in this paper will be of more interest to the theorist than to the design engineer, the problem itself is of considerable practical importance. As the authors have pointed out, adequate logistics support at reasonable cost for maintainable complex systems can be as important as proper design. This is an area in which the theorist can make a practical contribution, provided the system considered satisfies the underlying assumptions, and adequate input data for the calculations are available. ##

Serial Number 2487
ASQC Codes 814;821;838

TITLE: Optimum redundancy under multiple constraints

AUTHORS: Frank Proschan and T. A. Bray (Boeing Scientific Research Laboratories, Seattle, Wash.)

SOURCE: Operations Research, vol. 13, p. 800-814, Sep-Oct 65 (*see RATR 2486); also Mathematical Note No. 298, Boeing Scientific Research Laboratories, May 63

PURPOSE: To solve the problem of maximizing system reliability without exceeding any of several linear constraints.

ABSTRACT: In this paper an algorithm is developed for allocating redundancy among subsystems so as to achieve maximum system reliability without exceeding any of several linear constraints on redundancy. The procedure is a generalization of the one developed by Kettelle for the case of a single constraint on redundancy (see RATR 416). The system considered consists of k "stages," and functions if and only if each stage functions. Stage i consists of n_i units of type i in parallel, and functions if and only if at least one of the n_i units functions. Associated with the unit i there is a "cost" c_{ij} of the j th type (weight, volume, money, etc.) A linear constraint on cost c_{ij} is expressed in the form: sum of $c_{ij}n_i$ over all i must not exceed a specified value c_j. It is assumed that a unit of type i has probability p_i of functioning, independently of the functioning or non-functioning of the other units in the system. For any set of n_i, i = 1, 2, ..., k, the system reliability is expressed as the product over all i of the probabilities that at least one of the n_i units of type i functions. The problem is to choose the vector of n_i so as to maximize system reliability subject to the given constraints.

Dominating sequences of redundancy allocations are defined, and procedures for generating them are described for two-stage and for s-stage systems. Approximations for use in applying the procedure for s-stage systems are given. Methods for generating starting values for the n_i are outlined. An example is presented, and a computer program is described. The practicality of the method and its applicability to other types of problems are discussed.

REVIEW: This is a well-written mathematical paper, and constitutes a rather sophisticated treatment of the problem of redundancy allocation for multi-stage systems. It may not be the sort of thing which the design engineer can use directly and easily, but it is a tool which the theorist can use to assist the designer to meet his reliability objectives within given constraints. As such it would have a place in the early concept stages of the development of complex equipment where parallel redundancy is being considered for reliability improvement. ##

Serial Number 2488
ASQC Codes 813;830

TITLE: Equipment reliability--better or worse?

AUTHOR: Robert A. Lincicome (Management-Marketing Editor, Electric Light and Power)

SOURCE: Electric Light and Power, vol. 43, Apr 65, p. 46-49

PURPOSE: To discuss the reliability of today's utility equipment from a management viewpoint.

ABSTRACT: There are serious doubts in the minds of utility engineers and purchasing executives as to whether or not new equipment will perform as well as earlier equipment under normal operating conditions over a normal life expectancy. Large excess capacities, which once were designed intentionally into all equipment, are no longer present due to manufacturers' attempts to salvage profit out of the cost-price squeeze since the early 1960's. The tendency of manufacturers to design and build equipment to nameplate ratings, coupled with utilities' tendency to overload equipment, has resulted in higher failure and trouble rates, outages and shorter life expectancies. Caught between the need for continued cost-cutting and meeting increasingly complex demands from customers, manufacturers have reappraised their design and manufacturing processes, with special attention to reliability improvements. Many companies, especially the larger ones, have initiated extensive reliability improvement programs. The objectives, organization and operations of the company-wide reliability programs of Westinghouse Electric Corporation and General Electric Company are described on the basis of statements made by the respective directors of reliability.

REVIEW: This paper will be of interest to management personnel concerned with reliability programs for commercial products. While the specific reference is to utility equipment, the principles described have much wider applicability. There are important elements of fallout from reliability programs developed for military components which can and should be applied in the manufacture of nondefense equipment--for the mutual benefit of both manufacturer and user. Although the paper is brief, it touches upon many of the important considerations. ##

Serial Number 2489
ASQC Codes 841;844

TITLE: Mathematical concepts in reliability

AUTHOR: Ralph L. Madison (Booz, Allen Applied Research Inc., Bethesda, Md.)

SOURCE: Presented at the 1965 Joint Automatic Control Conference, Rensselaer Polytechnic Institute, Troy, N. Y., 22-25 Jun 65, p. 842-847 in Conference Volume

PURPOSE: To present a history of reliability mathematics.

ABSTRACT: The evolution of reliability analysis methods for electronic parts is summarized with particular emphasis on the data-gathering and interpretation problem. Early reliability models postulated constant failure rates and some sophistication was added by consideration of mixed models to account for catastrophic and wear-out type failures. Emphasis began to change from parts reliability to systems reliability and questions of maintenance, repair, and operator effects were considered. The next logical step was the attempt to combine parts reliability data in a system model to predict system reliability. Many refinements have been proposed for system prediction, including the grouping of piece parts into groups (active element groups) to eliminate certain interactions. Finally, the limitations of our present prediction techniques are discussed as well as the statistical problem of reliability demonstration testing. (Author)

REVIEW: This is a rather brief discussion of the problems encountered in early attempts at reliability analysis. It is both qualitative and to some extent subjective, but it does cover the essential aspects of the subject. There is little in the paper that will be new to anyone other than the novice in the reliability field. ##

Serial Number 2490
ASQC Codes 831;844

TITLE: Applied reliability analysis

AUTHORS: David W. Weiss and Dale M. Butler (Booz, Allen Applied Research Inc., Bethesda, Md.)

SOURCE: Presented at the 1965 Joint Automatic Control Conference, Rensselaer Polytechnic Institute, Troy, N. Y., 22-25 Jun 65, p. 848-856 in Conference Volume

PURPOSE: To show how reliability analysis techniques can be utilized in system design, development, and operation.

ABSTRACT: This is a survey paper which summarizes the value of and some of the problems associated with reliability analysis during the design, development, and operational phases of system evolution. The application of systems reliability analysis in the design phase of a new system is discussed. The importance of clear definitions of performance and failure, analysis of failure modes and effects, and meaningful presentation of results is emphasized.

Problems related to system reliability modeling and computation are presented to indicate some of the modeling methods and their potential value. The reliability growth process during the system development phase is discussed along with methods of measuring this growth.

To illustrate the use of reliability analysis with a system in service, an example of a mechanical clutch assembly is presented. The problems associated with the analysis of manufacturers' warranty data are illustrated as well as the value of such analysis in evaluating warranty costs and customer good will. These data can then be used as the basis for reliability predictions on the next generation of hardware. (Authors)

REVIEW: In keeping with its role as a brief survey, this paper mentions a number of important topics, but treats none of them in any detail. For example, there is a general discussion of system reliability modeling, but the example treats only the very simplest case--a system in which the components are logically in series and the failure events are statistically independent. An underlying exponential distribution of times-to-failure is assumed, and component failure rates are added to yield an equivalent system failure rate. Thus the discussion is concerned essentially with the elementary or "classical" approach to reliability analysis.

The equality sign is missing in the equation which gives R(n), the reliability at the end of the n th interval, in terms of the fraction survived at the end of the i th interval. Incidentally, if the intervals were consecutive and contiguous, and if the number of items surviving at the end of the i th interval were the same as the number of items starting in the (i + 1) th interval, the expression for R(n) would take a simpler form than that given in the paper. It would be simply (N - f)/N, where N is the number of items on hand at the start of the first interval and f is the total number of items failing in the n intervals. However, for the example presented in the paper, the authors' formula is correct. ##

Serial Number 2491
ASQC Codes 824;837

TITLE: The moment technique for predicting the drift reliability of control systems

AUTHORS: J. B. Wertz, R. E. Mesloh, and J. L. Easterday (Battelle Memorial Institute, Columbus, O.)

SOURCE: Presented at the 1965 Joint Automatic Control Conference, Rensselaer Polytechnic Institute, Troy, N. Y., 22-25 Jun 65, p. 857-870 in Conference Volume

PURPOSE: To describe the moment technique for predicting the drift reliability of control systems.

ABSTRACT: A technique is described that can be included in system-design procedures to improve reliability. The variance and limits of each performance characteristic resulting from the combined effect of parameter variations within their specification limits can be predicted, and the parameters most significant to each performance characteristic can be identified. This method allows the inclusion of reliability as one of the design factors by permitting the designer to determine critical areas of the device while in the design stage without waiting until the device has been manufactured or a failure has occurred in the field.

The technique uses transfer functions that relate performance characteristics of a system to its input and internal parameters. Utilizing the propagation of variance formula permits relating the variance of the system-performance characteristic to the parameters and permits identification of critical parameters. This identification enables the designer to determine the points where time-dependent and environmental influences such as wear, degradation, temperature, corrosion, etc., would have the greatest effects in producing undesirable shifts in performance. Thus, the designer can make changes to improve his design, compare similar designs, or seek economic advantages by requiring strict tolerances on only critical parameters while relaxing tolerances on those which are unimportant. Examples of the application of the techniques are presented. (Authors in part)

REVIEW: The technique described in this paper can be a powerful tool for the designer--a tool for use in design improvement, in the comparison of alternative designs, and in the estimation of reliability. The material is clearly and concisely presented, and the examples in the appendix have good illustrative value. An important feature of this technique is that it is concerned with drift-type failures. These have received less attention than have catastrophic failures. Thus the paper fills an important need.

The heart of the analytical part of this approach is the propagation of variance formula, which is explained in reasonable detail in the paper. For application to a specific system, it will be necessary for the user to have a sound and detailed knowledge of how the system functions and how it reacts to the environments to be encountered. In practice, this could be a severe restriction. (See also RATR 2492.)
##

Serial Number 2492
ASQC Codes 824;837

TITLE: Variability analysis

AUTHORS: Donald G. Mark* and Lawrence H. Stember, Jr. (Battelle Memorial Institute, Columbus, O.; *current affiliation: Motorola, Inc., Military Electronics Div., Scottsdale, Ariz.)

SOURCE: Electro-Technology, vol. 76, Jul 65, p. 35, 37-48, 7 refs.

PURPOSE: To describe methods for determining the ability of a system to continue to give specified performance while its component parts change value within specified limits.

ABSTRACT: Several methods for determining drift reliability are discussed in this article. The fundamental approach in each method involves the systematic manipulation of a suitably arranged circuit model to give the desired information. All depend on the speed and accuracy afforded by the modern digital computer to manipulate the model and to process the data resulting from this manipulation.

The worst-case approach is designed to give basic information concerning the sensitivity of a circuit configuration to variability in the parameters of its component parts. This information is useful to the designer in selecting economical but adequately stable components for the circuit and in modifying the configuration to reduce critical effects of certain parameters. The moment and Monte-Carlo methods use parameter-variability data to predict the probability that performance is inside tolerance specifications. The predictions of these methods are limited mainly by the quality of the input data describing the variability of the component parts and the ability of the mathematical model to simulate actual circuit behavior. The moment method provides information that is extremely useful to the designer in pinpointing sensitive areas and reducing this sensitivity to parameter variability.

Physical variability - analysis models differ from conventional breadboards in that they have special provisions for varying the circuit parameters. Circuit-performance data for both moment and worst-case analyses can be obtained from these physical models.

In addition to providing data on drift-type failures, the techniques are capable of giving information on voltage and power dissipation for estimating catastrophic-failure rates. They are useful, powerful tools through the use of which reliability can be designed initially into a circuit rather than being an evolutionary by-product of test and field experience. (Authors in part)

REVIEW: This paper is on the same topic as the one covered by RATR 2491. The techniques arose from research projects at Battelle Memorial Institute sponsored by the Air Force, NASA, and internally funded programs. Both are very competent pieces of reporting on a topic of considerable practical importance. This paper is broader in scope and goes into more detail on the analytics. While some of the discussion is common to both, the papers complement rather than duplicate each other, and the reader interested in this topic will find it worthwhile to study both. ##

Serial Number 2493
ASQC Code 837

TITLE: Predictable design using statistical methods

AUTHORS: Paul Baird and Louis Dohse (Hewlett-Packard Co., Inc., Loveland, Colo.)

SOURCE: Electrical Design News, vol. 10, Jul 65, p. 56-60, 65

PURPOSE: To show how percentage errors of individual components affect the percentage errors of outputs for some simple circuits.

ABSTRACT: In certain simple configurations (series, parallel, divider circuits) it is possible to express the percentage error of the output as a linear function of the individual percentage errors of the components. If the percentage component errors are independently distributed, then, using convolutions, the distribution of the output percentage error may be obtained quite easily. Several examples and graphs are shown to illustrate the ideas.

REVIEW: This paper is of some interest once one manages to discover the authors' unstated assumptions. For example, it is stated that E_1 and E_2 are the "individual errors of R_1 and R_2" but only after working backward from the given relationships does one find that these are percentage errors (more precisely, fractional errors). That is, the true value of R_1 is $R_1(1 + E_1)$. Once this is known, the results follow quite easily. Some errors should also be noted: in the definition of a random variable, "can be predicted" should be replaced by "is known." In the statement "multiple convolutions always can be expected to produce a density function that approaches a normal curve," always should be replaced by usually.

It is sometimes better in engineering statistical analysis to replace the word "error" by "uncertainty" since "error" often implies a known figure rather than an unknown one. ##

Serial Number 2494
ASQC Codes 813;814;836

TITLE: Organizing for reliability

AUTHOR: John W. Greve (Editor, The Tool and Manufacturing Engineer)

SOURCE: The Tool and Manufacturing Engineer, vol. 54, Mar 65, p. 55-59

TITLE: Making products that last...the story of the Westinghouse reliability program

AUTHOR: Carl R. Weymueller (Associate Editor, Metal Progress)

SOURCE: Metal Progress, vol. 88, Nov 65, p. 98 et seq.

PURPOSE: To describe the corporate reliability program of the Westinghouse Electric Corporation.

ABSTRACT: To achieve the objectives of customer satisfaction and improvement of internal operations, Westinghouse devised a formal plan to organize and coordinate reliability efforts on a company-wide basis. Instituted in each division are a reliability manager, a reliability panel, and a definite reliability policy set up according to individual needs. The reliability panel, coordinated at the division manager's staff level, sets and approves reliability goals for each product, reviews results of design reviews and verification tests, reviews division audits of each department's reliability effort, and administers employee training programs.

Once a design has been accepted in all particulars and put into production, the reliability which has been engineered into the product is retained throughout all manufacturing and shipping operations by the use of rigid quality control. Functional and customer audits are continually employed to assess the program's effectiveness. A description of a typical design review illustrates the program in practice.

REVIEW: These are clear descriptions of the more important aspects of a particular reliability program--one which has apparently been quite successful. The two papers do not emphasize exactly the same features of the program, so that both are worthwhile reading for those who are concerned with the management of a reliability function. Papers such as these can be very useful in emphasizing to engineering and management personnel the value and importance of a sound reliability program. A point which has been made elsewhere but is worth emphasizing is that high-reliability programs can pay for themselves in reduced warranty costs and improved customer satisfaction.
##

Serial Number 2495
ASQC Code 782

TITLE: The moon: its environment and what it means for instrumentation

AUTHORS: M. A. Broner and G. A. Lander, Jr. (Lockheed Missiles and Space Co., Sunnyvale, Calif.)

SOURCE: ISA Journal, vol. 12, May 65, p. 53-58, 14 refs.

PURPOSE: To present a summary of present knowledge of the environment of the moon and its influence on instrumentation.

ABSTRACT: Design of instrumentation for use in lunar exploration will be affected radically by the lunar environment and by constraints on size and weight. Known data and speculation are employed to establish a lunar environmental model that can be used to define requirements for instruments for use in moon exploration. Observations concerning the moon's atmosphere, meteoroids, radioactivity, surface structure and chemical composition are analyzed.

Specific requirements of lunar exploration instruments are indicated. All missions will require special instruments since the purpose of early exploration is to gain knowledge. In general, the instruments must provide maximum operating time during the lunar day because they probably will be powered by solar energy conversion; they must also be designed to survive unattended on the surface for periods up to a year. For analysis of specific design objectives, requirements and problems, the instruments are grouped in three categories: biomedical, astrophysical and engineering. The first category involves design of instruments that eliminate wires between the human body and recording or display devices; they must also permit the explorer to telemeter physiological data back to his base station. Astrophysical instruments will be required to measure the physical properties of the moon. Engineering measurements will determine physical properties of the lunar surface including surface and subsurface texture, petrological analysis and body structure.

Several technical investigations in recognized problem areas that must precede lunar exploration are suggested.

REVIEW: This article is both informative for the designer and interesting for the general reader. It is a concise presentation of present knowledge of the lunar environment, supported by some 14 references which will be of value to those who wish to obtain more detail. Hopefully, the near future should produce great advances in knowledge of the moon's surface and environment. The accomplishment of these advances will involve in part the optimum use of present knowledge, and a paper such as this serves a very worthwhile purpose.
##

Serial Number 2496
ASQC Code 838

TITLE: Redundant circuit design: payoffs and penalties

AUTHOR: J. J. Suran (General Electric Company, Electronics Laboratory, Syracuse, N. Y.)

SOURCE: EEE, the Magazine of Circuit Design Engineering (formerly Electronic Equipment Engineering), vol. 12, Sep 64, p. 51-55 (adapted from a paper presented by the author at the 1964 International Solid State Circuits Conference, Philadelphia, Pa., 19-21 Feb 64)

PURPOSE: To discuss redundant circuits.

ABSTRACT: Passive redundancy, wherein all components are always connected, is considered. Moore-Shannon redundancy of switching networks is summarized and the general formula for reliability is given. The quad circuit is an example of this redundancy. The use of it with resistors, transistors, etc. involves degrading factors such as greater parameter variation, more heat dissipation, and reduced circuit capabilities. The MTBF is not too good a measure of improvement, whereas failure rate for a given time period will show gains due to redundancy. Majority logic is another method of redundancy. Several examples of redundant circuits are cited from the literature. Several cautions in the use of redundancy are given.

REVIEW: This paper can be useful for one who knows something about the subject already or just has curiosity about it. In such a short paper the treatment, even of limited subjects, is not complete, and the subject does change fairly often. There are some editorial problems which may be disturbing. The cautions concerning the use of redundancy are well founded. Some of the analyses imply that good/bad is a reasonable description of the element behavior. It may also happen, as in majority logic, that good/bad is not a sufficient description of the behavior; the analysis is then more complex.

In a private communication the author has emphasized that the paper as published was abstracted by EEE from the oral presentation and is much less complete than was the talk. ##

Serial Number 2497
ASQC Codes 711;712

TITLE: Interference fasteners for fatigue life improvement

AUTHOR: Clarence R. Smith (General Dynamics/Convair)

SOURCE: Presented at SESA Annual Meeting, Cleveland, O., 28-30 Oct 64, 12p, 7 refs. (Society for Experimental Stress Analysis, 21 Bridge Square, Westport, Conn.)

PURPOSE: To describe the use of interference fit fasteners for improving fatigue life.

ABSTRACT: The fatigue life of parts and structures can be improved considerably through the use of interference fasteners. The use of pressed-in-bushings in lugs and the use of tapered bolts for controlled interference are described. The benefits from interference fits stem from the reduction in cyclic load at the point of stress concentration. Because of interference fit the minimum load at the concentration is increased statically so that the net difference between the maximum load and the minimum load (cyclic load) at this point is reduced. The benefits obtained increase with increased interference until a maximum value is reached beyond which a further increase in interference fit results in no further gain. Extreme interference fits with straight shank bolts or bushings that are not chamfered on the end entering the hole initially may result in a loss in fatigue life due to the material being extruded ahead of the pin or bushing. Tapered bolts (Taper-Lok) are commercially available which make it possible to establish the interference fit with some degree of accuracy and without the problem of material extrusion.

Three different sets of experiments were made to evaluate the benefits of interference fits. The experiments compared open holes, holes filled with standard bolts (NAS 333 CPA-5), and holes filled with Taper-Lok bolts. In these tests, the specimens with Taper-Lok bolts were superior in fatigue at all loads. In some cases at long lives, the Taper-Lok bolts offered only slight improvement. In others the Taper-Lok bolt specimens were superior despite the fact that some of the loads in the spectrum were high enough to relax interference fit. The effect of interference fits although suitable for explaining the increase in life that results within the proportional limit, does not explain the effect of increase in life that occurs when plastic deformation should have removed the interference fit.

REVIEW: Probably the greatest increase that can be made in improving the fatigue strength of a riveted structure or lug joints is through the use of interference fits. If not used properly, interference fits may lead to problems of stress corrosion or a reduction in fatigue strength because of metal extrusion holes or plastic yielding at the hole. This paper gives an excellent illustration of mechanics of stress which account for the benefits of interference fasteners in the proportional range; however, it fails to shed any light on why improved life was obtained where the material at the hole yielded plastically. ##

Serial Number 2498
ASQC Codes 835;844

TITLE: Reliability of integrated circuits used in missile systems

AUTHORS: J. L. Easterday, R. G. Bowman, W. L. Gahm and B. C. Spradlin (Battelle Memorial Institute, Columbus, O.)

SOURCE: Report RSIC-330, prepared for Research Branch, Redstone Scientific Information Center, Directorate of Research and Development, U. S. Army Missile Command, Redstone Arsenal, Ala., under Contract No. DA-01-021-ARM-203(Z) by Battelle Memorial Institute, Columbus, O., 30 Oct 64, 60p, 24 refs. (AD-614 103)

PURPOSE: To provide estimated average failure rates and acceleration factors for microcircuits based on a compilation of available reliability data.

ABSTRACT: Failure rates for off-the-shelf silicon monolithic integrated circuits have been established on the basis of some 68 million part-test-hours of data. The observed failure rate from system and field operational tests was 0.012 %/1000 hr. At 125°C, the observed operating-life failure rate for laboratory tests was 0.087 %/1000 hr. Estimated failure rates (in %/1000 hr.) for laboratory storage tests range from 0.0055 at 25°C (extrapolated), to 0.23 at 150°C, and 2.4 at 300°C. In a new, fast-moving industry such as microelectronics, the failure rates obtained are out of date before sufficient life-test hours are accumulated to establish failure rates. Also, the failures may be caused by misapplication rather than as a result of inherent characteristics or faulty manufacturing processes. It is evident, however, that with proper care, failure rates on the order of 0.01 %/1000 hr. can be achieved at the present time. Analyses of the available data did not reveal significant differences among the capabilities of the manufacturers of integrated circuits, among the circuit configurations, nor among the circuit functions. It appeared that some such differences might exist, but the preponderance of tests in which no failures were reported prevented evaluating the relative merits of the microcircuits in terms of any of these three categories. Recommendations based on this investigation are that the use of failure rates to estimate microcircuit reliability be considered with a due amount of skepticism, that research be initiated to establish new and better techniques for reliability estimations, that work on procurement specifications be continued, and that a standard test procedure be established. (Authors in part)

REVIEW: The data were compiled with due consideration to the many existing limitations; however, they resulted in some potentially useful information. Those interested in reliability prediction and in reliability considerations of integrated circuits should read this report. Few vendors, contractors, or government agencies can support the testing needed to measure reliability under a diversity of conditions or have access to controlled operational data. Data collections and analyses of this sort are needed on a large-scale basis if the effectiveness of reliability predictions and other related evaluations are to be increased.

Other reports have shown considerable differences between vendors; see, for example, RATR 2467. ##

Serial Number 2499
ASQC Codes 802;871

TITLE: The development and evaluation of an improved electronics troubleshooting manual

AUTHORS: James P. Rogers and H. Walter Thorne (HumRRO Division No. 5, Air Defense, Fort Bliss, Tex., The George Washington University, Human Resources Research Office)

SOURCE: Technical Report 65-1, prepared for Office, Chief of Research and Development, The Department of the Army under Contract DA 44-188-ARO-2 (DA Proj 2J024701A712 01) by HumRRO Division No. 5 (Air Defense) Fort Bliss, Tex., The George Washington University, Human Resources Research Office, Mar 65, 51p, 12 refs. (AD-614 606)

PURPOSE: To develop a type of maintenance manual that would permit trained technicians to troubleshoot modern complex electronic equipment faster and more accurately.

ABSTRACT: Hypotheses were developed as to what information should be included in a troubleshooting manual and how the information should be presented and organized. These hypotheses were based on a review of the literature on troubleshooting, an analysis of the behavior involved in troubleshooting, determination of the information needed at each stage of troubleshooting, and a comparison of presentation techniques. The Nike Ajax missile and its associated test equipment were used as the primary system in developing hypotheses but other systems, larger and smaller, were examined also. To evaluate the hypotheses, an experimental manual was prepared for use in troubleshooting the Nike Ajax and its test equipment. This manual was evaluated by means of an objective test in which two groups of inexperienced technicians were required to locate malfunctions in the system. The experimental group used the standard schematic and functional diagrams and personal notes. Troubleshooting by the group using the improved troubleshooting manual was substantially faster and more effective than that by the group using conventional manuals. The improved manuals differ from conventional manuals in two ways. They present some information that is currently not supplied, and the information is organized according to when and how it is to be used in troubleshooting. The improved manuals do not differ significantly from conventional manuals in size, and they contain all of the information that is presented in current manuals used in troubleshooting. (Authors in part)

REVIEW: A facet of maintainability was investigated which has tended to be ignored in the search for methods of maintainability improvement. Note also that a guide has been developed for the preparation of manuals in accordance with the findings of this investigation, and it is referenced. The experimental manual was evaluated by what appears to be a limited evaluation relative to the large area of military electronics troubleshooting manuals. Some limitations of the evaluation are: a total of 16 technicians, a single type of system, inexperienced technicians, a vacuum tube design, and a total of 44 malfunctions. Thus, while the results of this evaluation are indeed favorable, it would seem that a broader evaluation would be appropriate before any large-scale change is initiated toward the different type of manual. ##

Serial Number 2500
ASQC Codes 711;713;716;
782

TITLE: Design and manufacturing techniques to prevent stress corrosion

AUTHOR: L. K. Crockett (North American Aviation, Inc., Space and Information Systems Div., Downey, Calif.)

SOURCE: Presented at the ASME Design Engineering Conference, New York, N. Y., 17-20 May 65, Paper 65-MD-45, 7p (*The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To present a general discussion on stress corrosion--causes and prevention.

ABSTRACT: A combination of three conditions must exist before stress corrosion cracking can occur. These are:

1. A metallurgical condition causing material susceptibility,
2. A sustained surface tensile stress, and
3. A corrosion environment.

Typically, stress corrosion occurs with almost total absence of normal corrosion. Its causes are mechanical and electromechanical. The metallurgical structure provides an electrochemical solution potential in the presence of a sustained stress and a corrosive environment. Susceptibility to stress corrosion cracking is a material consideration which can be influenced by material treatment and avoided by material selection. Not only applied stresses must be considered; even more important are residual stresses which result from heat treatment, fabrication, assembly, etc. Whether an environment is corrosive or not depends on the material.

A general discussion of some of the design factors which must be considered in order to avoid stress corrosion is included. Two commonplace examples of stress corrosion are presented along with a material selection and treatment case history.

REVIEW: This is a good general discussion of stress corrosion cracking; it is recommended reading for design engineers. Two of the author's statements, however, should be considered with caution:

1. "Because the stresses from heat-treatment are compressive in the surface and tensile in the core..."
2. "The residual stresses resulting from assembly procedures require either close-tolerance fitup or provisions for shimming and avoidance of interference fits."

Stresses resulting from heat treatment are not always compressive on the surface. For example, a decarburized carbon steel most probably will have high tensile stresses on the surface. Avoidance of interference fits may be desirable to minimize stress corrosion; however, the loss of interference fits may also severely reduce fatigue life (if the part is subjected to alternating stresses).
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Serial Number 2501
ASQC Codes 711;712;713

TITLE: Thermal-stress and low-cycle fatigue data on typical materials

AUTHORS: K. E. Horton, J. M. Hallander (American Standard, Advanced Technology Laboratories Div., Mountain View, Calif.), and D. D. Foley (Northrop Aircraft, Newbury Park, Calif.)

SOURCE: Presented at the ASME Gas Turbine Conference and Products Show, Washington, D. C., 28 Feb - 4 Mar 65, Paper 65-GTP-13, 15p, 15 refs. (*see RATR 2500)

PURPOSE: To present low-cycle fatigue data for either thermally strained or mechanically strained ferrous alloys used in nuclear reactors.

ABSTRACT: Thermal fatigue tests of the following materials were completed:

- Cold worked (18% reduction in area) 304-L stainless steel
- Annealed 304 stainless steel
- Annealed 403 stainless steel
- Normalized A302-B steel
- Annealed A387-D (Croloy 2-1/4) steel
- Annealed Incoloy 800
- Cold worked (27% reduction in area) Zircaloy-2
- Solution treated Rene 41

Detailed descriptions of the specimens, procedures, temperature gradients within the specimen, chemical analyses of the materials, and test apparatus are presented. The data are reported graphically and analyzed using theories developed by pioneers in the field--based on plastic strain-range measurements.

Fatigue life in strain-independent fatigue tests is determined by the ability of the material to withstand plastic strain. Fatigue tests where thermal strain is the independent variable are often independent of significant changes in mean temperature, hold time, and metallurgical variables such as grain size. The results from the constant temperature fatigue tests and thermal fatigue tests were generally the same. The superior fatigue resistance of a particular alloy condition exists over all failure ranges. However, alloys exhibiting superior fatigue resistance in one failure range often become inferior to other alloys in a different failure range. (Authors in part)

REVIEW: This paper gives a clear and concise account of the apparatus, facilities and procedures employed in the conduct of these tests. A good bibliography on the subject of thermal fatigue could be prepared from the references included. The thermal fatigue data pertaining to the various alloys would be useful to design engineers. Some of the conclusions would perhaps be useful to the research engineer concerned with thermal fatigue. ##

Serial Number 2502
ASQC Codes 711;712;713

TITLE: Effects of surface imperfections on the thermal-fatigue life of metals

AUTHORS: J. R. Kattus and A. C. Willhelm (Southern Research Institute, Birmingham, Ala.)

SOURCE: Presented at the ASME Gas Turbine Conference and Products Show, Washington, D. C., 28 Feb - 4 Mar 65, Paper 65-GTP-23, 12p, 19 refs. (*see RATR 2500)

PURPOSE: To present information on the effects of surface roughness and surface imperfections on the thermal-fatigue life of two steels and two superalloys.

ABSTRACT: Thermal fatigue tests of annealed type 304 stainless steel, Udimet 500 nickel-base alloy, 2.25Cr-1.0Mo steel, and heat treated X-45 cast cobalt-base alloy with four variations in surface finish were conducted. The surface finishes evaluated were:

1. Electropolished after machining to < 32 RMS,
2. 1000 RMS rough machined,
3. Point defects formed by 136-degree-diamond pyramid impression in electropolished surfaces, and
4. Circumferential notches in electropolished surfaces.

Chemical analyses, mechanical properties and heat treatment of materials are listed. A complete description of the test apparatus and test variations--temperature gradients and strain gradients in the specimen gage length--are also included. Notched specimens failed at the notch, and specimens with point defects generally failed at the defects. The majority of the remaining specimens failed in the necked sections.

The results of the thermal fatigue tests were scattered and inconsistent, but statistical analyses indicate that surface roughness and imperfections decrease thermal fatigue life. In general, continuous shallow notches or cracks perpendicular to the direction of thermal stresses are more damaging to the thermal fatigue life of a material than general surface roughness or isolated point defects. Under the conditions of these tests, superalloys demonstrated superiority over common steels.

REVIEW: This paper is well written; it handles the material in a clear, concise manner. The results of this investigation will be of interest to the design engineer concerned with surface finishes and temperature fluctuations. In general, these results should establish useful guide lines and first-order approximations regarding thermal fatigue life. ##

Serial Number 2503
ASQC Codes 824;844

TITLE: Skewed load-strength distribution in reliability

AUTHOR: Eberhard H. Baur (Aerojet-General Corp., Research and Advanced Technology Div., Liquid Rocket Plant, Sacramento, Calif.)

SOURCE: Report 9200-6-64, Aerojet-General Corp., 10 Feb 64, 19p

PURPOSE: To introduce a particular skewed Normal-like distribution for stress or strength and to solve for the failure probability.

ABSTRACT: The skewed distribution is made up of two "halves," each a Normal distribution, but with different variances. The "halves" are joined at the mode of each. The stress-strength model of failure is then used to calculate the probability of failure, viz., the probability that stress > strength. An approximation is used which is shown to have negligible effect on the accuracy. An example shows the difference between taking the skewness into account and ignoring it.

REVIEW: The actual mathematics in this report appears to be accurate and the analysis of the model is useful, at least from the viewpoint of theoretical considerations. The practical utility of the model is something else again. Deciding that the actual distribution is in fact adequately represented by this model--rather than some other tractable model may be virtually impossible. It should also be noted that only the case in which the true parameters are known is treated, but it is suggested that the parameters be estimated by approximate techniques from a sample.

All in all, it would be well to wait, before using this model, until further analysis is available on distinguishing whether or not a sample is from this or another distribution. ##

Serial Number 2504
ASQC Codes 832;872

TITLE: Maintainability prediction: methods and results

AUTHORS: Joseph W. Rigney and Nicholas A. Bond (University of Southern California, Department of Psychology)

SOURCE: Technical Report No. 40 prepared for Personnel and Training Branch, Psychological Sciences Division, Office of Naval Research under Contract Nonr-228(22) by Department of Psychology, University of Southern California, Jun 64, 122p, 80 refs. (AD-603 241; OTS $4.00)

PURPOSE: To take stock of the major maintainability prediction methods and to estimate their effectiveness.

ABSTRACT: A history of the maintainability concept is presented; 1953 is selected to date the beginning of the literature. Current trends caused mainly by the new military specifications are to emphasize indexes of maintenance effectiveness and prediction of maintenance characteristics. Various predictive approaches have appeared, but the field remains chaotic. The usefulness of mean-time-to-restore as typically the sole maintainability index is questioned; clear assurance that restoration will be completed within a reasonable time was found to be of more concern to Naval maintenance officers. General measurement considerations are introduced as background, with emphasis on relevance, measurement error, ability to explain, and demonstrable significance. A brief excursion into decision theory provides further orientation on the notion of the utility of maintainability prediction, which is a more advanced notion than simple validity. Six different approaches to maintainability prediction are reviewed: (1) extrapolation from historical maintainability data, (2) time synthesis of maintenance sub-tasks, (3) checklists which score the degree of conformity to presumably good design practices, (4) simulation methods such as laboratory or computer models, (5) expert judgment, and (6) matrix tabulations of symptoms and failure modes. Selection of a particular technique is discussed; it often boils down to the informal estimate of the utility of the method. Some of the problems are cited that the next generation of maintainability prediction methods will have to deal with more satisfactorily. Conclusions are itemized. (Authors in part)

REVIEW: A general overview of maintainability prediction is given in this report. The viewpoint (and the terminology) is that of industrial psychology rather than engineering. The report is highly professional relative to the general "...ability" literature, and is an excellent example of the basic type of work which is needed in the "...abilities." Those persons interested in maintainability prediction will want to read this report thoroughly, and the 16 conclusions which are itemized would be instructive to users of RATR. Many of the basic points and criticisms which are made here are applicable also to reliability and effectiveness predictions. ##

Serial Number 2505
ASQC Codes 838;870

TITLE: Current concepts and issues of in-space support

AUTHOR: Sidney I. Firstman (The RAND Corporation, Santa Monica, Calif.)

SOURCE: Report P-2966, The RAND Corporation, Santa Monica, Calif., Aug 64, 11p (AD-606 580; CFSTI prices: Hard Copy $1.00, Microfiche $0.50)

PURPOSE: To describe the in-space support concepts of in-flight repair and of switching redundancy, and to discuss factors related to their applicability.

ABSTRACT: The operational domains considered in this report are the in-flight and lunar mission phases of the next set of manned space missions, i.e., Gemini and Apollo. Equipment reliability resulting from current technology makes in-flight maintenance necessary. Operational and design factors highly influence the selection of a maintenance concept. Spaceflight experience to date indicates that weightlessness should not preclude in-flight maintenance, and time would be available in long-duration coasting periods. However, for time-critical periods, failure remedies should be rapid and not require diversion of the crew. Other operational and design factors discussed are humidity, design flexibility, and weight. Confidence and diagnostic testing equipment are needed to indicate the presence of a failure and to ascertain its location. Two general approaches for this checkout system are manual and automated. Some of the more significant factors which influence the selection of a checkout system are weight, checkout time, multiple-use computers, and crew skills. Each of these is discussed briefly.

REVIEW: An overview of the basic considerations of spaceflight maintenance is presented. The report is brief and well written in simple, semi-technical terms and makes easy reading for someone seeking basic orientation on this topic. It is all qualitative discussion, containing no illustrations, numbers, or references. ##

Serial Number 2506
ASQC Codes 431;824;837

TITLE: Strength margins for combined random stresses

AUTHOR: James R. Fuller (The Boeing Company, Airplane Division, Renton, Wash.)

SOURCE: Document No. D6-2561 TN, The Boeing Company, Airplane Div., P. O. Box 707, Renton, Wash., Oct 64, 20p

PURPOSE: To analyze the effects of random loading on flight vehicles.

ABSTRACT: Statistical mechanics procedures are widely used in the aerospace industry to analyze the effects of random loading on flight vehicles. However, while existing procedures give the structures analyst real insight into the loads to which various parts of the vehicle are subjected, they do not provide the stress analyst with a usable procedure for evaluating the structural stresses on an element under combined random stresses. The procedure developed here permits the determination of the mean number of times per unit time that various strength margin levels are exceeded. (Author in part)

REVIEW: This is a rather technical paper which obtains, using somewhat heuristic methods, the mean number of crossings of a curve in the xy-plane by a two-dimensional random process. Two references to related work are cited in the paper. The results are specialized to Gaussian processes and fairly explicit answers are obtained for special curves. ##

Serial Number 2507
ASQC Codes 801;831

TITLE: Concepts relative to system effectiveness

AUTHOR: Julius Widrewitz (Rome Air Development Center, Research and Technology Div., Reliability Branch, AFSC, Griffiss Air Force Base, N. Y.)

SOURCE: Technical Memorandum No. EME-TM-64-4, Reliability Branch, Rome Air Development Center, Research and Technology Div., AFSC, Griffiss Air Force Base, N. Y., Jun 64, 19p (AD-609 637)

PURPOSE: To present a definition of and a mathematical model for the measurement of system effectiveness which incorporate improvements over present practices.

ABSTRACT: Two concepts currently missing in the usual definition of system effectiveness are (1) a system does not necessarily succeed or fail in accomplishing any of its missions, and (2) upper and lower limits exist with regard to useful mission performance. Examples of a simple-minded system are presented to illustrate these concepts. It is suggested that an effectiveness measure be an average value which is normalized to insure that the value lies between 0 and 1. Extensions are made to extend this measure to include limits of useful performance and to generalize it for multi-function systems. In general non-mathematical language, system effectiveness is defined as a merit value which measures the extent to which a system performs a set of specified functions (or missions) with stated importance factors, given that certain minimum mission performance and effectiveness levels are met. (Author in part)

REVIEW: The two limitations cited in this report are certainly valid. This discussion is compatible with current thinking on system effectiveness concepts, as exemplified by the recent WSEIAC report (see RATR 2200). No mention is made of any applications of this model for real-world decision-making. Thus, some ideas are presented here which require experimental application and further study. ##

Serial Number 2508
ASQC Codes 871;872

TITLE: An extension of ARINC's maintainability prediction

AUTHOR: James Alfred Cline (Lehigh University, Bethlehem, Pa.)

SOURCE: Thesis presented to the Graduate Faculty of Lehigh University in candidacy for the degree of Master of Science, 1964, 78p, 23 refs.

PURPOSE: To develop a complete complement of Elemental Activities for ground electronic equipment maintenance at the base shop level.

ABSTRACT: A brief historical review is given of six efforts to quantify maintainability. The most recent technique, which is for the prediction of airborne equipment maintenance, was developed for the Air Force by ARINC. The initial phase of extending this technique to ground electronic equipment is the development of the Elemental Activities which partition total maintenance time into sub-elements. A complement of 54 Elemental Activities was developed to cover all functions performed by technicians during the active repair portion of ground electronic equipment. These activities are broadly similar to, but differ in detail from the previously developed activities for airborne equipment. Mean time used for the performance of an activity was also investigated. An analysis of variance of two activities indicates there is no variation in a mean time from system-to-system, which is contradictory to an assumption of the basic ARINC work. Data used in this study were collected at Olmstead A. F. Base, Pa. from a sample of a total population of 2,000 different equipments. Appendices include raw data and some related data collection information.

REVIEW: The prediction technique used as a starting point in this thesis is found in the report covered by RATR 2354. Relative to the other theses which have been appearing in the "...abilities," this one is different in that it has pursued a detailed area at the real-world level, including the development of some original data. Much of the detail procedure is presented, and perhaps other uses may be found for these data. There is no concise summary or conclusions and the thesis does not lend itself to quick reading. The information presented here would be of definite value in the application of the referenced technique to ground electronic equipment. ##

Serial Number 2509
ASQC Codes 871;872

TITLE: Background and synopsis of the corrective maintenance burden prediction procedure

AUTHOR: --

SOURCE: Report No. 64-34, Federal Electric Corporation, Contract Nonr 3821(00), New Development Research Branch, Personnel Research Division, Bureau of Naval Personnel, 31 Jan 64, 17p

PURPOSE: To present a synopsis of the Corrective Maintenance Burden Prediction Procedure (CMBPP) and indicate its potential applications.

ABSTRACT: A means for determining the maintenance time by skill level required to perform electronic corrective maintenance on an equipment or system is provided by the CMBPP. It is based on the task time intervals developed from fleet data and on human factors considerations through which the maintenance technician accomplishes tasks. These considerations resulted in a chart that details the level of complexity which can be encountered in performing the various maintenance tasks and the skill required to perform the task. The six basic steps which an analyst would go through in using the CMBPP are outlined. By comparing the skills required with the Navy's maintenance personnel inventory, the availability of the required personnel can be determined. The personnel implications of the CMBPP were effectively demonstrated when the procedure was applied to two equipments. The procedure represents improvements over present methods and is adaptable to automatic data processing techniques. In the long range, the procedure has the potential of becoming the basis for a specification which would allow the Navy to impose maintenance burden parameters in the development of equipment and to measure whether the delivered designs meet the specified requirements. However, before a meaningful specification which imposes overall maintenance personnel manning requirements can be implemented, it will be necessary to develop similar procedures for bench and preventive maintenance. (Author in part)

REVIEW: In a concise essay style this report presents the results of the study. Of highest interest from the design viewpoint is the possibility of determining at an early time the effect of alternate approaches on personnel requirements. It is stated in this report that the procedure was effectively demonstrated by its application to two different radars. Apparently the demonstration consisted of making predictions and did not include the actual measurement of the maintenance personnel burden for validation of the predictions. The report contains no references other than the contract number. More detail on the study and procedure will be found in [1].

REFERENCE: [1] Predicting the corrective maintenance burden, Volumes I and II, by B. H. Manheimer, S. R. Goldberg, and G. L. Pfeiffer, prepared for New Developments Research Branch, Personnel Research Division, Bureau of Naval Personnel by ITT Federal Electric Corporation, Paramus, New Jersey, 30 Apr 63. ##

Serial Number 2510
ASQC Codes 831;872;882

837;850

713;720;837

836;844

817;820;844

TITLE: Reliability prediction for degradable and non-degradable systems

AUTHORS: Sheldon J. Einhorn and Morris Plotkin (AUERBACH Corp., Philadelphia, Pa.)

SOURCE: Technical Documentary Report No. ESD-TDR-63-642, Directorate of Computers, Electronic Systems Division, AFSC, USAF, L. G. Hanscom Field, Bedford, Mass., prepared under Contract No. AF 19(628)-2824 by AUERBACH Corp., Philadelphia, Pa., Nov 63, 38p, 6 refs.

This is the final report on the contract referenced in the paper covered by RATR 2172, and contains little that is not in that paper.

TITLE: Apollo reliability by demonstration or assessment

AUTHOR: Roy B. Carpenter, Jr. (North American Aviation, Inc., Downey, Calif.)

SOURCE: North American Aviation, Inc., Downey, Calif., 1 Mar 64, 8p

This report is the same as the paper covered by RATR 1283.

TITLE: Evaluation of the effects of manufacturing processes on structural design reliability

AUTHOR: Paul Kluger (Aerojet-General Corp., Sacramento, Calif.)

SOURCE: Report 9200-19-63, Aerojet-General Corp., Sacramento, Calif., 22 Oct 63, 16p

This report is the same as the paper covered by RATR 1285.

TITLE: Failure studies help engineers predict jet engine reliability

AUTHOR: Gerhard Reethof (Large Jet Engine Dept., General Electric Company)

SOURCE: SAE Journal, vol. 72, May 64, p. 100-102

This article is based on the paper covered by RATR 1977.

TITLE: Get to know reliability control

AUTHORS: John de S. Coutinho (Grumman Aircraft Engineering Corp.), Lionel Levy (Aerospace Corp.), and Fred E. Marsh (Boeing Co.)

SOURCE: SAE Journal, vol. 72, Aug 64, p. 32-39

This article is based on the book covered by RATR 1593-1600. ##

Serial Number 2511 -1
ASQC Code 813

I. TITLE: Product assurance at RCA

AUTHOR: F. L. Ankenbrandt (Radio Corporation of America)

II. TITLE: The ideal corporate quality assurance function

AUTHOR: E. F. Dertinger (Raytheon Company, Equipment Div.)

III. TITLE: System effectiveness critical activities

AUTHOR: Leslie W. Ball (The Boeing Company, Seattle, Wash.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 1-5, p. 6-15, p. 16-21 (*sponsored by Reliability Group of IEEE, Electronics Division of ASQC, SNT, and IES; Proceedings available from Editorial Department, IEEE, 345 East 47th Street, New York, N. Y., 10017; price $5.00)

PURPOSE: To examine and clarify some current topics in reliability program planning and management.

ABSTRACT: I. The objectives of product assurance, such as customer satisfaction and cost reduction by assuring that the job is done right the first time, are found throughout the range of RCA activities. Commercial customers have no formal programs, but have the toughest test of all in actual field use and express their preference in the nation's market place. Government customers, on the other hand, are more cooperative and know when the state of the art is being pushed. The organization of RCA and the approach to product assurance within the various major groups are briefly described. When the facade of organizational variations is penetrated, a great similarity exists among the techniques employed in the groups. A give and take exists between the techniques used in the two types of business, which leads to universal adoption of those techniques which have proven their usefulness.

II. The term "quality assurance" is used to include reliability, components, quality control, and other specialist activities which have product quality considerations as a prime responsibility. A corporate quality assurance staff will enhance a company's chances of producing better proposals, producing products of higher quality/reliability, and simultaneously reducing total costs. There are ten activity areas--in addition to the customary policy, procedures, and audit functions--in which the corporate quality assurance function should be effective. These areas are: (1) proposals and advertisements, (2) specifications, (3) keeping company image bright, (4) keeping abreast of industry, (5) intra-company technique exchanges, (6) parts standardization, (7) cost reduction, (8) training, (9) consultation, and (10) public

relations. Each area is described and the tasks are visualized for the ideal corporate quality assurance staff.

III. The term "system effectiveness" which has come into widespread use during the past few years has both a quantitative and a program-management aspect. It is not enough to be able to predict, require and measure; design and manufacturing activities must be controlled so as to achieve the predicted quantitative values. At the present time, both customer quantitative and program requirements are established separately for each contributing characteristic, such as reliability. This can lead to incompatible quantitative requirements, and it does lead to overlapping activity requirements. Program requirements for each characteristic contributing to system effectiveness should be derived as subordinate parts of an overall system effectiveness assurance management system. The essential foundation for such a system is a logically developed list of System Effectiveness Critical Activities covering reliability, maintainability, quality, and all other equipment characteristics. A basis for such a list is presented.

REVIEW: Give and take between groups serving commercial and government customers is mentioned in I, but the specifics cited pertain mainly to the compatibility of the groups. Design review, integrated testing, quality cost data, and cost effectiveness are said to have long been an integral element of commercial operations, which are being adopted by government operations. The commercial groups are said to not want the formal functions of government groups, because the luxury of excessive staff operations cannot be afforded. Thus the commercial customer, who does not try to understand the supplier but rather expresses his attitudes in the market place, apparently has forced methods of supplier operation which are truly cost-effective. Hopefully the government customer is moving in this direction through such practices as incentive contracting and total package procurement.

The definition of quality assurance used in II describes what is more popularly termed product assurance in the government-oriented companies. The author notes in a private communication that, even though his title is Product Assurance Manager, he does not assure anyone of a product, but rather he tries to assure the customer of a certain level of quality in the product. A staff function as described here indeed contributes to the strength of the large, multi-division organization, and any company which does not have this should consider establishing one. It should be noted that much can be done with a very small staff.

The currently-popular system effectiveness viewpoint is shown in III to substantiate the need for true integration of the various "...ability" program tasks. The details of the reliability and other program tasks are unaltered by the effectiveness viewpoint, in that no new tasks are required. Use of the list of activities which is presented will provide confidence that critical activities will be identified. ##

Serial Number 2512
ASQC Codes 837;843;844

TITLE: Implementing computer methods for circuit analysis

AUTHORS: A. Secor and J. R. Merritt (Collins Radio Co., Cedar Rapids, Ia.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 32-44, 7 refs. (*see RATR 2511)

PURPOSE: To summarize the experience in the derivation and application of computer circuit analysis techniques at Collins Radio Company.

ABSTRACT: The objectives of a properly-planned computer analysis are to increase stability, reduce parts costs, reduce design changes, improve producibility, and improve the interchangeability of electronic circuits. The foremost requirement in assuring the ultimate success of the analysis programs is to support adequately the programs with the correct organization and sufficient computer facilities. A company should first plan a programming phase rather than try to derive and implement programs simultaneously. Criteria are given which should guide program development. Procedures are cited for performing the analysis properly. The types of analysis which have been the most usable are parameter variation analysis, worst case analysis, and statistical analysis. Each type is described. An example is given to illustrate the methods. (Authors in part)

REVIEW: For some years there has been much discussion in reliability circles of this sort of analysis, but few serious applications have appeared. This paper indicates that another organization has made a serious effort toward applications. The extent to which these analyses have been tried, e.g. the number and types of circuits analyzed, is not given, nor are any specifics on how well the objectives were achieved. The various aspects of circuit performance variation analysis which are cited here bring the picture together in an introductory manner. The paper would be of most value to someone thinking about this for the first time by showing the areas which must be considered. The first author has pointed out in a private communication that those considering initial implementation should heed particularly the broad procedural steps on page 34, as his experience with subcontractors indicates that objectives achieved are largely proportional to the degree of adherence to these guidelines.

Some statements in the paper are made without qualification although they are not literally true. For example, "Moment Method. This method assumes that all parts parameters and all circuit performance characteristics have a normal distribution." The moment method includes higher-order moments as well as correlations and can be fitted to other than normal distributions. ##

Serial Number 2513
ASQC Codes 837;843;844

TITLE: The IBM Electronic Circuit Analysis Program (ECAP)

AUTHORS: Howell N. Tyson, Jr., Gerald R. Hogsett, and Donald A. Nisewanger (International Business Machines Corp., Data Processing Div., Los Angeles, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 45-65 (*see RATR 2511)

PURPOSE: To describe an integrated system of digital computer programs designed to aid the electrical engineer in the design and analysis of electronic circuits.

ABSTRACT: The Electronic Circuit Analysis Program (ECAP) can produce DC, AC, and/or transient analyses of electrical networks from a description of the connections of the network (the circuit topology), a list of corresponding circuit element values, a selection of the type of analysis desired, a description of the circuit excitation, and a list of the output desired. The engineer requires neither a knowledge of the internal construction of the system of programs, nor of computer programming techniques to use ECAP effectively. It is, however, necessary that the user be acquainted with the methods of communication with ECAP. These include (a) the technique of describing a circuit to the program, (b) the specification of the type of analysis desired, and (c) the results. ECAP recognizes the following standard electrical circuit elements: (DC) resistor, fixed voltage source, fixed current source, dependent current source; (AC) resistor, capacitor, inductor, mutual inductance, fixed rms voltage source, fixed rms current source, dependent current source; (transient) resistor, capacitor, inductor, fixed or time dependent voltage source, fixed or time dependent current source, dependent current source, switch. Any electrical network that can be constructed from any or all of the different elements in the set can be analyzed. The program can handle electrical networks that contain as many as 20 nodes (not including ground nodes) and 60 branches. ECAP is written in FORTRAN II-D, and is designed to be used in conjunction with the IBM 1620 Data Processing System. However, ECAP can easily be converted to FORTRAN IV so that it can be run on the IBM 7040, 7044, 7090 or 7094 computers. Several examples that involve the use of equivalent circuits are included in this paper. Worst case, standard deviation, and sensitivity calculations can be obtained at the user's option.

REVIEW: The program has apparently been developed to an extent which essentially reflects earlier approaches which are suitable for practical applications. This paper does a good job of describing the program, including many helpful figures and illustrations. Some effort will be required of the engineer in developing equivalent circuits for diodes and transistors according to the rules of the program, but this should not be any real handicap. Actual experiences with the program are not cited, such as how extensively it has been used, the costs of use, and what contributions it has really made when used. ##

Serial Number 2514
ASQC Codes 831;843;844;
874

TITLE: Computer studies of abnormally operating circuits

AUTHORS: D. A. Hausrath and R. Ranalli (Autonetics, a Division of North American Aviation, Inc., Data Systems Div., Anaheim, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 66-86 (*see RATR 2511)

PURPOSE: To present a new computer program utilizing nonlinear analysis techniques to generate failure mode data from abnormally operating circuits.

ABSTRACT: The success of nonlinear modeling made possible, for the first time, realistic predictions of the behavior of electronic circuits operating in abnormal modes. Such abnormal modes of operation are high- or low-power supply voltages, shorted terminals, and operation with failed components. This paper first considers the general method of nonlinear solution which makes analyses of abnormally operating circuits possible. The second consideration is the results obtained when this nonlinear solution technique is incorporated into a computer program which evaluates the behavior of a circuit as a result of catastrophic part failure modes. The third consideration is the response of an integrated circuit to external abnormal conditions. Finally, the construction of greatly improved fault isolation procedures are discussed. The resulting information can be applied to provide increased equipment reliability, better maintainability, and potentially large reductions in manufacturing test and repair time for the producer, as well as reduced diagnosis and repair time for the customer. More valid reliability mathematical models for circuits also become available. Some examples are presented which show interesting results. (Authors in part)

REVIEW: The computer techniques used in this paper for evaluating the effects of part failure modes and for obtaining fault isolation procedures constitute fresh approaches in reliability analysis. They appear to have practical value, and are an excellent example of using a computer to do studies which are impractical to do otherwise. The approaches presented here are developed without any use of probability and statistics; thus they are directed toward uncovering potential failure modes and do not become entangled in reliability indices. The paper is easy to read and well illustrated; no references are given. It should be of value to those interested in practical reliability and maintainability analysis of electronic circuits. ##

Serial Number 2515
ASQC Codes 824;831;843

TITLE: Computer technique for estimating system reliability

AUTHORS: Stuart A. Weisberg and John H. Schmidt (Grumman Aircraft Engineering Corp., Bethpage, Long Island, N. Y.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 87-97 (*see RATR 2511)

PURPOSE: To describe a computerized technique for obtaining a prediction of system reliability for complex systems.

ABSTRACT: In evaluating the possibilities for failure of equipments constituting a system there will be as many time intervals for the first failure of a given equipment as there are phases of the mission in which the equipment has a positive failure rate. Combining all the possibilities for failure of each equipment gives the possible system outcomes. The number of possible outcomes is much too large to consider in attempting to evaluate the system mission success reliability.

A method which does offer a workable solution gives a lower and an upper bound estimate to mission success reliability; it permits operational doctrine, functional degradation, and functional redundancy of equipments to be incorporated into the model. The procedure has been mechanized by a Fortran program for the 7094 computer. The main portion of this paper is concerned with a description of this computer program. An approach is also given for the estimation of crew-safety probability using the computer program. A method for incorporating degraded modes of operation into the mission-success and crew-safety models is explained. It is not necessary for those using the program to have any knowledge of the mathematics involved in the estimation technique, only a knowledge of the system being evaluated. The program allows flexibility in input and output, and does not generally require an excessive amount of computer time. It has proven successful when applied to various aero-space systems.

REVIEW: The basic approach to reliability prediction described in this paper is simply that of using a logic relationship along with discrete reliability indices. When a system becomes large and there are many operational phases then this conventional approach to reliability prediction becomes unwieldy. By using the combination of a lower bound or conservative reliability prediction and a computer, a technique for applying the conventional approach to reliability prediction of complex situations is developed. Another way of making reliability predictions for complex systems is to use a Monte Carlo approach; see, for example, RATR 1192. It is highly desirable that alternate approaches to Monte Carlo, such as that described here, be pursued. The paper is well done; terms are clearly defined and simple illustrations are given. It should be noted in the example of Appendix II that what is called the success model in Step B must be reduced by the minimal success paths in order to obtain the true reliability model in Step H. On page 89, the final Phase 1 success path, (1, 2, 3, 4, 5, 6), apparently should be (1, 2, 3, 5, 6), (4, 5, 6). ##

Serial Number 2516
ASQC Codes 814;821;872

TITLE: Some elements of planned replacement theory

AUTHORS: C. F. Bell, M. Kamins and J. J. McCall (The RAND Corporation, Santa Monica, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 98-117, 25 refs. (*see RATR 2511)

PURPOSE: To investigate the problem of determining the age at which an operating part in a missile or aircraft should be replaced with a new part.

ABSTRACT: This study investigates replacement policies for aircraft and missile parts. The appropriate policy for a part depends on its failure characteristics and the cost of an in-service failure relative to the cost of a planned replacement. For planned replacement to be worthwhile, the part must display a wear-out characteristic (a failure rate increasing with time); and the cost of an in-service failure must be greater than the cost of a planned replacement.

For parts with a constant failure rate the optimum replacement policy--to minimize expected cost per unit time--is: Never plan to replace before failure, regardless of the problems caused by in-service failures. A new part is likely to be no better than a serviceable part of any age. On the other hand, many parts have an increasing failure rate; the age for replacement depends on the cost ratio of in-service failure to planned replacement. For a given aging effect, the higher the relative cost of an in-service failure, the shorter should be the planned-replacement interval. Similarly, for a given in-service failure cost, the more severe the aging effect the shorter the replacement interval. Specific replacement policies are obtained for parts which have the Normal, Log-Normal, or Weibull failure distributions. The failures of many aircraft parts fit one of these distributions. A computational routine has been developed to determine the optimum planned-replacement interval for parts whose failure characteristics are best described by discrete distributions.

The gross savings from following a planned-replacement policy rather than a replace-at-failure policy have been computed for the above distributions. When the relative cost of an in-service failure is large, such savings can be significant. The net value of a planned-replacement policy is the gross savings less the additional cost of administering the policy.

REVIEW: This is a well-written, well-documented paper on planned replacement. It is concerned with the application of existing methods, and helps to bridge the gap between sophisticated mathematics and applications in this topic area. The discussion can be followed by a reader familiar with fundamental statistics, and the 25 references cited will serve the needs of those who wish to go into more detail. Illustrative tables and charts are included, and the major conclusions are clearly summarized. ##

Serial Number 2517
ASQC Codes 814;871

TITLE: Cost-effective maximum times for aircraft engines

AUTHOR: John L. Madden (Operations Analysis Office, Hq. Air Force Logistics Command, Wright-Patterson Air Force Base, Dayton, O.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 118-124 (*see RATR 2511)

PURPOSE: To describe a method for determining optimal maximum operating times for aircraft engines, and its application by the USAF.

ABSTRACT: A mathematical model for determining optimal maximum operating times for aircraft engines and its application by the United States Air Force is described. Maximum operating times are administratively established, defining the total number of operating hours that engines are permitted to accumulate before overhaul is mandatory. An optimal maximum time is one for which long-run total system costs are minimized. Costs include operating and maintenance charges as well as penalties for loss of aircraft effectiveness.

The model uses discrete failure rates that can vary by engine age since new or last overhaul. The failure rates are used to forecast the number of engine repairs that are needed for a given program period, for each maximum time policy being considered. Repairs considered are those which require the engine to be removed from the aircraft, and include base level repair in which only the defective parts are replaced without changing engine age since last overhaul, and depot level repair in which a complete overhaul is performed and the engine age since last overhaul is reset to zero.

All significant system costs associated with each repair action are estimated. These include average removal and reinstallation costs, costs of transporting the engine to and from the repair facility, and repair costs (materials and labor). In addition, the costs of extra spare engines to support the higher frequency of removal when low maximum times are used is considered as well as the estimated costs of downtime and risks associated with unscheduled engine failures. Downtime costs reflect estimates of the lost utility of the aircraft and risk costs reflect the risks of mission abort, accidents, injuries, or deaths that may be caused by permitting engines to operate until failure.

Total system costs are then determined by pricing out the penalties and repair actions with the average cost factors for each maximum time policy. By iteration, the least cost maximum time can be found. (Author in part)

REVIEW: This paper illustrates the application of previously-developed results on planned replacement to a specific system--an aircraft engine. References to the previous results are cited, and should be consulted for background and technical detail. The method would be applicable to any system in which failure rate is known to increase with age and for which the necessary input data are available. It appears to be a useful management tool for quantifying the risks and costs associated with maximum-time policy decisions. ##

Serial Number 2518
ASQC Codes 844;864

TITLE: Component performance and flight operations of the X-15 research airplane program

AUTHORS: James E. Love and William R. Young (NASA Flight Research Center, Edwards, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 125-132 (*see RATR 2511)

PURPOSE: To discuss and analyze the system and component failures that have occurred during the X-15 program.

ABSTRACT: The X-15 research airplane program has provided data on component performance while performing research in hypersonic flight, sub-orbital flight, and piloted re-entry environments. This paper discusses and analyzes the failures in the engine system, the auxiliary power system, and the propellant system. Failures of shelf-stock components prior to their installation on the flight vehicles are also examined.

The X-15 program has demonstrated that a failure rate expressed as a rate per flight is a more realistic method of reporting component performance for experimental vehicle programs than the statistical sampling and failure distribution techniques in popular use. During the program, component failures have been more numerous than reliability predictions indicated. A small number of components have been responsible for most of the failures regardless of system complexity. There has been no appreciable decrease of failures with time.

The program has also demonstrated that the industry-wide problem of excessive defects of shelf-stock components can be improved by close cooperation between the user and the manufacturer. This approach must include a realistic and timely method of reporting failures and a constant effort to impress individuals with the importance of their personal responsibility in handling components. (Authors in part)

REVIEW: This is a brief report of field-performance of certain systems on the X-15 program. Reliability data from such programs can be very valuable in providing a realistic picture of component performance under operational conditions. These data point the way to component improvements, examples of which are found in the appendix to this paper. ##

Serial Number 2519
ASQC Code 872

TITLE: Maintainability diagnosis techniques

AUTHOR: J. de Corlieu (C.F.T.H., Bagneux, France)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 133-142 (*see RATR 2511)

PURPOSE: To describe some diagnosis techniques which can be used whenever the existence or the cause of a failure is not obvious to a qualified operator.

ABSTRACT: Diagnosis is defined as the art of determining the existence, the location and the nature of any actual and potential failure of an equipment, along with all the causes and consequences of that failure. A diagnosis technique is a choice of tests, and of their possible results, in the set of all tests which could be performed on the equipment. Four diagnosis techniques are discussed which have their own distinctive features of interest. In the entropic method, the equipment is successively divided into two groups of assemblies totalling equal failure rates until the failure is located. The decreasing probability method checks the assemblies in the decreasing order of their failure rates. The linear analysis technique provides a way of obtaining a diagnosis which does not require any other access to the circuits than those existing for its normal operation. The theory of sets is used to establish a technique for equipment accepting inputs and producing outputs at discrete time intervals. Some examples are given to illustrate these techniques. The necessity to consider diagnosis methods at the design stage is emphasized.

REVIEW: The readability of this paper understandably suffers from an author writing in other than his native language. However, this is just a distraction. The examples and illustrations are particularly useful. Those persons concerned with establishing maintainability features will want to insure they are aware of the techniques cited here. ##

Serial Number 2520
ASQC Code 814

TITLE: Cost-effectiveness analysis: an appreciation

AUTHOR: E. S. Quade (The RAND Corp., Santa Monica, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 143-148 (*see RATR 2511)

PURPOSE: To clarify the nature and scope of cost-effectiveness analysis and to point out its proper role as an aid to decision-making.

ABSTRACT: A cost-effectiveness analysis is an analytic study designed to assist a decision-maker to identify a preferred choice from among possible alternatives. It is characterized by a systematic and rational approach, with assumptions made explicit, objectives and criteria clearly defined, and alternative courses of action compared in the light of their possible consequences. An effort is made to use quantitative methods but computers are not essential. What is essential is a model that enables expert intuition and judgment to be applied efficiently. The method provides its answers by processes that are accessible to critical examination, capable of duplication by others, and, more or less, readily modified as new information becomes available. And, in contrast to other aids to decision-making, which share the same limitations, it extracts everything possible from scientific methods, and its virtues are the virtues of those methods. At its narrowest, cost-effectiveness analysis offers a way to choose the numerical quantities related to a weapon system so that they are logically consistent with each other, with an assumed objective, and with the calculator's expectation of the future. At its broadest, it can help guide national policy. But, even within the Department of Defense, its capabilities have as yet to be fully exploited, and it has barely entered the domain of the social sciences. (Author in part)

REVIEW: This is a readable essay on the fundamental aspects of cost-effectiveness analysis. No equations or numbers are used. The points which are made are illustrated with simple examples. Limitations are given coverage equal to that given to the virtues. The tone of the essay reflects meaningful experience. ##

Serial Number 2521
ASQC Codes 831;872;882

TITLE: The system effectiveness concept

AUTHOR: Everett L. Welker (General Electric/TEMPO, Santa Barbara, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 149-161 (*see RATR 2511)

PURPOSE: To focus attention on the elements of the system effectiveness concept, their interrelationships, and their uses in management decisions.

ABSTRACT: A logical structure is developed from the three elements of system effectiveness--use requirements, equipment condition, and performance characteristics--related to time as a base. Definitions are presented for the time categories, operational time and active repair time, and for the concepts, operational readiness and maintainability. Problems of prediction as applied at the research and development stage are discussed. The ways in which management can use this system effectiveness structure in formulating decision criteria are examined. Several uses are given of these concepts to isolate and quantify areas of trouble and to assign responsibility for accomplishing improvement. Much remains to be done in the quantitative analysis of system effectiveness and the associated concepts. Methods and data are particularly limited on repair times, free times, availability, design adequacy, types of mathematical functions involved, etc. Other future research requirements are briefly cited. (Author in part)

REVIEW: This paper is a refocusing of current system effectiveness notions as the author sees the area. It is mainly discussion of the sort which is heavy reading relative to much of the reliability literature, but which does a good job of uncovering some of the limitations of system effectiveness concepts if the reader pays close attention. The paper will be of interest mainly to those concerned with research and development of system effectiveness methodology, and would be valuable background to others involved with system effectiveness (but they may find it tedious reading).

The definition of availability in symbolic fractional notation on page 152 is wrong. The denominator should be operating time plus downtime. This error is corrected in the author's reprints of the paper. ##

Serial Number 2522
ASQC Codes 814;841;846

TITLE: Cost data-collection and use

AUTHOR: W. Grant Ireson (Stanford University, Dept. of Industrial Engineering, Palo Alto, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 162-167 (*see RATR 2511)

PURPOSE: To discuss the collection, analysis, and use of cost information on reliability program elements.

ABSTRACT: An ideal cost collection system would enable one to relate each expenditure incurred throughout the research, development engineering, production, and use phases to a specific resulting value or cost. This ideal will never be attained because the quality and reliability costs are in a very complex structure. The costs can be roughly divided into two categories: controllable and resultant. The controllable costs include those items that can be planned in advance and budgeted, such as labor, investment, and material. The resultant costs include the internal failure, scrap, rework, maintenance, repair parts, spares, and servicing the system after it has been delivered. The ultimate purpose of setting up a cost collection and analysis system would be to establish a relationship between the resultant cost and the controllable cost, and thus establish the level of the controllable effort which would minimize the total cost.

Two techniques for effective use of the cost information are given. The first is a trend chart which relates the various cost elements to time. The second examines the resultant cost critically, infers the causes, and estimates the cost of corrective action. (Author in part)

REVIEW: This paper provides general background information on collecting and using cost information on quality and reliability program elements essential to the successful implementation of cost effectiveness. The use of the techniques is a very worthwhile effort. The purposes are very closely associated with the objectives of a quality control program. ##

Serial Number 2523
ASQC Code 815

TITLE: Pitfalls for the unwary

AUTHOR: Donald L. Costello (ARINC Research Corporation, Annapolis, Md.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 168-172 (*see RATR 2511)

PURPOSE: To show that overuse of statistics in specifications can cause problems.

ABSTRACT: In writing specifications, distinguish between what you want and how you propose to check that you have gotten it. Just because many statistical concepts can be put into specifications, and just because they look erudite there, doesn't mean they do any good or do no harm. There are many kinds of proof of a statement and statistical proof is not the only acceptable kind. Some probability statements are ambiguous. For example, 90% desired reliability could mean that we are satisfied if 90% of the items are reliable, or it could mean that we are willing to take a 90% chance that the item is reliable. Always be aware that probabilistic criteria are much easier to state than to meet.

REVIEW: This is a very good paper and should be read by everyone who is concerned with reliability specifications. Some parts may be hard to follow, especially the discussion on requirements vs. criteria for meeting requirements, but they are important. Perhaps more often than the author implies, a requirement of 93% reliability means that equipment must last out the mission at least 93% of the time.

The discussion on what is meant by "proof" should be studied by every engineer. ##

Serial Number 2524
ASQC Codes 761;833

TITLE: Spacecraft component reliability

AUTHOR: C. M. Ryerson (Hughes Aircraft Co., Culver City, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 173-179 (*see RATR 2511)

PURPOSE: To summarize component experience on some Hughes satellites.

ABSTRACT: This paper discusses the screening of quality lots to remove parts which might fail in flight use. Each part is screened by observing changes in its appropriate parameters during power-on aging. Those parts which show little change or especially changes which "level-out" as time goes by, and have no erratic behavior, are selected as good parts. This is much better than older quality control tests which concerned themselves with group averages. Reliable spacecraft have been built by this technique.

REVIEW: Since this technique itself is worthwhile, but not new, it would have been helpful to describe how one knew which parameters should be monitored, how many good parts get thrown out with the bad, and what the failure experience is on screened parts vs. raw ones. The MIT Apollo experience in integrated circuit screening as given in the reports covered by RATR 2467 conveys more knowledge, for example, than does this report. This report would be helpful to those not familiar with this kind of screening and who want only a general knowledge. ##

Serial Number 2525
ASQC Codes 833;844

TITLE: High-power high-frequency reliability techniques

AUTHORS: Leonard R. Doyon (Raytheon Co., Wayland, Mass.) and Martin J. Seigmann (Naval Applied Science Laboratory, Brooklyn, N. Y.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 180-197, 12 refs. (*see RATR 2511)

PURPOSE: To describe reliability analysis and design techniques in high-power high-frequency applications.

ABSTRACT: Relatively little statistically-significant data have been published on high-power high-frequency components in spite of the well-known fact that such components as a class have exhibited failure rates several orders of magnitude higher than low-power low-frequency components. Two of several principal reasons stated for the scarcity of published data are (1) the cost of performing life tests on a statistically-significant sample size is often prohibitive, (2) since the modes of failure of high-power and high-frequency components are extremely complex, and the volume of data is low and statistically marginal, manufacturers release data reluctantly, fearing that such data will be misinterpreted.

The estimated mean-time-between-removal values (with 90 percent confidence limits) of high-power high-frequency tubes are given for two data sources. In addition a ranking is given of the "top-ten" component/sub-assemblies having the highest frequency of failure or removal in radar transmitters from field failure reports on 40 radar systems operating aboard ship during 1964.

Certain statistical analyses were performed on the data to test for constant hazard rate versus decreasing (or increasing) hazard rate characteristics. The authors caution the reader that failure data of items having individual survival functions with constant hazard rate when pooled may exhibit decreasing hazard rate characteristics. It is stated that system configuration and design may significantly determine the failure modes and failure rates of high-power high-frequency components.

Three major failure problems encountered in high-power high-frequency components are discussed; namely, (1) "low emission" and/or incorrect output, (2) open filaments, and (3) arcing. Some suggestions are made for resolving these problems. They are to derate components generously, improve structural design, make greater use of monitoring equipment, and design more detection and protection devices into a system. (Authors in part)

REVIEW: This is primarily a reliability-engineering applications paper. Its principal objective is to provide information for system, reliability, and components engineers who have decision responsibilities for electronic system configuration. The authors have made a contribution toward this objective in providing useful data and suggesting some design techniques for attaining improved electronic system reliability in high-power high-frequency applications. ##

Serial Number 2526
ASQC Codes 833;844;864

TITLE: Operational reliability of components in selected systems

AUTHOR: T. L. Tanner (Bell Telephone Laboratories, Whippany, N. J.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 198-211, 12 refs. (*see RATR 2511)

PURPOSE: To provide replacement (failure) rates for electronic components and devices based on field experience with four military systems and to report on component experience with undersea cable repeaters.

ABSTRACT: Since tests to demonstrate very low failure rates are difficult and extremely costly to obtain in the laboratory, field experience from four military systems, containing primarily solid state digital circuitry, was analyzed. These systems contained over 3 million components which accumulated over 80 billion operating component hours. Modifying factors for each of the four systems were used in order to combine replacement data and to provide a table of replacement rates for the various classes of components and devices. This study indicates replacement rates per billion component hours of 0.1 to 5 for most resistors and capacitors and of 5 to 20 for semiconductors.

In a similar analysis of components used in the submarine cable repeaters, no failures have occurred in approximately 4 billion operating component hours. In this application only components of a proven construction and materials with long records of trouble-free performance were considered; extreme precautions were taken to prevent these materials from degrading or becoming contaminated during assembly. Furthermore, all materials were thoroughly qualified and tested before they were used, and, wherever possible, premium materials, capacitor paper, mica laminations, magnet wire, etc., were procured under rigid specifications. To detect potential early failures, all components were submitted to stabilizing treatment consisting of repeated temperature cycles and accelerated aging. Any components exhibiting unusual changes in electrical parameters were discarded. But, of utmost importance, it was decided that design specialists would be present in the manufacturing area at all times to insure that nothing was left unchallenged that might affect the reliability of the manufactured components and assemblies.

Design reviews, properly selected components, attention to manufacturing details, engineering for use by people, and failure analysis/reporting are essential for good reliability. (Author in part)

REVIEW: This paper can be useful for the data it gives on replacement rates for digital and computer type circuitry and the brief insight it gives on the philosophy behind parts selection and manufacture for the submarine cable repeaters, in which there have been no failures so far. The methods suggested for improving reliability are conventional and good. ##

Serial Number 2527
ASQC Codes 810;833;844

TITLE: Parts reliability problems in aerospace systems

AUTHOR: Welfred M. Redler (Office of Reliability and Quality Assurance, National Aeronautics and Space Administration, Washington, D. C.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 212-220 (*see RATR 2511)

PURPOSE: To discuss some limiting reliability factors for parts and to present approaches in the management area that could contribute to improvements.

ABSTRACT: Electronic parts technology has advanced sufficiently to enable the providing of many types of parts with inherently low failure rates. Physics of failure and aging information is likely to provide the basis for needed improvements in parts designs. The reliability of electrical interconnections might eventually be the limiting factor of the intrinsic reliability of electronic equipments. Mechanical and electromechanical parts and components are apt to be the limiting factors in space system reliability unless more effort is applied to their analysis and to mathematical modeling for failure and wearout calculations. The greatest problem is that of getting sufficient quality control and care in the production, handling, storing, testing, fastening and application of parts and materials with higher performance and life characteristics. There will not be enough different types available unless a market for them is created. Both government and industry can continue to improve the reliability of space systems by a continued expansion of efforts in the parts management and R&D fields. There is still much to be done before reaching the point of diminishing returns.

REVIEW: A capsule view of the parts area from the reliability viewpoint is presented in this paper. Although it is interesting to read, the engineer who does the detailed work will find little here in the way of something he can implement in his daily work. Rather, the conclusions drawn are the sort which must be acted on by management through the initiation of particular programs. Noteworthy among the material presented as background for the parts area are some figures on failure causes of the Saturn system during inspection and test at Cape Kennedy. The quantities of failures which are attributable to manufacturing quality and operations are approximately an order of magnitude larger than the quantities attributable to design. Yet most efforts for improvements are still in the design area.

In a private communication the author has stated that the paper is directed at reliability engineers, and cites it as indicating the low failure rates that may be used in system reliability estimations if adequate quality assurance is provided and that 100% acceptance screening has great value. These are indeed valid points, but neither they nor other similar points which could be used by the engineer who does the detailed work are emphasized in the paper. ##

Serial Number 2528
ASQC Code 836

TITLE: Competitive product designs via design reviews

AUTHOR: Richard M. Jacobs (Westinghouse Electric Corp., Pittsburgh, Pa. 15235)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 222-230 (*see RATR 2511)

PURPOSE: To show that formal design review is a powerful, low-cost, quickly-evaluated method of improving the reliability of a product.

ABSTRACT: Design Review at Westinghouse is defined as a formal, documented, and systematic study of a design by specialists not directly associated with its development. It hastens the maturing, within cost limits, of all elements of a design--function, reliability, value, and appearance. The exact procedure for conducting formal Design Reviews may vary between companies, between divisions and among product groups; yet the underlying philosophy remains identical.

Fifteen case histories are summarized on three charts, and three are discussed in detail. They are grouped under the following three headings which represent goals of the design review: improved performance, improved reliability, and routine. Some of the design reviews contributed to cost reduction while others increased the cost of the product; however, all improved the performance of the product and its reliability. A handy form for use by the person given the responsibility of conducting a design review is shown. The value and importance of design reviews are emphasized. (Author in part)

REVIEW: This paper should do much to convince skeptics that design review in particular and reliability programs in general can in fact contribute to the improvement of a company's competitive position. That will be the chief value of the case histories which are presented. For details on design review procedures, readers are referred to the paper (by the same author and an associate) covered by RATR 2103. ##

Serial Number 2529
ASQC Codes 720;813

TITLE: Preserving the integrity of product design during manufacturing

AUTHOR: R. G. Tate (IBM Corporation, Boulder, Colo.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 231-240 (*see RATR 2511)

PURPOSE: To describe a manufacturing reliability program used in producing reliable commercial data processing systems.

ABSTRACT: The pressures of high volume, a competitive market, and increased performance requirements are felt strongly in the commercial data processing industry today. The corresponding effect upon the organizations responsible for assuring product performance results in some dramatic differences between the defense-oriented industry and those which produce commercial products. Organizational responsibilities for reliability are examined, with the role of quality control and manufacturing considered in more detail. Quality control is concerned with "customer satisfaction and product performance," not merely "control of the manufacturing process." For instance, if a problem is defined as design-oriented, quality control should seek corrective action through product engineering. Some of the manufacturing reliability programs which have been instituted are: (1) early entry into product development, (2) component and supplier approval, (3) process and test equipment evaluation, (4) component reliability and stress tests, (5) product line audit, and (6) data collection and failure analysis. Of particular interest is the product line audit program, which is a method of conducting more extensive testing on samples of products. Any problems detected during the tests are investigated thoroughly to determine if process or design improvement is required. Some of the basic concepts of the program are discussed. As a result of these tests, the following types of problems were detected and corrected: (1) inadequate design, (2) manufacturing quality problems, and (3) inadequacy of certain sections of test programs. An analysis of the data from the product line audit can help determine the optimum length of extended run to which each production machine should be subjected as a part of the normal testing procedure. (Author in part)

REVIEW: The program described in this paper is essentially what is more widely referred to as quality assurance. It is concisely outlined and those working in this area might want to check it for ideas. It is difficult to pinpoint from the paper what is supposed to be dramatically different between this and a defense-oriented program. A difference of sorts probably does exist, but is not cited in the paper. It is that in the defense-oriented industry this type of program is usually implemented only if the procuring agency explicitly requires a reliability program or a quantitative reliability demonstration, whereas the producers of commercial products implement it for customer satisfaction. However, effective reliability programs are currently found with increased frequency in the defense-oriented industry. This is the type of paper on reliability programs and organizations which was more prevalent some years back, in which such words as philosophy and responsibility are used in such a way as to detract from the substance of the paper. ##

Serial Number 2530
ASQC Codes 817;833;844

TITLE: Reliability analysis of a new product in the early design phase

AUTHOR: Curtis E. Vetter (Caterpillar Tractor Co.; present affiliation: General Electric Company, Houston, Tex.)

SOURCE: Presented at the Earthmoving Industry Conference, Central Illinois Section, Peoria, Ill., 6-7 Apr 65, SAE paper S422, 8p (*Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N. Y. 10017)

PURPOSE: To explain a reliability prediction procedure that can be conducted in the early design phase of a new product without benefit of directly-related failure data.

ABSTRACT: Reliability prediction in the earliest design phase of a totally new product is an effective means of assuring proper emphasis and direction of the development program, but lack of failure data and/or complex quantitative analysis often make it impractical for use by the mechanical equipment designer. This paper discusses the application of failure mode identification and analysis relative to a new product without benefit of field failure data. The examples used are two design versions of a variable-geometry nozzle for a gas turbine engine, a mechanism not manufactured by Caterpillar prior to the conduct of this study.

The first step is failure mode identification or defining what constitutes a failure. For analysis, the device is divided into systems, components, subassemblies and then into basic elements. A failure analysis form is used to list failure modes for each element, subassembly or component, whichever is the smallest practical unit to use. Opposite each failure mode, the effect on component, system and engine is identified. From this it is possible to assign a seriousness classification to each failure mode. There are four classifications of seriousness based upon the effect of each failure on the component, system, and major end-item. Four categories of failure probability are then set up. The value of each category is initially arbitrary and they are later revised as data become available through development testing. After completing the failure mode identification, seriousness and probability study, the information must be converted into a useful form. A tabulation of seriousness/probability combinations shows the number of potential failure modes requiring additional development and/or testing. The analyst and designer can then logically determine the corrective action required, the priority of such correction and the degree needed.

REVIEW: This paper is essentially a case history of a failure modes, effects, and criticality analysis conducted on a mechanical device. While the paper is brief, and some readers might wish for more detail on some points, it does a good job of presenting the basic ideas. Identification of failure modes and their seriousness (criticality) in the early design phase is a good practical approach which no design engineer should overlook. It could be extended by considering the cost of improvements and proceeding on the basis of the greatest decrease in system failure probability per dollar expended. ##

Serial Number 2531
ASQC Code 824

TITLE: Reliability estimation under plausible assumptions

AUTHOR: F. Proschan (Operations Research Center, University of California, Berkeley, Calif.)

SOURCE: Report ORC 65-13, Operations Research Center, University of California, Berkeley, Calif., May 65, 25p, 22 refs. (AD-619 873; CFSTI Prices: Hard Copy $2.00, Microfiche $0.50)

PURPOSE: To review the recent research in reliability estimation when the underlying failure distributions have increasing (decreasing) failure rates.

ABSTRACT: This paper presents an expository survey of recent research in reliability estimation based on assumptions made not simply for mathematical convenience but because they correspond closely to the physical situation. The class of statistical problems considered thus lies somewhere between parametric problems (in which the underlying failure distributions are assumed known up to a finite number of parameters) and nonparametric problems (in which no information on the underlying distributions is assumed known). Specifically, the following topics are considered: (1) the errors resulting from using standard exponential life test and estimation procedures when in fact the distribution has an increasing failure rate or a decreasing failure rate, (2) statistical tests for monotone failure rate, (3) estimation of the failure rate function, the distribution and the density, and (4) estimation of reliability growth.

REVIEW: This is an excellent survey paper for the statistician or reliability engineer with a basic knowledge of statistics. Some proofs are given to indicate the type of arguments used but most proofs are left to the references cited in the paper. The latter should be very useful to those who wish to delve further into the details. ##

Serial Number 2532 -1
ASQC Code 850

TITLE: Reliability demonstration: theory, application and problems

AUTHORS: G. H. Allen; D. D. Bishop, Maj., USAF; R. DeMilia; G. Grippo, Capt., USAF; W. J. Henshaw, Capt., USAF; L. L. Levy, Capt., USAF; A. E. Smith, Lt. Col., USAF; L. E. Staples; and J. W. Zwiacher, Maj., USAF (Technical Requirements and Standards Office, Electronic Systems Div., Air Force Systems Command, USAF, L. G. Hanscom Field, Bedford, Mass.)

SOURCE: Technical Documentary Report No. ESD-TR-198, Technical Requirements and Standards Office, Electronic Systems Div., AFSC, USAF, L. G. Hanscom Field, Bedford, Mass., Apr 65, 64p

PURPOSE: To present a series of four papers by ESD reliability engineers on the statistical and engineering aspects of reliability demonstration.

ABSTRACT: I. At ESD constraints such as high MTBF coupled with limited schedules, budgets, and sample sizes handicap the standard sequential type of decision model in the MIL-R family. Typical consequences have been to waive demonstration or to accept some kind of analytical proof; these are not acceptable solutions. Two key propositions in seeking improvements are that no one decision rule can be universally applied and that ESD cannot insist on high confidence while limiting dollars and time. A proposed MIL-STD on reliability demonstration presents revised plans and the rationale of their development. Difficulties of the AGREE method are discussed. ESD proclaims that test plans shall be devised which make risks compatible with the specific needs of the procurement in question. One method is presented for constructing such plans; it ignores the accumulation of risk as a result of having multiple decision points. Several reasons are given for not being unduly concerned, including unknown errors of the Poisson model assumption, imperfect test conditions, and the fact that the procedure will be used only with early truncation. The procedure has higher applicability than the AGREE approach, and will help to overcome the fact that no demonstration method is equivalent to no quantitative requirement.

II. Recently completed sequential testing for the reliability demonstration of a large computer is discussed from the viewpoint of the lessons learned. The tests were from MIL-R-26474, and the computer was tested as a whole to reduce total test time. Ground rules of failure relevancy were established, requiring some effort to do so. The contractor rescheduled the test period many times, largely because there were effectively no complete system checkouts or reliability dry-runs. During the debugging activities the System Project Office computer manager was able to provide extensive helpful guidance in system engineering which prevented even longer delays. A conclusion is that the contractor should be required to have successfully tested each item before attempting to demonstrate it to the government as contract performance. A recurring question is what to do with failures that occur during maintenance time.

III. There is really no typical communication system and each must be analyzed and planned as a unique system. Three actual systems are described to illustrate their unique problems. The examples

show that the critical problems include the lack of adequate test time and the limitations of available test plans. Another illustration is that to a very large degree propagation considerations in communication system design and propagation reliability are overlapping concepts, so that the functions of the system design and the reliability engineer merge indistinguishably.

IV. The Minuteman program is reviewed for guidance on approaches to demonstrating weapon system reliability. This program has exceeded the DoD availability goal using Air Force operation and maintenance. Missile field operation and the management and engineering approaches used for reliability are described. Some of the conclusions are the following. (1) A reliability program which presents real solutions to real problems can be sold; it must be formulated upon quantitative reliability requirements. (2) The sheer momentum of the entire program would not have allowed the rejecting of equipment essential to the success of the overall program. (3) An effective contractor surveillance, in addition to demonstration, is needed. (4) Demonstration must be tailored to the requirements of the individual program with emphasis on reaching a decision at low test times even at the expense of high confidence levels, providing that extensive engineering knowledge has been gained. (Authors in part)

REVIEW: A timely collection of discussions is presented which reflects the real world problems of reliability demonstration and which illustrates some of the reasons why reliability demonstration tests have just not achieved a solid status. Viewed collectively, the four papers show some problem patterns and propose several recommendations. In I the proposed method is based on a Poisson failure pattern; it would be fruitful if there were more actual data published to illustrate what infant mortality periods have been experienced and to substantiate that a Poisson process is applicable. In II there is a call for contractors to perform reliability "tests" for their own satisfaction before performing them for formal government "demonstration." There is little precedent for this in terms of other tests such as the more routine qualification or production acceptance test, unless the purchaser makes it clear that he wants this and will pay for it. Otherwise a contractor would strongly hurt his competitive cost and schedule position.

III nicely shows that in the performance variation sense no distinction can be made between conventional system engineering and reliability engineering. The Minuteman reliability program of IV almost singly stands out as the DoD implementation of an idealized reliability approach.

No mention is made of using actual operational experience for reliability demonstration (see RATR 1955 and 2264). Yet another different philosophical approach is to attempt to discriminate between the "good" and the few "bad" subsystems, rather than to attempt to demonstrate at a high confidence that a certain reliability level has been attained (see RATR 2270). ##

Serial Number 2533
ASQC Codes 431;838

TITLE: Feasibility studies on use of ARTRONS as logic elements in flight control systems

AUTHORS: R. E. Mirabelli, E. M. Connelly, and J. E. Worthen (Melpar, Inc., Falls Church, Va.)

SOURCE: Technical Documentary Report No. FDL-TDR-64-23, Flight Dynamics Laboratory, Research and Technology Div., Air Force Systems Command, Wright-Patterson Air Force Base, O., prepared under Contract No. AF 33(657)-11026 by Melpar, Inc., Falls Church, Va., Sep 64, 134p (AD-607 764)

PURPOSE: To present the results of a feasibility study of the application of a reliable, trainable logical network to flight control systems.

ABSTRACT: The theory of reliable, trainable logical networks is presented from the point of view of probabilistic automata. System state change is shown to be a Markov process, and the training procedure is discussed. General training theory is developed, and various training techniques are presented.

Goal circuits for self-organizing control systems, using Lypunov functions, provide a stable control system despite internal failures in the logical network or changes in the controlled system. A digital computer simulation is described, presented, and its results analyzed.

A laboratory feasibility model, the RELIATRON, is described in detail. Tests on this device are also described, and the results discussed.

REVIEW: This report has much more substance than its title implies--besides answering the feasibility question (in the affirmative) it gives a concise presentation of the theory of trainable logical networks, and even gives the instructions for building one in considerable detail. The proofs and test results are quite convincing evidence that the authors' elements will do what they are designed to do. The theory has been well developed and will provide a good reference.
##

Serial Number 2534
ASQC Codes 821;838

TITLE: The synthesis of redundant multiple-line networks

AUTHORS: M. K. Cosgrove, P. A. Jensen, W. C. Mann, and G. M. Schechter (Westinghouse Defense and Space Center, Surface Div., Advanced Development Engineering, P. O. Box 1897, Baltimore 3, Md.)

SOURCE: Second Annual Report, Contract Nonr 3842 (00), for the period 1 May 63 to 1 May 64, prepared for the Office of Naval Research by Westinghouse Electric Corporation, Surface Div., P. O. Box 1897, Baltimore 3, Md., 1 May 64, 62p (AD-602 749)

PURPOSE: To present a procedure for synthesizing systems with reliability due to redundancy, in an optimal manner.

ABSTRACT: This study deals with multiple-line redundancy, which was chosen by the authors as the most effective of several redundancy schemes which are used to achieve reliability. Restorers are placed at several locations in the network so as to keep failures from resulting in performance degradation. (The "restorers" are majority gates.) After a section containing definitions, the report describes a synthesis procedure in detail. The procedure sums costs due to weight and power penalties and those due to system failure and gives a design which will minimize these. Costs other than the cost of failure sum up to the "functional cost" (which may include, in some cases, items other than weight and power penalties.)

The result of the synthesis procedure is a statement of the best degree of redundancy, and a designation array describing the best placement of restorers. (Approximations are made which greatly reduce the labor of synthesis, but which result in a near-best solution.)

The report states that a program for this analysis has been run successfully on a digital computer. Appendices describe an example and the computer implementation.

REVIEW: This is an annual report dealing with a particular type of reliability improvement. It deals with it very thoroughly. It should be a useful tool for the engineer who will want to investigate this particular means of optimizing circuits. The value lies in the presentation of new techniques rather than new basic theory. The method is well presented and the example is helpful. ##

Serial Number 2535
ASQC Codes 431;821

TITLE: Stochastic wear processes

AUTHOR: Richard C. Morey (Operations Research Center, University of California, Berkeley, Calif.; present affiliation: Institute for Defense Analyses, Weapons Systems Evaluation Group, 400 Army-Navy Drive, Arlington, Va. 22202)

SOURCE: Report ORC 65-16, Operations Research Center, University of California, Berkeley, Calif., Jun 65, 33p, 18 refs. (AD-619 875)

PURPOSE: To define a class of stochastic processes called stochastic wear processes and derive some of their properties.

ABSTRACT: A new class of non-decreasing stochastic processes is characterized. These processes satisfy a generalization of the notion of an increasing failure rate. From physical considerations, these processes seem suitable for describing the process of cumulative wear or damage. The main interest with the model is an investigation of the first time until the process exceeds a random barrier.

For this class of processes, it is shown that the first passage time random variable across a random barrier has an increasing failure rate, regardless of the distribution of the barrier. In addition, by the use of certain intuitive, non-parametric assumptions, tight bounds on the moments of this first passage time random variable are obtained. (Author)

REVIEW: This is a rather theoretical paper from the reliability point of view; however, the basic model, i.e., the definition of a stochastic wear process, seems quite reasonable on the basis of physical considerations. A few omissions should be noted. From the results which follow it is clear that the random threshold X introduced on p. 12 must be assumed to be <u>independent</u> of the basic process $\{Z_t\}$. Similarly in Lemma 7, p. 19, the exponential random variable V must be <u>independent</u> of both $\{Z_t\}$ and X. It is hoped that further research together with some applications will be forthcoming. ##

Serial Number 2536
ASQC Codes 615;817;838

TITLE: Maximization of system reliability using a digital computer and oscilloscope search technique

AUTHOR: Roger K. Hoppe (Captain, USAF)

SOURCE: Thesis submitted in partial fulfillment of requirements for the degree of Master of Science in the Department of Industrial and Management Engineering in the Graduate College of the State University of Iowa, Jan 65, 77p, 14 refs. (AD-611 566)

PURPOSE: To propose and demonstrate a technique for maximizing the reliability of a redundant system.

ABSTRACT: A reliability problem which has received much attention in the literature is that of maximizing the reliability of an N-state system which has duplicate components at each stage operating in parallel. The maximization is to be carried out subject to fixed maximum cost and weight of the total system. Several variations of this problem have been considered elsewhere, most of which involve dynamic programming solutions. The difficulty involved in obtaining an optimal solution is the increase in dimensionality that results when the number of constraints increases beyond one. Previous authors have incorporated a Lagrange multiplier into the two-constraint problem to reduce the dimension to one. An ordinary dynamic programming algorithm is then used iteratively to obtain an optimal value for the Lagrange multiplier. Each iteration involves the solution of a one-dimensional dynamic programming problem. The purpose of this paper is to devise a systematic method of searching for the optimal multiplier through the use of a digital computer in a direct tie with an on-line oscilloscope.

REVIEW: This paper gives no theory concerning the solution of the stated problem and consequently the reader wishing to implement the described techniques must be somewhat familiar with basic "dynamic programming." The main idea of the technique involved here is that when an iterative method is being carried out, quicker convergence is possible if intermediate results are available to the investigator so that he can control the point at which the next iteration is made. The specific device used for displaying intermediate results is an oscilloscope. Two points which were not mentioned in the paper seem appropriate. Firstly, with today's high-speed computers, the method would surely be limited to small or possibly medium size computers since on-line control of a large-scale machine would be exceedingly wasteful. Secondly, the solution of very many such optimization problems would be required to justify the time and expense of obtaining and setting up the apparatus necessary for using the technique. Complete computer programs and description of the apparatus are given in the paper.

For other approaches to the maximizing of the reliability of redundant systems see RATR 496, 978, 1267, and 2023. ##

Serial Number 2537
ASQC Codes 711;712

TITLE: Low-cycle fatigue of materials (laboratory investigations)

AUTHOR: M. R. Gross (Marine Engineering Laboratory, Annapolis, Md.)

SOURCE: Report No. MEL-TM-37/64, Marine Engineering Laboratory, Annapolis, Md., 13 May 64, 11p, 9 refs.

PURPOSE: To discuss fatigue in terms of its complexities and influencing factors.

ABSTRACT: Since it is desirable to design deep submergence vehicles with a minimum hull-weight-to-displacement-weight ratio, considerable emphasis has been placed on the development and use of materials of high strength-to-weight ratio. These materials give rise to questions concerning whether or not material properties such as fatigue, stress corrosion, toughness, ductility etc. may not become controlling factors in the life of structures with high strength-to-weight ratios. Because the number of pressure fluctuations that result from depth excursions rarely exceed several thousand cycles during the lifetime of submergence vehicles, low cycle fatigue (defined here as less than 10^5 cycles) is of primary interest in evaluating specimens of proposed structure materials. Strain has been found to be the dominant factor in low cycle fatigue since both plastic and elastic deformation occur under loading. When cycles to failure are plotted in terms of total strain, the fatigue life of specimens ranging in yield strength from 45,000 to 250,000 psi. was quite similar. Above 10^5 cycles, strain predominantly is in the elastic range and fatigue strength is affected by the yield strength of the material. Factors affecting low cycle fatigue are discussed; they include material notch sensitivity, residual stress, corrosion, rate of crack propagation, yield strength, and the relationship of maximum and mean stress to fatigue at conditions when the maximum stress exceeds the yield strength, and also when it does not. The effects of these factors on high cycle fatigue are also discussed. Stress raisers are generally less detrimental as cycles to failure decrease. Corrosion is time-dependent and the rate of cycling must be considered. Crack propagation was found to be proportional to the fourth power of the total strain range for quenched and tempered steels. The latter suggests that the growth of low cycle fatigue is independent of strength and that the only advantage of a high strength material is to support larger stresses in the elastic region.

REVIEW: This paper is mainly a summary of accepted ideas in the field of low cycle fatigue and does not contribute anything new other than further substantiation of these ideas by actual testing. The paper does an excellent job of presenting the effects of factors which must be considered in the low cycle behavior of high strength steels. ##

Serial Number 2538
ASQC Codes 713;821

TITLE: The structural reliability of airframes

AUTHORS: A. M. Freudenthal and A. O. Payne (Columbia University, New York, N. Y.)

SOURCE: Technical Report No. AFML-TR-64-401, AF Materials Laboratory, Research and Technology Div., AFSC, Wright-Patterson Air Force Base, O., prepared under Contract No. AF 33(616)-7042 by Columbia University, New York, N. Y., Dec 64, 86p, 15 refs. (AD-615 654)

PURPOSE: To present a theory for determining the probability of structural failure in specified aircraft under ultimate and fatigue loading.

ABSTRACT: This report is an extension of a previously developed theory for determining the probability of structural failure under ultimate and fatigue loading. An approach to the problem of evaluating the probability of structural failure at any stage of operation is presented. Probability of failure due to ultimate and fatigue loading has been evaluated for three types of aircraft (fighter aircraft, civil transport, and heavy bomber) and two sources of loading (atmospheric gusts and maneuver accelerations). Data were gathered from many sources on the operational characteristics and service histories of the three types of aircraft. Atmospheric gust data were obtained from published studies of gust frequencies in thunderstorms. Limited data, obtained on U. S. heavy bombers only, were applied to all aircraft for estimating probabilities of loading due to lateral gusts.

Flight load data were obtained in the form of frequency distributions and transformed into probability distributions in terms of the total number of load occurrences per hour (or per mile). An estimate of the variance of ultimate strength of aircraft structures was obtained from multiple test data on 11 different types of structures and nine types of mainplane panels. The development of the application of reliability theory to probability of failure is presented in terms of design parameters for ultimate strength and fatigue sensitivity factors for the three types of aircraft.

Tables and graphs show predicted probabilities of failure under different atmospheric and maneuver loadings for aircraft having various design parameters. Other tables and graphs compare predicted probabilities with service data. Additional study is needed to extend the theory presented to aircraft in general. The greatest need is for reliable data for better estimates of the various factors which influence service life of aircraft. This application of reliability theory yields design parameters which can be used as a basis for a comparative reliability analysis of new designs involving new materials and maneuver characteristics.

REVIEW: This report will best be understood by those with a good background in the aircraft design and reliability fields. It should be of considerable value to such individuals since it could serve as a basis for the evaluation of new designs and materials. ##

Serial Number 2539
ASQC Codes 711;712

TITLE: Low-cycle fatigue characteristics of ultrahigh-strength steels

AUTHORS: C. M. Carman and J. H. Mulherin (Frankford Arsenal, Research and Development Group, Philadelphia, Pa. 19137)

SOURCE: Report R-1707, Frankford Arsenal, Research and Development Group, Philadelphia, Pa. 19137, AMCMS Code 5910.21.84201, Feb 64, 51p, 7 refs. (AD-601 188)

PURPOSE: To investigate a crack propagation theory proposed by G. R. Irwin using high strength material under constant crack tip driving force.

ABSTRACT: Crack growth studies on D6Ac steel, heat treated to 240,000 psi yield strength, using pre-cracked center notched specimens are described. In these studies the crack tip driving force was held constant for each cycle. Plate thicknesses of 0.160 and 0.075 inch were investigated.

A correlation exists between the steady state model proposed by Irwin and the results of this investigation. Two specific types of behavior are evident in the data. These behavior patterns are a function of plate thickness and can be explained to some degree by the consideration of two factors: (1) the elastic constraint present in the specimen, and (2) the ease with which vertical shear displacements can be attained.

In the thick plate behavior, which is exemplified by the 0.160 inch specimens, the plate thickness is substantially larger than the local plastic zone at the advancing tip of the crack. The elastic constraint, therefore, dominates the rate of crack propagation. Because of the lower elastic constraint present in a 45° oblique shear fracture, the rate of crack propagation at a constant driving force is less than that for a cup-cone condition.

In the thin plate behavior, the shear displacements on the "y" axis dominate, rather than the elastic constraint. The 45° oblique shear type of fracture, therefore, results in a greater rate of crack extension because the vertical displacements are larger than for the cup-cone type of fracture. (Authors)

REVIEW: An understanding of this paper is contingent upon a grasp or knowledge of fracture mechanics as advanced by Irwin. Sufficient publications are, however, available in the literature on this topic and are referenced. Besides the theoretical discussion, this paper presents data of considerable practical importance. Just what the authors mean by "100% reliability" is not known. The title also suggests a more comprehensive paper than is actually given.

Serial Number 2540
ASQC Codes 713;715;770

TITLE: In-reactor studies of low cycle fatigue properties of a nuclear pressure vessel steel

AUTHORS: J. R. Hawthorne and L. E. Steele (Reactor Materials Branch, Metallurgy Division, U. S. Naval Research Laboratory, Washington, D. C.)

SOURCE: Report 6127, Naval Research Laboratory, Washington, D. C., 27 Jul 64, 16p, 7 refs.

PURPOSE: To investigate the effect of nuclear radiation on the fatigue resistance of reactor structural materials.

ABSTRACT: Notch ductility characteristics and fatigue resistance of the pressure vessel are two major concerns with respect to nuclear power reactors. Although there has been a rapid growth in experimental data concerning the notch ductility of irradiated steels, relatively little information exists on the effects of nuclear radiation on the fatigue resistance of reactor structural materials. This paper covers a program designed to determine low cycle fatigue behavior of ASTM type A302-B steel irradiated at 500^{o}F. Reversed bend fatigue tests were conducted on sheet type specimens placed in an experimental irradiation assembly developed for in-reactor fatigue testing. A helium atmosphere was maintained to minimize corrosion. The average instantaneous fast neutron flux was approximately 3.2 x 10^{12} n/cm^2-sec.

The specimens were cycled to 20 or less cycles per day until an exposure of approximately 8 x 10^{18} n/cm^2 and 465 cycles were obtained after which cycling was maintained at 18 cycles per minute. Tests were limited to 250,000 cycles. The results of the 500^{o}F out-of-reactor control tests showed no significant difference in fatigue strength except that the irradiated specimens had a slightly higher fatigue strength in the region above 50,000 cycles. No definite conclusions appear warranted, however, until considerably more data are obtained. Presumably the fatigue resistance of irradiated materials cannot be predicted from the response of tensile properties of the material to irradiation. Additional tests are being planned on ASTM type A302-13 steel as well as on other selected steels and alloys.

REVIEW: The test assembly, associated test apparatus, test procedures, and results are described and illustrated very well. References are given concerning work done by other researchers on pressure vessels. The scope of the paper is much narrower than the title implies. ##

Serial Number 2541
ASQC Code 775

TITLES: Nondestructive testing
The unique role of nondestructive testing in development programs

AUTHOR: Douglas W. Ballard (Sandia Corp., Manufacturing Research Div.)

SOURCES: Industrial Research, vol. 7, Oct 65, p. 68-72
Sandia Corporation Reprint SC-R-64-175, Jul 64, 16p, 11 refs.

PURPOSE: To note new applications of nondestructive testing (NDT) and to review the unique role that it can play in support of a dynamic development program.

ABSTRACT: Previously used only for defect detection during production, nondestructive testing methods have become dynamic techniques for materials evaluation throughout the entire research-to-production cycle. Testing of structures, components, systems and materials without damage to the object under test is being furthered by breakthroughs into new frontiers that will contribute to product quality. At least six new areas have been invaded by NDT: (1) materials properties testing, (2) research and development tools, (3) dynamic and quantitative NDT applications, (4) multiple nondestructive testing, (5) electronic component and systems testing, and (6) infrared and microwave testing. Each of these new applications is discussed with concrete examples of its importance.

While the use of nondestructive test methods such as radiography and ultrasonics has shown a tremendous increase on the production line, the designer has often failed to capitalize on the unique benefits of these tools during development programs. The designer should review his nondestructive test programs in the light of more demanding requirements for nuclear and aerospace componentry. Close teamwork is urged between the designer and test engineer in the planning and execution of a comprehensive NDT program. Benefits resulting from this cooperation include a better correlation of design and production test data, more information from destructive tests, fewer expensive destructive tests during development, a source of unique test data hitherto unavailable to the designer, and a more definitive product design. Examples are given of each of these benefits without explaining in detail the specific nondestructive test methods involved. (Author in part)

REVIEW: The first paper highlights new areas in which nondestructive testing is being used. For those who are concerned with finding the most effective test methods for use in research, design, and production, the examples cited may provide worthwhile ideas.

The second discussion is directed toward designers with some background in available testing techniques, but not necessarily expert in any of the specific methods. The main message of the paper, and a good one, is that designers should be aware of the methods available to them, and should strive for a complementary role for destructive and nondestructive tests during design stages so as to achieve smooth transition from design to production. ##

Serial Number 2542
ASQC Code 830

TITLE: Design to eliminate automotive corrosion

AUTHOR: (Editorial Matter)

SOURCE: SAE Journal, vol. 73, Mar 65, p. 38-41 (*see RATR 2530)

PURPOSE: To show designs developed to eliminate automotive corrosion.

ABSTRACT: Case histories of proved designs show how dissimilar metals, box sections, fuel tanks, pipes and fittings, electrical connectors, and lamps can be protected from corrosion by proper design. The design objective is to eliminate any construction that would tend to collect dirt and/or moisture, and to minimize possible galvanic action corrosion of the metals. In some applications both good design and protective coatings are necessary. The designs shown were developed during the revision of SAE Information Report "Prevention of Corrosion of Metals" by the Ferrous and Non-Ferrous Committees of the Materials Engineering Activity.

REVIEW: This is a brief and clearly illustrated presentation of design ideas to prevent corrosion. While the specific reference is to automotive design, the ideas should have applicability in other areas where corrosion is a problem. ##

Serial Number 2543
ASQC Codes 830;870

TITLE: Starve the maintainability wolf

AUTHOR: J. M. Brearley (Bureau of Naval Weapons, Avionics Division)

SOURCE: SAE Journal, vol. 73, Mar 65, p. 56-57 (*see RATR 2530)

PURPOSE: To mention the advanced design techniques which are being used to close the "maintainability gap" existing in the avionics industry.

ABSTRACT: The spiraling complexity of modern avionics systems has left the Navy's experienced maintenance capability far behind, creating an internal "maintainability gap" that is ultimately resulting in mission degradation with respect to downtime. Compounding this problem is an increasing loss of experienced maintenance technicians; in fact, the near future will find the Navy needing approximately six times the number available.

In addition to augmentation of military personnel, broad programs have been initiated within the avionics industry in an attempt to reverse this trend toward decreasing avionics effectiveness. Starting with the concept that good design can do much toward reducing both maintenance time and skill levels required, the avionics industry has focused, at the design stage, on the major target areas affecting maintainability--specifically, reliability and serviceability, prime contributors to system effectiveness. Cost reductions are a necessary corollary to this effort. Prominent among these advanced design techniques are: microcircuitry; digital data processing; visual fault location; modular construction; redundancy; and special test programs. A system design that intelligently and intensely applies these various techniques should yield significant improvement of mission effectiveness by markedly reducing the logistics of supply and maintenance. Early results of these programs on Naval Bureau of Weapons systems show a rewarding pattern of higher reliability. (Author in part)

REVIEW: This article is based on the author's SAE paper 640345 (856C), which should be consulted by those who desire more details. The article is a clear and concise presentation of the highlights of the paper, and gives a bird's-eye view of design ideas which can be used to improve the maintainability of avionics systems. ##

Serial Number 2544
ASQC Codes 815;833

TITLE: R. F. connectors: Achievement of reliability through standardization and testing

AUTHOR: M. Deacon (Signals Research and Development Establishment, Ministry of Aviation, England)

SOURCE: Electronic Components, vol. 6, Jan 65, p. 31-37, 7 refs.

PURPOSE: To describe the United Kingdom's program to achieve r. f. connector reliability on a national scale.

ABSTRACT: The selection and standardization of radio frequency connectors to meet present-day service requirements for reliability and improved electrical characteristics have resulted in the publication of a revised Defence Specification for these components. The drafting of this specification and means of achieving the requirements called for in the document are discussed with particular emphasis on reliability.

Reliability has been achieved in the r. f. connector field by concentrating on basic design and materials, rigorous testing of the finished article, and systematic quality assurance tests, instead of conducting lengthy and exhaustive tests designed to give a failure rate in terms of time. The Defence Specification is considered to be a consolidation of experience gained by manufacturers and users over many years rather than the complete answer to connector reliability, and it is anticipated that many new developments will be forthcoming to further increase reliability. (Author in part)

REVIEW: This is a concise presentation of British experience in achieving reliability in r. f. connectors. Those who are concerned with the connector reliability problem should read this paper. They may find it useful to compare the findings with those in some of the papers on this subject which have appeared in the American literature (see, for example, RATR 1681, 1682, 1683, 1846, and 1967). It may be noted that reliability tests for connectors have been subject to much controversy in this country. ##

Serial Number 2545
ASQC Code 838

TITLE: Reliability is no redundancy

AUTHOR: R. A. Yereance (Battelle Memorial Institute, Columbus, O.)

SOURCE: ISA Journal, vol. 12, Apr 65, p. 57-60

PURPOSE: To discuss the pros and cons of redundancy as an aid to reliability.

ABSTRACT: Instead of the theoretically predicted improvement in reliability, a decrease in reliability may actually result from the use of redundant elements or systems. By examining the characteristics of redundant equipment and by mathematically predicting system performance using component reliability data, it is shown that redundancy by equipment or function is seldom an effective means of accomplishing improved reliability. The alternative to redundancy, the use of highly reliable parts, is much more successful.

However, redundancy has often proven worthwhile, particularly where personnel safety is involved. In manned spacecraft, for instance, redundancy is employed to improve safety, even though reliability is decreased. Examples show that systems redundancy may also be desirable where the reliability growth of a system does not follow the reliability growth of most of its components, due to unforeseen system complexity or dependence upon a part or parts exhibiting atypical reliability growth. In relation to microcircuits, redundancy will be difficult without incurring large weight and size penalties relative to the weight and size of the circuits themselves. In addition, the reliability growth of microcircuits appears promising, and redundancy may not be necessary for most applications.

REVIEW: At a first glance, the reader may wonder if there is an error in the title of this paper. However, there is not. The author's point is that it is generally better to achieve reliability without using redundancy--by producing more reliable single elements. This point is clearly brought out, and the paper is well written. The merits of redundancy and cases in which it can be necessary are also treated. It may be noted that if the "theoretically" predicted improvement in reliability due to redundancy is not found in practice, then the conceptual model on which the theory is based is inadequate. This is very often due to the failure of the model to take into account all of the relevant factors. ##

Serial Number 2546
ASQC Code 800

TITLE: The preparation of reports on fatigue of structures and materials

AUTHORS: W. Barrois and F. Bollenrath

SOURCE: Report 477, Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization, 64 Rue de Varenne, Paris VII, Jul 64, 12p

PURPOSE: To suggest a standardizing of fatigue-test reports in order to make them easier to read and understand.

ABSTRACT: This report is the result of an effort by the Structures and Materials Panel of the Advisory Group for Aeronautical Research and Development to standardize fatigue test reports to help improve the dissemination of such information among the NATO nations. The report is divided into four parts. The first part is considered as a formal panel recommendation and deals with data required for the general use of test results. Such information includes specimen geometrical data, definition of the material and its conditions, definition of loading, static strength, crack initiation and growth data, and statistical variation in test results. The second part deals with terminology and covers definitions of fatigue area, endurance limit, temporary endurance, unlimited endurance, load sequence, load intensity, and terms which describe the statistical frequency and distribution of loading. In Part Three abbreviated symbols are given for fatigue loads. Finally, Part Four lists factors that influence the resistance of materials undergoing testing. Such factors give consideration to the physical properties of the test piece, testing machine, and testing conditions.

REVIEW: This paper is an attempt to standardize the methods for reporting fatigue results and also the terminology that is used whenever such data are reported. With the tremendous amount of fatigue work being done in this country and abroad, this paper presents a reasonable approach to solving problems arising from the various nomenclatures being used and to assuring that all fatigue reports give sufficient information to be useful.

Several ASTM publications on fatigue will also be helpful in this regard. ##

Serial Number 2547 -1
ASQC Codes 711;712;714

TITLE: A study of the phenomenon of fretting-fatigue with emphasis on stress-field effects

AUTHOR: Jack Adam Collins (The Ohio State University)

SOURCE: Dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of the Ohio State University, 1963, 139p, 24 refs. (Xerographic copies may be purchased from University Microfilms, Inc., Ann Arbor, Mich., order no. 64-6890)

TITLE: The effect on stress direction during fretting on subsequent fatigue life

AUTHORS: J. A. Collins (Arizona State University, Mechanical Engineering Dept., Tempe, Ariz.) and S. M. Marco (Ohio State University, Mechanical Engineering Dept., Columbus, O.)

SOURCE: ASTM Preprint No. 69, 1964, 12p, 18 refs. (American Society for Testing and Materials, 1916 Race St., Philadelphia 3, Pa.)

TITLE: Fretting-fatigue damage-factor determination

AUTHOR: J. A. Collins (Arizona State University, Mechanical Engineering Dept., Tempe, Ariz.)

SOURCE: Presented at the ASME Winter Annual Meeting, New York, N. Y., 29 Nov - 3 Dec 64, Paper No. 64-WA/MD-10, 5p, 16 refs. (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To determine the effect of an existing stress field on damage from fretting and also to determine a fretting fatigue damage factor based on the endurance limit.

ABSTRACT: These papers deal specifically with the effect of stress direction during fretting on subsequent fatigue life and with the determination of a fretting fatigue damage-factor. Fretting is defined as a combination of a mechanical-chemical action that takes place when two solid bodies are pressed together and then caused to undergo relative sliding motion. The phenomena are (1) fretting corrosion, (2) fretting wear, and (3) fretting fatigue. Only the latter is dealt with in these papers.

Of fifty parameters associated with fretting fatigue, seven have been selected as being the most important. These are: (1) amplitude of relative motion, (2) pressure between the two fretted surfaces, (3) existing state of stress, including magnitude, direction, and variation with time in the region of the fretted surface, (4) number and frequency of fretting cycles, (5) material and surface conditions, (6) temperature in the region of fretting, and (7) atmospheric environment. A relationship between these seven

variables and the reversed fatigue limit of the virgin material was hypothesized and expressed through the use of a fatigue damage factor.

An experimental program was designed in which 4340 steel specimens were fretted against 4340 steel shoes. Four of the seven parameters listed above (items 4, 5, 6 and 7) were held constant. Only items 1, 2, and 3 were varied. Of these three, the amplitude of relative motion and the surface pressure were selected in combinations to form conditions designated as mild fretting or severe fretting. The existing stress-state was assigned three values: those resulting in a surface stress at fretted surface of static tension, zero stress, and static compression. After each group of specimens were subjected to an identical number of fretting cycles, they were fatigue tested to determine the fatigue limit.

Failure did not always occur in the fretted area; however, when it did, specimens subjected to severe fretting had a lower fatigue limit than those with mild fretting. Fretting under conditions of static compression was more detrimental to fatigue strength than either zero surface stress or static tension. This appears to be in opposition to other investigations. The explanation given is that after the fretting treatment has been completed and the compressive force removed, the stored elastic energy returns the specimen to its original dimensions and the stress concentration at the crack tip results in a localized tensile stress. The reverse is said to be true for specimens run with static tension so that localized compressive stresses result at the crack tip. A comparison of the fatigue results of the fretted specimens with the fatigue results of virgin specimens, leads to an illustration of how a fretting fatigue damage factor is determined.

REVIEW: These papers contain a wealth of information on the subject of fretting fatigue. The results are clearly illustrated, as are the procedures used in testing and in designing the test apparatus. The explanation given for the unexpected low fatigue results obtained from the static compression tests seems adequate but additional work is needed for verification. Similar work by other investigators (references are given) also resulted in an increase in life for static tension where fretting was in process during cyclic loading until failures in specimens were obtained. In the latter tests comparison of static tension data was made with zero-stress-level data rather than with static compression data; however, this still shows that fretting damage is decreased with an increase in static tensile stress.

Designers need not study the entire contents of these papers, but should be aware of the phenomenon and procedures for its control.
##

Serial Number 2548
ASQC Codes 773;774;851

EVENT: Second Seminar on Fatigue and Fatigue Design, Columbia University, May 5, 1964

TITLES:
1. The fatigue history simulator
2. Full-scale fatigue test on the P3 aircraft
3. Full-scale fatigue test on the DH-112 Venom aircraft
4. Fatigue safety of aircraft in service and its supervision

AUTHOR: J. Branger (Eidg. Flugzeugwerk Emmen, Switzerland)

SOURCE: Technical Report No. 5, Institute for the Study of Fatigue and Reliability, Department of Civil Engineering and Engineering Mechanics, Columbia University in the City of New York, sponsored by the Office of Naval Research, Air Force Materials Laboratory, and Advanced Research Projects Agency, Contract No. NONR 266(91), Jun 64, 92p, 6 refs. (AD-611 414)

PURPOSE: To report on a full-scale aircraft fatigue testing facility, on two case tests, and on its importance to the fatigue safety of aircraft in service.

ABSTRACT: The history of full-scale testing, leading up to full-scale fatigue testing, is briefly summarized. The requirements and development of a full-scale fatigue history simulator facility at Flugzeugwerk Emmen, the Swiss Government Aircraft Establishment, are described in detail. Two case histories describing full-scale fatigue tests of operational aircraft (Pilatus P3 Training Aircraft and De Havilland DH-112 Venom) are included. The fatigue safety of aircraft in service and its supervision is covered in considerable detail.

REVIEW: This report consists of four lectures which have been published under one cover, entitled by the event. The publication contains a few typographical errors, but they are not detracting. The author, accomplishes his purpose quite well.

A large amount of useful and valuable experience concerning full scale aircraft fatigue testing is described. The treatment is thoroughly detailed and is presented in such a manner that it does not bore the reader or insult his intelligence. The technical results and experiences will be of value to design and test engineers concerned with aircraft service life. ##

Serial Number 2549
ASQC Codes 817;870;880

TITLE: Improved parameter trade-off decisions in Air Force weapon system acquisition

AUTHOR: David Henry McElveen

SOURCE: Thesis submitted to the faculty of the School of Engineering and Applied Science of the George Washington University in partial satisfaction of the requirements for the degree of Master of Engineering Administration, 30 Aug 63, 72p, 40 refs.

PURPOSE: To present results of research on trade-offs among reliability, maintainability, and other parameters along with recommendations for improving the quality of decision-making in system program offices.

ABSTRACT: A basis is built on which to develop a plan for improved trade-off decisions. The three major trade-off parameters--reliability, maintainability, and availability--are discussed in detail. The interactions are analyzed between reliability and several performance and constraint parameters. A rather simple way is provided of thinking about the trade-off decision situation in a system program office. Elements of the AF system for managing the acquisition of weapons that satisfy reliability and maintainability requirements are described. The following specific actions should be taken by the Air Force Systems Command:

1. Issue a strong policy statement which will reinforce existing policies.
2. Provide more tangible evidence of continued interest by top level officials.
3. Broaden the effort to increase the number of qualified officers.
4. Develop improved methods, such as prediction and control, through research.
5. Revise procurement regulations to provide substantial incentives for successful performance.

Suggestions are presented for testing, implementing, and controlling these recommendations.

REVIEW: Most of this thesis is devoted to background discussion which is to form the basis for the recommendations. The discussion tends to dwell on the "big picture" viewpoint and does not really get into much "meat." Here and there a few very elementary formulas are injected, but otherwise the quantitative approach is avoided. The recommendations essentially say to do a better job of what already is being attempted. ##

Serial Number 2550
ASQC Code 780

TITLE: Electronic component reliability: the role of environmental testing

AUTHOR: L. W. D. Sharp (The Plessey Company Limited, Components Group, Kembrey Street, Swindon, Wiltshire, England)

SOURCE: British Communications and Electronics, vol. 12, Jun 65, p. 354-356, 7 refs.

PURPOSE: To discuss the role of environmental testing in the investigation of electronic component reliability.

ABSTRACT: Environmental testing has been used for design acceptance and qualification approval for many years, but in general it has not been able to provide useful data on reliability. However, the techniques of testing under controlled environments are being extended to provide more specific information on reliability. Since the causes of component failure are often inherent in the materials, processes and structures of the component, reliability is a basic objective in component design. Thus controlled environment testing can be a useful design tool. Accurate control of environment is essential in the study of failure mechanisms, the elimination of rogue failures, and in reliability assessments by long-term or accelerated tests.

Environmental testing is the subjection of component, material or complete equipment to carefully controlled conditions in respect to one or more of the environments in which it is expected to operate; e.g. steady temperature, humidity, vibration, contamination, thermal cycling, corrosive atmosphere, pressure, voltage. The over-stress method, most commonly using temperature as the accelerating stress, is useful in determining systematic failure mechanisms in simple basic components such as diodes and resistors. Accelerated life test techniques can be used to provide extrapolation factors for accelerated testing of production samples. In an attempt to detect and eliminate rogue failures, non-destructive testing techniques have been developed. These factory-performed tests usually assume that such failures will occur relatively early in life and that by consuming a small fraction of the component's useful life by burn-in tests, the rogues will fail before leaving the manufacturer. New methods of test now being studied will give additional or alternative safeguards and will thus supplement burn-in tests without loss of useful life. (Author in part)

REVIEW: This is a good brief description of the role which environmental testing can play in the achievement of component reliability. As such, it will be directly useful to those who want a bird's-eye view of the subject. For those who desire more detail, the seven references cited in the paper should be helpful. Other papers on the value and importance of environmental testing in reliability programs were covered by RATR 1900, 1916, and 2231. Papers dealing with topics related to the measurement/control of environmental effects may be found under ASQC Code 782. ##

Serial Number 2551
ASQC Codes 412;824

TITLE: Reliability confidence limits for complex systems

AUTHORS: Randolph R. M. Geoghagen and Sung C. Choi (Aerospace Corp., El Segundo, Calif.)

SOURCE: Report No. TDR-469(5303)-1, SSD-TDR-64-269, prepared for Commander Space Systems Division, Air Force Systems Command, Los Angeles Air Force Station, Los Angeles, Calif., under Contract No. AF 04(695)-469 by Aerospace Corporation, El Segundo, Calif., 31 Dec 64, 36p, 21 refs.

PURPOSE: To obtain confidence intervals for system reliability by simulation.

ABSTRACT: This report describes a method for determining estimates and confidence intervals for the reliability of complex systems. Using subsystem test results, approximate Monte Carlo solutions are obtained that are nearly identical to analytic solutions in the cases in which both can be applied. The method was developed for use on a digital computer and is applicable to series, parallel, or series-parallel systems.

REVIEW: This report is extremely difficult to read in that many assumptions and definitions are not explicitly given. For example, on page 5 we are told that (T_i, r_i) are the test data, where T_i is the total test time and r_i is the number of failures on the i-th component. Presumably one of these is fixed and one is random--which one? Appendix A, which reviews work on this problem by earlier authors, is useful. The references cited in the report (21 in all) will be helpful to those who desire more details. ##

Serial Number 2552
ASQC Codes 831;844

TITLE: Computer reliability study

AUTHORS: Donald O. Baechler and David E. Van Tijn (ARINC Research Corporation, 1700 K Street, N. W., Washington 6, D. C.)

SOURCE: Technical Documentary Report No. SSD-TDR-63-150, Headquarters, Space Systems Div., AFSC, Air Force Unit Post Office, Los Angeles, Calif., prepared under Contract No. AF 04(695)-147 by ARINC Research Corporation, 1700 K Street, N. W., Washington 6, D. C., Jul 63, 203p

PURPOSE: To report on a study to find ways of improving the performance of a computer and measures for establishing quantitatively the degree of improvement.

ABSTRACT: An entirely new dimension in reliability has to be found so that it will be possible to develop the necessary confidence in space computers. Classical techniques for reliability prediction lead to a pessimistic estimate of the effect of part failure on mission potential.

A digital computer suitable for use in a spaceborne guidance system was designed to the degree of completion necessary to make it adequate as a study vehicle. Its logic design is presented. A method of measuring the performance of digital computers is developed which is based on observation that failures in a computer generally do not result in wrong answers for all combinations of inputs. The percentage of wrong answers obtained with a particular failure can then be used as a measure of the severity of the failure. This percentage multiplied by the probability of this failure's occurring can serve as an absolute measure of the severity of the failure. Several techniques are described that are incorporated into the logic design of a circuit to render it less sensitive to failures of non-redundant parts. A method of flip-flop failure mode control is also described. The logic reinforcement method is applied to the digital computer and the measure of performance is used to evaluate the computer. Follow-on efforts are recommended for further development and application. (Authors in part)

REVIEW: The shortcomings of conventional reliability prediction cited in this report are certainly valid. This study shows that reasonably accurate reliability analysis which considers possible failure modes at the part level is indeed much more complicated than conventional practices. The technique presented here for establishing quantitatively the degree of improvement appears promising, but requires accurate reliability information on the failure modes, which is usually not readily available. This is a rather extensive report which will be of interest to those concerned with more realistic approaches to reliability analyses of digital computers. ##

Serial Number 2553
ASQC Codes 800;830

TITLE: Mariner IV: Developing the scientific experiment

AUTHOR: Glenn A. Reiff (National Aeronautics and Space Administration, Office of Space Science and Applications, Washington, D. C.)

SOURCE: Science, vol. 151, 28 Jan 66, p. 413-417, 6 refs.

PURPOSE: To describe the development of the Mariner IV spacecraft.

ABSTRACT: For 307 days the Mariner IV successfully sampled the interplanetary environment until, on 1 October 1965, the receipt of scientific data was discontinued, ending the 1964-65 Mariner mission. This article recounts the development of the scientific payload for the Mariner IV flight by summarizing the steps taken to combine the scientific instruments with the other vital elements of the spacecraft.

Because of weight limitations, extreme communication distances, and the requirement for long life, the scientific instruments had to be very closely integrated with the other spacecraft elements and developed under stringent quality-assurance controls. In the final design, 11% of the total weight of the spacecraft was alloted to the scientific subsystem, yet this subsystem contained about 50% of the 32,000 electronic components used in each spacecraft. A table lists the scientific instruments flown on the Mariner IV and defines the purpose of each.

Once the instruments had been selected, engineering models of the instruments and other assemblies were built, and testing was begun. Tests for space certification, screening, design verification and fabrication, integration, type approval, flight acceptance, life, prelaunch and mission support were performed in the various phases of qualification test, flight and spare spacecraft development. After launch and during the flight of Mariner IV, the proof-model spacecraft was frequently operated to test previously untried command sequences. As changes in the operational plans were required during the 7 1/2-month flight to Mars, alternative procedures were tested and practiced by the operations team with the proof-model spacecraft. Analyzing, testing, adjusting, rechecking and sometimes compromising were thus a part of each phase from project inception until mission completion in the creation of the reliable and spaceworthy craft.

REVIEW: This article, appearing as it did in the general technical literature, is worthy of note because of the implicit emphasis on reliability. Many of the examples are worthwhile illustrations of "infinite attention to detail" and of various tradeoffs. The article is directed toward the general scientist and engineer. ##

Serial Number 2554
ASQC Codes 773;833;841

TITLE: Job instrumentation--key to product reliability

AUTHOR: E. F. Gildermaster (Caterpillar Tractor Company)

SOURCE: Presented at the Earthmoving Industry Conference, Central Illinois Section, Peoria, Ill., 6-7 Apr 65, SAE paper S421, 7p (*see RATR 2530)

PURPOSE: To describe job instrumentation in relation to product reliability.

ABSTRACT: This paper outlines steps to achieve reliability for earthmoving industry products by measuring their work requirements and communicating these requirements to the design engineer by means of a process called job instrumentation. Job instrumentation requires judicious job selection, adequate instruments, precise measurement, careful data evaluation, and a concise projection of that data so that it is understood by the designer.

Forces, temperatures, hydraulic pressures, flows, accelerations, deflections and speeds can be measured while the machine works. The results can be applied to the design of an engine, hydraulic cylinder, transmission or any component subjected to dynamic conditions. Utilizing suitable techniques and equipment, job operating conditions can be measured during the normal work cycle by mounting recording equipment on the earthmoving machine. Data acquisition on magnetic tape is useful for it can be read by computers which produce the desired information in minutes. Recordings of these measurements are a guide to establishing laboratory test procedures and aid evaluation of the results for predicting component life expectancy. Methods suggested for extracting and presenting this recorded data are (1) single maximum or minimum conditions; (2) simultaneous condition chart showing interactions of forces, temperatures, pressures, etc.; (3) force-occurrence histograms; and (4) single force equivalents. With such information, the engineer has an effective tool for designing a reliable product. (Author in part)

REVIEW: The concept described in this paper can make an important contribution to the design of reliable components for mechanical equipment. While the specific reference in this paper is to earthmoving equipment, the methods would have applicability in a much wider frame of reference. The paper is a clear and concise description, and is well illustrated. ##

Serial Number 2555
ASQC Codes 412;824;831
822;823
412;822;824
814
830;870
700;800;813;
831

TITLE: Reliability growth during a development testing program

AUTHORS: Richard E. Barlow and Ernest M. Scheuer (University of California, Berkeley and The RAND Corporation)

SOURCE: Technometrics, vol. 8, p. 53-60, 8 refs., Feb 66

This paper is based on the report covered by RATR 2476.

TITLE: An investigation of the burn-in problem

AUTHOR: Michael J. Lawrence (Operations Research Center, University of California, Berkeley)

SOURCE: Technometrics, vol. 8, p. 61-71, 13 refs., Feb 66

This paper is based on the report covered by RATR 2296.

TITLE: An exact asymptotically efficient confidence bound for reliability in the case of the Weibull distribution

AUTHORS: M. V. Johns, Jr. and G. J. Lieberman (Stanford University)

SOURCE: Technometrics, vol. 8, p. 135-175, 28 refs., Feb 66

This paper is based on the report covered by RATR 2234.

TITLE: Reliability and military economics

AUTHOR: L. N. St. James (Bell Telephone Laboratories)

SOURCE: Bell Laboratories Record, vol. 43, May 65, p. 163-166

The essentials of this paper are in the one by the same author covered by RATR 2175.

TITLE: Improving components to pace jet transport needs

AUTHOR: L. W. Vance (Vickers Inc., Aerospace Div.)

SOURCE: SAE Journal, vol. 73, Jun 65, p. 58-63

This article is based on the paper covered by RATR 2251.

TITLE: The Relay communications satellite: A study in the achievement of high reliability

AUTHORS: H. L. Wuerffel and R. P. Dunphy (RCA Astro-Electronics Division, Princeton, N. J.)

SOURCE: Industrial Quality Control, vol. 22, p. 355-363, Jan 66

This paper is essentially the same as the one covered by RATR 1491.
##

Serial Number 2556
ASQC Code 813

TITLE: Design for reliability

AUTHOR: W. D. Raymond (Lockheed Missiles & Space Co., Missile Systems Div., Sunnyvale, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 241-244 (*see RATR 2511)

PURPOSE: To describe some of the specific techniques which were used to obtain the high reliability of the Polaris missile.

ABSTRACT: The high reliability of the Polaris missile is the result of the effective implementation of well-known procedures. Functional analysis is performed independently of the designers. While designers consider the question "will it work?", the reliability engineers ask "why won't it work?" This technique provides necessary checks and balances. Stress calculations are made for all parts to determine if they are operating within their ratings. Failure mode analysis consists of reviewing each part in each of its modes of failure to determine the effects on system operation. For some types of designs, a worst case analysis has proven very useful. Reliability predictions are especially useful for making comparisons of different design concepts. Special tests provide designers with economical answers to complicated questions. Reliability parts specialists generate a preferred parts list, approve applications, and generate specifications. All results of the reliability analysis are documented in detail. Numerous changes have occurred in the Polaris missile design strictly as a result of recommendations made by reliability engineers. Safety is also considered--problems are "assumed" and the possible causes are searched out. Design reviews serve as a periodic check. After recommendations have been documented in correspondence to the design groups, the information is fed into a computer which furnishes a daily print-out, called the "action tape," listing all open recommendations and their specified completion dates. Reliability reports to management at the same level as design, manufacturing, and other major divisions. Thus, in the event of disagreement with the designers, reliability has a "pipeline" to top management. (Author in part)

REVIEW: A thorough design reliability program is described in this paper. A factor in its success is surely that in order to implement it the reliability department must have a technical staff of some depth, both in numbers and in technical ability capable of designing. Safety analysis is an approach which has not received much publicity and which may be a new thought for some. As the author notes, it is close to conventional methods, but requires a reversed approach. Perhaps it could be termed a failure mode and cause analysis. This paper does not mention whether or not the designers also perform any of the steps cited in the reliability analysis. Certain of the well-known reliability techniques--such as stress calculations, failure mode analyses, and worst case analyses--are so close to the actual design process that it seems reasonable to have the designers implement them, in addition to including them in the detailed design review conducted by a group independent of the designers. However, this apparently is not usually the situation. ##

Serial Number 2557
ASQC Codes 830;844

TITLE: Design for reliability of NC machine tool control

AUTHOR: D. L. Pierce (Westinghouse Electric Corp., Systems Control Div., Box 225, Buffalo, N. Y. 14240)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 245-259, 11 refs. (*see RATR 2511)

PURPOSE: To review the design of a new vintage of numerical machine tool control from the reliability point of view.

ABSTRACT: The complexity of numerical machine tool control has increased to such a point that the reliability and time to find and correct troubles are of prime concern to users. One of the main purposes of the design was to obtain greater reliability and less down time. The paper covers some of the design problems and testing of the prototype model. The approaches used to obtain reliability are outlined. The functions of each of the subsystems are briefly described, and the unique reliability and servicing features of each are cited. Included is a reliability analysis which shows that the design goals for reliability can be met. The analysis is of further advantage in that failure rates are estimated relative to the subsystems. Any very great deviation of any of the subsystems from the predictions will immediately point out that there is danger of exceeding the overall failure rate and should bring about corrective action.

REVIEW: As this paper is concerned with the non-government area, it is somewhat set apart from the majority of reliability papers. The methods used in an effort to achieve reliability are some of the rather standard reliability and quality control approaches, and are only briefly cited. Emphasis is on the conventional reliability prediction method of adding failure rates; the results are used to indicate that a numerical goal has been satisfied. No actual system use or life-test data are cited.

The author in a private communication has commented as follows: "Continuing tests, which have been in process since preparation of the paper, do not show anything to indicate the analysis is too far wrong. We are also following all field use and failure experience. It is hoped that by follow-up and collection of factual data, we will be able to predict reliability to a reasonable degree for industrial application." ##

Serial Number 2558
ASQC Codes 844;846

TITLE: Man-rating the Gemini launch vehicle (Crew hazard and mission analysis)

AUTHORS: Frederick P. Kiefer, Ward Bishop and Jack W. Carter (The Martin Company, Baltimore, Md.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 260-268 (*see RATR 2511)

PURPOSE: To describe a flight hazard analysis.

ABSTRACT: The mission is broken into phases during which various conditional probabilities of success remain reasonably constant. There will be one of five possible outcomes for each phase: no failures; some failures, but mission success; mission failure, but crew safe; mission failure, escape possible but fails; mission a catastrophic failure. Data from previous experiments and various tests are combined to give best estimates of the probabilities of each element in each phase. The mission is broken down several times until the level is reached where the reliability of elements is easily calculated.

REVIEW: This type of analysis is very useful in trying to make sense out of the mountains of data that become available for large systems. Similar analyses have been published covering the Apollo project. The mathematics and probability involved are quite elementary in principle; the problems involved are in applying them to very complex situations. The complexity in practice of even these simple principles graphically shows why more esoteric principles are usually bypassed for analysis of large systems. The descriptions of some probabilities are not clear, undoubtedly due to the difficulties in putting partially conditional probabilities into words. ##

Serial Number 2559
ASQC Codes 833;837;838

TITLE: Some precepts of reliable electronic design

AUTHORS: Martin F. Chamow and Walter M. Smith (General Electric Company, Re-Entry Systems Department, Philadelphia, Pa.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 269-275, 8 refs. (*see RATR 2511)

PURPOSE: To present some precepts for reliable circuit design.

ABSTRACT: To make a circuit reliable, both the causes and effects of a failure in the components must be considered. Also, the effect of the changed circuit back on the components may be important. The effects of circuits on part degradation can be suppressed by controlling source impedance, eliminating the effect of transients, simplifying the circuit, and careful application of reliable parts. The effects of part degradation on the circuit can be suppressed by various kinds of redundancy, by reducing the effects of a failure, making circuits as fail-safe as possible, worst case design, and providing low impedance paths for leakage and transients in semiconductor circuits.

REVIEW: The guidelines presented here are good if it is always kept in mind that the system is more important than the parts--that it is the system we wish to optimize. Individual suggestions made in the article are not always applicable, as would be expected, for example:

1. In logic circuits it may be better to use only one type of logic element. This complicates part of the design, but may simplify the overall effort for a net improvement in reliability.
2. Derating may not always be a good idea. Relay contacts are an example. Just be sure that the part application parameters are such as to produce the best system.
3. In using redundancy, remember that failures caused by an unexpected environment are generally not reduced much by the redundancy.
4. Worst case circuit design may not always produce the best system. In logic circuits, for example, fan-in and fan-out may be decreased to the point where additional circuits are necessary.
5. There are circumstances where narrowing the tolerance margins may be the best way to improve the system, given all the constraints.
6. In the composite illustration it should be noted that the circuit was improved by adding parts, not removing them.
7. The implication that early and wear-out failures are not random apparently means that they are not Poisson-distributed. The use of the term "random" to imply the presence of a Poisson distribution is not good practice. ##

Serial Number 2560
ASQC Codes 612;814

TITLE: System design tradeoffs and economic planning

AUTHORS: C. R. Borchers and R. E. Churchill (International Business Machines Corporation, Federal Systems Division, Space Guidance Center, Owego, N. Y.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 276-282, 8 refs. (*see RATR 2511)

PURPOSE: To discuss the implications on national budgets of inaccurate estimates of system effectiveness or of the missions to be accomplished.

ABSTRACT: There are two important aspects to projecting space and weapon system budget requirements, the first having to do with estimates of the capability of the proposed system, and the second having to do with estimates of the character of the missions on which the system will be employed. Errors in the prediction of either can have important budgetary implications.

The central theme of this paper is the necessity for a quantitative analysis, based on the capability of the system and related to the character of the mission, which results in a determination of an inventory or force requirement. Such an analysis provides a proper basis upon which system budgeting can be undertaken.

The paper describes, in simplified form, the logic of a Monte Carlo model employed in the evaluation of airborne weapons systems. The model evaluates the capability of airborne weapons systems to carry out missions comprised of sequences of targets. After input data specifying the mission and the system to be evaluated are accepted, the program proceeds to compute the single shot kill probability of each weapon for each operable mode and for each target considered. The process continues sequentially until all targets have been destroyed. The inventory of systems required for mission completion is tabulated, together with such other items of interest as number of aircraft and weapons shot down, number of aircraft which abort due to subsystem failures, etc. The mission is repeated a number of times sufficient to determine an average force size requirement. The process is repeated for other missions and the forces combined to yield the total force, and hence total costs, for all missions. Examples based on data generated through the use of this model are discussed. (Authors in part)

REVIEW: This paper makes, quite emphatically, the point indicated in the PURPOSE, above. The authors' contribution to the solution of the problem is a rather brief description of a Monte Carlo model. However, it should be sufficient to convey the main points to those who are familiar with the Monte Carlo technique. A limiting factor in the application of the model would appear to be the adequacy of the input data. Certainly the topic is important from a value analysis point of view at a rather high level. ##

Serial Number 2561
ASQC Code 814

TITLE: Effects of reliability variations on system cost

AUTHORS: Howard L. Leve and Maurice M. Platte (Douglas Aircraft Company, Long Beach, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 283-295 (*see RATR 2511)

PURPOSE: To discuss certain cost aspects of reliability improvement.

ABSTRACT: Improvement in system reliability requires cost-effectiveness evaluation in order to ascertain whether the degree of improvement is desirable. To properly discriminate between alternatives having common effectiveness, a resource structure, referred to as a cost-of-ownership model, has been developed with the following three major categories: (1) Research, Development, Test and Evaluation, (2) Initial Investment, and (3) Annual Operating. This structure is divided and sub-divided into several levels of resource elements and the effects on the element costs due to reliability improvements are assessed with respect to tactical aircraft and space systems. It is shown that system support resources which are provided for non-reliability contingencies must be accounted for when evaluating the consequences of reliability improvement.

To illustrate cost sensitivities due to reliability improvement, a current model tactical aircraft system is quantitatively analyzed with respect to a reliability improvement in the avionics system. The analysis indicated that reliability improvement appeared to be feasible due to a large reduction in operating costs. It is then shown that an adverse factor which markedly affects the feasibility of reliability improvement is combat attrition.

The potential benefits of reliability improvement appear in the latter portion of a program due to highly significant reductions in operating and maintenance costs. If it is taken into account that the nation's economy has a persistent growth, then cost reductions made in the latter part of a program are not as beneficial with respect to the nation's economy as would be reductions in earlier expenditures, if no detrimental inflationary effects occur. This constitutes an adverse effect on reliability improvements. To properly evaluate future costs, the procedure of discounting to present value is used. For a set of possible discount rates, it is shown with respect to the considered tactical aircraft system that discounting future costs can significantly cause a reliability improvement to lose attractiveness. Obsolescence can also produce an adverse effect on reliability improvement. A quantitative method for determining the obsolescence potential of a system in any year of a program is developed. (Authors in part)

REVIEW: This is a closely-written discussion, the main points of which are indicated in the above ABSTRACT. The conclusions appear to follow reasonably from the assumptions which are made. Tables and charts illustrate the numerical results. The paper will be of interest to management personnel concerned with the economic aspects of reliability improvement. ##

Serial Number 2562
ASQC Codes 813;814;815

TITLE: Reliability aspects of "full life" product warranty

AUTHOR: Floyd J. Kreuze (Lear Siegler, Inc./Instrument Division, Grand Rapids, Mich.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 296-303, 8 refs. (*see RATR 2511)

PURPOSE: To introduce the "full life" warranty concept into military procurement.

ABSTRACT: To reduce military avionics support costs, methods must be developed to tie supplier profits to reliability attainment. The "full life" warranty approach as a self-enforcing means to this end is discussed. Both benefits and disadvantages are covered. The role of data in both reducing risk and improving profit margins is explored. This paper delves into both the concept and the mechanization of it from the reliability point of view.

The LSi Instrument Division is currently under contract with the Air Force for one product using partial life warranty and has offered several others under full life warranty to both the Air Force and the Navy. These proposals were made under the company's trade mark of Failure Free Warranty. (Author)

REVIEW: The idea here is an excellent one and should be zealously pursued by both government and industry. Obviously there are places where it may not be applicable at all, but this should not be allowed to hinder its use in situations where it may be of real value. One of the important advantages not mentioned explicitly is that it has the potential of reducing a lot of the burdensome paperwork involved now in the contracting and development phases. Every effort should be made to search out areas where the plan is most likely to succeed and then to try it. The search for application possibilities need not be limited to avionics equipment, but should cover the whole range of DoD equipment purchases.

This paper is obviously not the whole story, but it does introduce a "new" approach and should help form the basis of further effort.
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Serial Number 2563
ASQC Codes 844;863;871

TITLE: In-service reliability analysis - a guide for reducing maintenance costs and spares requirements

AUTHOR: T. D. Matteson (United Air Lines, San Francisco, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 304-314 (*see RATR 2511)

PURPOSE: To discuss the use of an easily understood technique for in-service reliability analysis which can be used to reduce maintenance costs, guide design improvement, and determine spares requirements.

ABSTRACT: The need was to develop an analysis method which: (1) uses normal service experience for short periods, (2) uses simple mathematics, (3) shows the effect of increasing age, (4) gives a failure rate estimate, and (5) gives redesign information. Selection of the fixed calendar period is a compromise between a large number of failures and the possibility that environmental elements can change. Identification, age, removal cause, and disposition of all installed units are the data required for a fixed calendar period. The analysis method is explained. When a failure is returned to service by overhaul it will be presumed to have been returned to some standard called zero-time. Some real data from a unit used on a large commercial jet transport is used as an example to develop conditional probability and survival curves for a range of experience from 0 to 4600 hours. These curves are used to obtain some answers to the questions:

- Would a scheduled overhaul be desirable?
- What other maintenance actions would be advisable?
- What design action is indicated?
- What long range average shop load and spares requirements will result?

The importance of the shape of the conditional probability curve rather than the MTBF when considering the maintenance program for a unit is briefly discussed. The conclusion is that simple techniques can be used effectively with in-service data to make reliability analyses.

REVIEW: The analysis method is described more by example than by a description in general terms, which will be a handicap to those wishing to thoroughly understand it. The method is indeed simple, and apparently some important decisions can be made without further complexity. It is assumed in the method that overhaul returns a unit to the same standard, called zero-time; nothing is said of any analysis to justify this assumption. However, the author in a private communication has indicated that analyses of this kind are being used in considerable quantity at United Air Lines to determine the age-reliability characteristics of a wide spectrum of repairable assemblies ranging from "black boxes" to turbine engines. Experience has indicated that "non-wearout" characteristics are much more prevalent than one might assume. The generalized "bathtub" shaped conditional probability (or hazard rate) curve often used in textbooks has, in fact, rarely been found for complex assemblies in real life. The paper covered by RATR 2305 is also on aircraft unit replacement policies. ##

Serial Number 2564
ASQC Code 433

I. TITLE: Bayesian statistics for the reliability engineer

AUTHOR: Alvin W. Drake (Operations Research Center and Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.)

II. TITLE: Application of Bayesian statistics in reliability

AUTHORS: R. J. Schulhof and D. L. Lindstrom (Hughes Aircraft Company, Space Systems Div., El Segundo, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 315-320; p. 684-695 (*see RATR 2511)

PURPOSE: To describe the application of Bayesian statistics to reliability.

ABSTRACT: I. This is a tutorial paper which introduces, in a simple and informal manner, some of the fundamental concepts of Bayesian (or "modern") statistics. The philosophy and procedures discussed form the basis for the development of a rational and consistent structure for the design of experiments and for decision making in the face of uncertainty. The Bayesian approach is of particular utility in small-sample situations.

II. Bayesian statistics can be used to solve the problem of estimating reliability with limited test data. It is possible then to combine prior information, sometimes engineering judgment, with test data to arrive at a combined estimate of reliability. This has caused considerable controversy, particularly with classical statisticians, and Bayesian techniques have not had widespread application. This controversy is the result, primarily, of misapplication of Bayesian techniques. This paper presents the theoretical foundation and the application of Bayesian statistics to reliability estimation and decision making along with some examples for small samples. (Authors in part)

REVIEW: The first paper is short and easy to read. It fulfills its purpose of introducing some of the concepts of Bayesian statistics. Most any engineer will be able to follow it easily. A consequence is, of course, that it does not go deeply into the matter.

In the second paper Bayesian statistics is considered to be a branch of Decision Theory based on loss functions. A Bayesian estimate of prior probabilities is necessary in evaluating the expected losses. The uninitiated may find this paper hard to follow since the line of reasoning is not carefully spelled out. There are several misprints which may cause confusion. Anyone using this paper for tutorial purposes should be careful not to confuse examples of the method with concepts which are inherent in it; it is easy to do here.

Bayesian statistics have much to recommend them for reliability analyses. They may be especially helpful in removing some of the problems that arise from the application of classical statistics to proving high reliability. ##

Serial Number 2565
ASQC Codes 821;844

TITLE: Reliability modeling with conditional probability logic

AUTHORS: Jerome D. Braverman and I. Paul Sternberg (Hughes Aircraft Co., Space Systems Div., El Segundo, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 321-331 (*see RATR 2511)

PURPOSE: To describe a simplified method of finding the probability of a success path for a complicated logic diagram.

ABSTRACT: When redundancies are involved, the usual set-theory expansion of the success path through a logic diagram is tedious. The expansion can be simplified by taking a subset of the logic blocks and using them as a set of conditions upon which the success path is expanded. Several examples are given.

REVIEW: This type of approach has appeared in the reliability literature before. The procedure can be somewhat more general than given in the text; the subset of logic blocks can be chosen so as to best simplify the algebra. No proof is given in the paper and the procedure appears mysterious to the uninitiated. All that really is involved is $P(S) = P(S|I)$ where I is any subset of events with a probability of unity. If $\{X_i\}$ are mutually exclusive events and the set is exhaustive (viz. one and only one must occur) then $\{X_i\} = I$ and $P(S) = P(S|X_1+\ldots+X_n) = P(S|X_1) + P(S|X_2) + \ldots + P(S|X_n)$. As mentioned before, judicious choice of the X_i (which can in themselves be combinations of other events) can tremendously simplify the analysis, especially if several of the events cause system failure.

Some of the notations and definitions are unusual at best and completely mystifying at worst, e.g., $\Sigma S_j G/S_j$ where S_j is the j-th state of the conditional set and G = conditional group logic. ##

Serial Number 2566
ASQC Codes 540;552;817

TITLE: Resource allocation for maximum reliability

AUTHORS: G. E. Neuner and R. N. Miller (TRW Systems, Redondo Beach, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 332-346, 7 refs. (*see RATR 2511)

PURPOSE: To show the universality of the Lagrangian multiplier approach in making tradeoffs for maximum reliability.

ABSTRACT: A procedure is described for quantitatively employing reliability as a major parameter in the determination of an optimum system design. The functional relationship between reliability and some other measure of system effectiveness, such as cost, weight, performance, etc., is described by a generalized equation. The measure of effectiveness is considered as a resource which is to be allocated to various parts of the system in a manner which maximizes system reliability. The method of Lagrange multipliers is employed and iterative solution techniques are discussed. A numerical example is given in which an optimum weight allocation is made to four areas of the design of an interplanetary spacecraft. (Authors in part)

REVIEW: The actual mathematics in this paper appears to be good and the general approach is worthy of consideration in making tradeoffs. It can probably be followed by most engineers, although it may take some effort. In the example, the method could be improved by doing the problem twice. The first time the individual tradeoff curves are drawn, they are faired through all the points. The second time, they should be faired only through the points in the vicinity of the first solution. The values of the coefficients in the second try may be quite different. This recommendation is more comprehensive than the "Selection of Optimum Configuration" in the paper. For example, the Transmitter and Propulsion subsystems show different behavior in the neighborhood of the solution than they do for the whole range. It might even be worthwhile to try all the possibilities in the neighborhood of the first solution--by computer if necessary. ##

Serial Number 2567
ASQC Code 821

TITLE: Problems in probability (an introduction to the pitfalls to be encountered when using probabilities)

AUTHOR: Ralph A. Evans (Research Triangle Institute, Durham, N. C.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., p. 347-353 (*see RATR 2511)

PURPOSE: To present an introduction to the pitfalls encountered by many engineers when using probabilities.

ABSTRACT: This paper discusses four problem areas:

1. The virtual impossibility of statistical independence of events with low probabilities.
2. The physical meaning of very low probabilities.
3. Physical vs. mathematical conditional probabilities.
4. Pips on the tails of probability distributions.

The benefits of redundancy depend on the statistical independence of several failure events. However if the apparatus is required to perform under several different environments and the events are independent only conditionally on a given environment, then the usual reliability equations must be altered. The appropriate relations are given and illustrated by numerical examples. In connection with (2) it is noted that when extremely low probabilities are under consideration, many factors which are usually extraneous are no longer negligible. Conditional probabilities are defined in a certain mathematical way. Sometimes they will not have the same meaning that an engineer intuitively associates with them. Two examples are given. Finally, one must be careful in estimating tail probabilities, especially far out in the tail. It is suggested that the tails be extrapolated no farther than the engineer is willing to accept a datum without calling it an outlier. Engineers who use probability theory must be willing to learn enough about it to decide when it is useful to them; to blame an ivory-tower statistician for their troubles is to abdicate their responsibilities. (Author in part)

REVIEW: This paper presents some useful discussion of practical problems in probability but it also misses the point in several places, especially in connection with (1). If several different environments are possible, conditional (physical) independence of redundant components is exactly what is desired, not (unconditional) independence. The correct way to calculate the reliability of such systems is to first find the reliability <u>conditional</u> on a particular environment, and then average over the probabilities of the various environments. Concerning (2), the example of the probability of survival of astronauts on a moon mission seems a little misleading since certainly what we are interested in is the probability of survival <u>given</u> that they go. The last section emphasizes the fact that if you estimate tail probabilities assuming a certain parametric form for the probability distribution when this distribution is in fact not correct, you may get into trouble. This is a little obvious but perhaps reliability personnel need to be reminded of it. ##

Serial Number 2568
ASQC Codes 820;844

TITLE: Methods of reliability physics

AUTHORS: J. Vaccaro and J. S. Smith (Rome Air Development Center, Griffiss Air Force Base, N. Y.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 354-363, 10 refs. (*see RATR 2511)

PURPOSE: To describe the theory of rate processes as applied to failure mechanisms of electronic parts.

ABSTRACT: There are several well-developed scientific disciplines which must form the basis for any systematic approach to modeling device degradation processes--chemical reaction rate theory, statistical mechanics (both classical and quantum) and irreversible thermodynamics. The fundamental task of reliability physics is to transform models structured on such a basis into useful engineering tools. The theory of chemical rate processes affords a conceptually useful frame of reference on which to analyze degradation processes. An important limitation of the transition state theory of rate processes is that the various partition functions are only relevant if all modes are thermally equilibrated in the normal and activated particles. Activation energy is a central concept in the analysis of change processes. Its usefulness in reliability problems is described here through the use of Arrhenius-Eyring methods for analyzing test data. A brief description of degradation in a semiconductor device illustrates the care required in selecting the proper mechanism and functional time dependence for analyzing high stress test data. (Authors in part)

REVIEW: The paper deals largely with the theory of rate processes and a specific application. The difficulty with the application is that the quite complex models are far beyond the possibility of being checked by experiment. This is one of the recurring problems in some avenues of physics of failure: it is easy to try to be too basic. There is a large gap between engineering and the basic models of physics. Some effort in this gap area is useful, but it is easy for it to become quite academic. The first author in a private communication has pointed out that attempts to apply basic models of physics to device degradation can serve as conceptually useful guides to more practical studies. ##

Serial Number 2569
ASQC Codes 770;844

TITLE: Reliability improvement as applied to power transistors

AUTHORS: G. F. Granger and E. W. Karlin (Radio Corporation of America, Electronic Components & Devices, Somerville, N. J.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 364-372 (*see RATR 2511)

PURPOSE: To summarize the activities of RCA's Component Quality Assurance Program (CQAP), the specific goal of which was to improve the reliability of a 20-ampere silicon epitaxial mesa transistor.

ABSTRACT: The failure mechanisms uncovered during the program are classified into three general categories: package failure mechanisms, interconnection failure mechanisms, and failure mechanisms associated with the device itself. There were 19 corrective actions taken to eliminate these failure mechanisms. Two of the most important failure mechanisms uncovered were (1) cracked silicon caused by stress induced during thermo-compression bonding, and (2) deterioration of the braze joining the silicon pellet to the package which was caused by the formation of an undesirable intermetallic compound in the braze. The first failure mechanism was found primarily on tests where a large change in temperature occurred (thermal shock, temperature cycling, etc.) and was uncovered by chemical removal of the bonded leads from the failed device. A significant reduction in the frequency of this failure mechanism was achieved by the use of ultrasonic thermo-compression bonding.

The second failure mechanism was found in tests where the device was subjected to prolonged exposure to high temperatures, dc-power operating life, high-temperature storage, etc. Failure of the device was indicated by increases in thermal resistance and V_{CE} characteristic. Visual analysis of the devices, after they were cross-sectioned, revealed a separation of the silicon pellet from the package in the brazed area. This separation was caused by the formation of an undesirable intermetallic compound in the braze. The condition was corrected by the identification and elimination of this material from the braze.

The amount of failure rate reduction was determined by measuring the reduction in the number of failures caused by a particular failure mechanism rather than evaluating a large number of samples under normal use or a small number of samples under conditions of accelerated testing. (Authors in part)

REVIEW: The approach to reliability described in this paper is to build better devices by ferreting out failure-prone processes rather than to prune away substandard units by judicious screening. The authors seem gratified with the improvements in reliability brought about by such a procedure.

The specific steps of the failure analysis are described in detail. The presentation seems complete, although not overly smooth. The reader has to work unnecessarily hard to follow the narrative. ##

Serial Number 2570
ASQC Code 844

TITLE: Application of physics of failure techniques in reliability failure analysis - case history

AUTHOR: P. E. Nickerson (General Precision, Inc., Kearfott Div., San Marcos, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 373-379 (*see RATR 2511)

PURPOSE: To describe a case history for a physics of failure approach which solved a field-failure problem.

ABSTRACT: Too often, failure analysis laboratories make a quick analysis and fix without getting to the heart of the matter. In this case history some of the failures in a computer were intermittent. They were finally traced to a capacitor which was shorting. All the usual tests failed to create the failure in the intermittent parts in the laboratory. After sectioning the capacitor the trouble was finally traced to silver migration. The moisture was entering through a defect created during the soldering-in of the part onto the pc board. The capacitor was completely redesigned to eliminate the problem.

REVIEW: This case history describes many of the trials and unsuccessful tests that were used, as well as the ones that finally led to a solution. It is instructive to show what can be done and is easily read by anyone. Obviously, the value of the paper is largely confined to this field and to showing the type of failure analysis that can be done if enough time, money, and effort are expended. ##

Serial Number 2571
ASQC Codes 711;712;844

TITLE: Fatigue phenomena in small metallurgically-bonded joints

AUTHORS: H. E. Frankel, A. J. Babecki, and R. E. Predmore (Materials Research & Development Branch, NASA Goddard Space Flight Center, Greenbelt, Md.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 380-394 (*see RATR 2511)

PURPOSE: To discuss fatigue phenomena in small metallurgically-bonded joints.

ABSTRACT: Fatigue problems are associated with the interconnections (micro-joints) of very small devices. Because of their minuteness, data at the basic metallurgical structural level concerning these failures are almost nonexistent. It is significant that these malfunctions required a repetitive cyclic loading in order to fracture. Examples of fatigue type failures are presented and as far as is known, the first metallographic evidence (at least in the case of the transistor) of a classic fatigue topography. An appendix gives an extensive discussion of bonding for microminiature devices.

REVIEW: It is certainly reasonable that many of the failures under shock and vibration loading are due to fatigue. Each failure analysis laboratory should have a metallurgist familiar with fatigue, on call at least. The publication of this paper should help arouse more concern about fatigue in the field of microminiature technology. It is recommended to all who are concerned with failures in the small devices. The appendix on bonding is rather general, but good. ##

Serial Number 2572
ASQC Codes 851;875

TITLE: RADC case histories in R&M demonstration

AUTHORS: Anthony Coppola and Anthony D. Pettinato (Rome Air Development Center, Griffiss Air Force Base, Rome, N. Y.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 395-408 (*see RATR 2511)

PURPOSE: To present examples of reliability and maintainability demonstration which illustrate the complications encountered and some innovations needed to meet unorthodox situations.

ABSTRACT: Rome Air Development Center now possess the records of numerous reliability and maintainability demonstrations. This paper discusses six case histories of reliability demonstration and six of maintainability demonstration. The reliability cases illustrate a wide variety of technical approaches as test methods were modified to the peculiarities of the particular procurements. The value of reliability tests was illustrated by the identification of numerous design problems. Workmanship and quality errors uncovered during the production phase would indicate that reliability tests have a worthwhile function. Also illustrated was the need to design tests to reflect as closely as possible the expected operating conditions in the field. One of the examples is an availability test, which forced the creation of new but compatible methods. The maintainability demonstrations are more homogeneous in approach, and generally supported the log-normal distribution of repair times. However, deviations were observed in some cases. (Authors in part)

REVIEW: It is highly desirable that experiences from formal attempts at reliability and maintainability measurement be digested and publicized as this paper does. Most government contractors do not have a diversity of experience with "...ability" tests, and they need to utilize the experiences of others. Also needed is the general dissemination to traditional engineering personnel and to management of the notion of literal measurement of the "...abilities." It provides a substance that is otherwise missing and makes organized efforts for them more understandable. In general, the reliability predictions made before these tests are moderately close to that measured after the removal of apparent design deficiencies. Extensive data are presented on maintainability, but unfortunately none on reliability. There is still interest in reliability in such questions as the typical length of the infant mortality period and the typical form of time-between-failure distributions as actually shown by controlled tests. Unfortunately, this paper is hard to read because of poor reproduction (probably caused by an improper typewriter ribbon), and of the lack of sub-titles within the paper, and of sparsely labeled figures. No references are given on any of the twelve tests which were presented. ##

Serial Number 2573
ASQC Code 775

TITLE: Time Domain Reflectometry in reliability testing

AUTHORS: L. L. Hewett and J. R. Petrick (General Electric Company, Apollo Support Department, Cape Canaveral, Fla.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 409-418, 11 refs. (*see RATR 2511)

PURPOSE: To stimulate the use of Time Domain Reflectometry as a screening tool.

ABSTRACT: Time Domain Reflectometry is a proven test method based on transmission line theory. The advent of solid state picosecond pulse generators and the transistorized sampling oscilloscope have made this an off-the-shelf test system that can be used for many quality assurance test problems. This paper contains a brief explanation of how Time Domain Reflectometry works, and shows three specific applications in which it has been used at Cape Kennedy. References are given for further study. (Authors in part)

REVIEW: The paper explains the system reasonably well for those who are familiar with circuit theory. All forms of screening tests should be used when potential defects must be eliminated. This tutorial paper should help in the case of Time Domain Reflectometry. ##

Serial Number 2574
ASQC Codes 711;712;713;
775

TITLE: Utilization of an ultrasonic fatigue damage indicator for inspection and design

AUTHORS: S. Zirinsky (Harry Belock Associates, L. I., N. Y.), H. Switzky (Grumman Aviation Corp., L. I., N. Y.), and A. Kenger (Space Systems Div., Fairchild Hiller Corp.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 419-430, 6 refs. (*see RATR 2511)

PURPOSE: To discuss an ultrasonic fatigue-damage inspection tool.

ABSTRACT: Accurate estimates of impending structural failures due to fatigue are difficult due to the lack of a convenient nondestructive observation of the accumulated fatigue strain damage prior to the formation of an observable crack.

Preliminary studies, using diagnostic Lamb and Rayleigh pulsed megacycle beams, have demonstrated the feasibility of monitoring the accumulating fatigue strain damage. This is based upon calibration of the loss of transmitted ultrasonic energy due to both sonic attenuation and sonic scattering on a micro scale during controlled fatigue loading. The technique has been demonstrated for both pulse echo and pulse transmission in tension-tension and reversed bending loading for both notched and unnotched specimens. When fully developed, two major benefits can accrue: (1) early indication of incipient structural failure under random loading conditions, wherein accurate prior prediction is not feasible, and (2) the development of improved design procedures based upon more accurate prediction of in-service structural performance. (Authors in part)

REVIEW: Any method for measuring the amount of fatigue damage (relative to that which will cause failure of that part) in situ will be most valuable. This one is still in the laboratory stage and so far works only on specimens designed for the method. Each such avenue as this should be explored in the hope that at least one will be feasible. This paper explains the method well although some familiarity with fatigue phenomena is required and preferably some knowledge of cumulative damage theories. (Figure A-4, concerning the life factor - L, is not clear.) ##

Serial Number 2575
ASQC Codes 770;782;851

TITLE: Reliability overstress testing of the Gemini inertial measuring unit system electronics package

AUTHORS: R. R. Ellis and J. J. Pollock (Honeywell Inc., Aero Div., St. Petersburg, Fla.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 431-436 (*see RATR 2511)

PURPOSE: To discuss an overstress test on a complex assembly which was successful in defining some marginal design characteristics.

ABSTRACT: The problem of reliability demonstration resolves itself into determining how to verify the achievement of the reliability necessary for manned space flight in a practical, cost effective manner. The strategy of overstress testing is to try to induce failures through overstress under simultaneous multiple environments, time, or both, and thus learn about the adequacy of design under severe field stress and over the equipment useful operating life. The equipment packaging techniques, circuit function, electronic part density, and form factor determine to a large extent the type of overstress testing to be conducted. The circuit function and mechanical configuration are described to give an understanding of the complexity of the equipment which was overstress tested. An analysis of spacecraft environments was conducted; the overstress environments selected were vibration and temperature-altitude. The assembly was first subjected to a low level vibration sequence to demonstrate the basic structural integrity and adequacy of workmanship. This resulted in the exposure and definition of minor discrepancies. Corrective action resulted in incorporation of a similar vibration as a production test requirement on each flight unit and inspection and process changes. Vibration at the overstress levels resulted in defining a problem in a relay package. Corrective action included a rearrangement of the mechanical assembly of relays and the modification of the relay internal construction. Temperature-altitude testing results indicated no significant performance problems. The conclusion from this experience is that stress testing can identify and remove marginal design characteristics during the development phase in a cost effective manner. The effectiveness of overstress testing when used as part of a total reliability program was demonstrated in this case by the successful accomplishment of pre-launch testing at Cape Kennedy and of four flights with no failures of this unit.

REVIEW: This paper presents a case history of a type of test which is often cited in the reliability literature but which is seldom implemented. The test apparently paid off here, and perhaps this will be some incentive for its wider use. The first author in a private communication has indicated that while the Gemini inertial measuring unit platform was not subjected to overstress testing as such, it did pass all requirements of a comprehensive qualification test program. It should be noted that the details of overstress testing will be unique for each assembly and intended use, which is also the situation for direct reliability demonstration (see the paper covered by RATR 2572). ##

Serial Number 2576
ASQC Code 800

TITLE: Air Force turns heat on reliability

AUTHOR: Allman T. Culbertson (Brig.-Gen., USAF, Air Force Systems Command, Research and Technology Division, Rome Air Development Center)

SOURCE: SAE Journal, vol. 73, Mar 65, p. 79-80 (*Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N. Y. 10017)

PURPOSE: To describe an Air Force reliability research program.

ABSTRACT: Ten years ago, the Air Force designed a reliability research program at its Rome Air Development Center (RADC) in an attempt to counter the rise in electronic equipment failure rate. Although the intervening years have seen tremendous improvement, reliability of electronic systems still remains a critical and very costly problem for the Air Force.

To achieve the Air Force reliability objectives, the RADC program has been divided into two disciplines: (1) reliability engineering--an attack on the short-range problem of gaining maximum equipment and system reliability with available components; and (2) reliability physics--a long-range solution to reliability through development of a better understanding of the basic failure mechanisms in the materials of components and of the progression of these failure mechanisms with time and stress. Most of the immediate progress has been made in reliability engineering--reliability can now be specified, measured, and predicted, given proper and sufficient data. Maintainability research will eventually provide a methodology for minimizing equipment downtime and associated costs. However, it is the reliability physics phase that will provide the fundamental knowledge needed to gain the orders-of-magnitude improvement required by future Air Force systems. This knowledge will also make possible a significant decrease in the cost associated with verifying the reliability of parts and systems.

While the reliability physics phase attempts no solution of immediate problems, the long run returns are potentially higher, as evidenced by its contribution to Telstar I, a nonmilitary system. Telstar I failed and was then restored by remote control from the ground, using knowledge resulting from RADC reliability physics research. Reliability research will obviously result in substantial savings for the Air Force and Department of Defense, but, in addition, there will be many commercial advantages spinning off from the Air Force-industry reliability efforts.

REVIEW: This paper outlines some of the important RADC contributions to the Air Force's reliability program. It specifies that many of the pressing reliability problems have been brought about by increases in equipment and system complexity. The author points out that work under way in reliability physics has the long-range potential to solve many of these problems. ##

Serial Number 2577
ASQC Codes 711;712;841;
843

TITLE: Tape recorder and computer foretell fatigue failures

AUTHOR: W. E. Schilke (GMC, Allison Division, Transmission Research and Development)

SOURCE: SAE Journal, vol. 73, Mar 65, p. 82-87 (*see RATR 2576)

PURPOSE: To describe an analysis of vehicle power-train component fatigue life using electronically-acquired and converted field data.

ABSTRACT: Rapid analysis of vehicle power-train component fatigue life using electronically-acquired field test data is now possible due to the current ability to convert the analog data to a versatile digital form. Power-train component duty-cycle data are collected in the field on analog tape recorders for subsequent digitizing and computer analysis in the laboratory. A given data recording can be analyzed in a number of ways to achieve different analytical objectives by utilizing specifically designed computer programs. In this paper, transmission output speeds and torque data collected using this technique are used to determine the fatigue life of a typical transmission spur gear transfer case.

REVIEW: This paper describes a good example of automated data acquisition and analysis. The specifics, which are clearly presented, will be of interest to those faced with similar problems. In a broader context, the ideas should be useful to those concerned with the collection and analysis of data for use in design and development work.
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Serial Number 2578
ASQC Codes 813;844

TITLE: Apollo reliability analysis

AUTHOR: Owen G. Morris (NASA Manned Spacecraft Center)

SOURCE: Astronautics & Aeronautics, vol. 3, Apr 65, p. 52-55

PURPOSE: To discuss the use of reliability analysis in the Apollo spacecraft program.

ABSTRACT: The development of the Apollo reliability program demonstrates that there is a productive place for both quantitative and qualitative aspects of reliability. For the Apollo program, a rigorous statistical demonstration of spacecraft reliability was not feasible; however, quantitative (probabilistic) methods were used in the design phase of the program and aided in the evaluation of test data as they became available. A hybrid (prediction-assessment) method was useful in providing a projection of Apollo reliability based on the data existing at any given point in time. As actual test data for a particular item became available they were assessed for validity in accordance with the ground rules (or reliability goals) and were then introduced into the mathematical reliability model in place of the prediction for each item. Used in this manner, statistical techniques made unreliable components clearly evident, permitting prompt and effective corrective action.

Qualitative elements--those not resulting in a probabilistic reliability prediction--receiving special emphasis or which were unique to the Apollo program included: a detailed failure mode and effect analysis made on the entire spacecraft; a closed-loop failure reporting and corrective action system; a qualification test, combined system test, and preflight checkout; and audits of the overall reliability program by both NASA and major contractors. At the time the paper was written the test program was well underway and several tests had been completed successfully.

REVIEW: This paper presents a general description of the principal features of the Apollo reliability program. In particular, it shows that a combination of probabilistic and qualitative techniques are required in order to assess the chances for mission success in spacecraft programs. The paper will be of interest to those concerned with the setting up and management of similar programs. ##

Serial Number 2579
ASQC Code 612

TITLE: Ways of assuring continued systems operation--diagnostic programming and malfunction display

AUTHOR: John R. Ottina (System Development Corporation, Santa Monica, Calif.)

SOURCE: Presented at the Systems Engineering Conference, Coliseum, New York City, 8-11 Jun 64, 11p

PURPOSE: To discuss techniques for constructing computer programs with features to deal with malfunctions which could prevent systems operation.

ABSTRACT: A malfunction in a computer program can be directly traced to: (1) a malfunction or error in the equipment, (2) a malfunction or error in personnel, or (3) an error in the computer program. Since, under the definitions stated in the paper, the computer program is not subject to malfunction, the concern is with equipment and personnel. Equipment malfunction detection may occur: (1) entirely within the equipment, (2) through a combination of special equipment features and computer programming, or (3) entirely within the computer program. Parity, reply back, and check sum techniques are examples in each of the three types of detection which are employed to solve one of the basic problems existing in any system--the successful transfer of information. More sophisticated detection techniques involve the use of diagnostic programs which cycle either upon demand or on a prescheduled basis to detect equipment malfunction. These computer programs are constructed either to stress known equipment limits and to compare the results with predetermined results or to compile results over periods of time and analyze these statistically in order to diagnose malfunction.

The most common technique employed to detect personnel malfunctions is to make all but certain actions illegal and to construct the computer program to present a display when the actions are taken. Another technique is to require two or more actions to be taken; if these actions do not correspond, the computer program will set an alarm or present a display.

Once a malfunction has been found, the action the computer program should take for total system effectiveness must be determined. A sequence of actions for response to malfunction is: try again, alternative source, avoid the source, best guess, start over, and stop-backup. Each of these is described briefly.

REVIEW: This is a very brief presentation of techniques for constructing computer programs with features to deal with malfunctions. No references are cited. It will be of interest mainly to those who are already somewhat familiar with the role of computers in command and control systems. ##

Serial Number 2580
ASQC Code 813

TITLE: Highlights of the Gemini reliability program

AUTHOR: A. S. Torgersen (McDonnell Aircraft Corporation)

SOURCE: Presented at the IEEE Group Meeting, Florida West Coast, 21 Jan 64, 5p

PURPOSE: To discuss the reliability aims and goals of the Gemini program.

ABSTRACT: The original intent of the McDonnell Aircraft Corporation on project Gemini was to have approximately double the reliability engineering effort that was actually maintained. Program cost limitations necessitated reduction or elimination of facets of the original plan--such as extensive parts tests, thorough design reviews, and close surveillance of suppliers. Due to Gemini's high reliability goals and long mission operating times, there was no practical way to demonstrate reliability performance to any significant confidence level; therefore, effort was geared to the preventive action thought to yield the greatest returns for the effort. This reliability effort and its results are described.

Very concerted effort was made during design, procurement, development and production phases to obtain the highest reliability equipment. Since the great bulk of the functional Gemini systems were developed and produced by suppliers, there was great dependence on their reliability understanding and capability. Although restricted by cost limitations, considerable effort was expended to evaluate and improve the selection of parts and to use design reviews, overstress tests and failure rate data, both by suppliers and in-house. The quality of supplier performance in these areas varied. To improve the value of failure reporting, analysis and corrective action, a Reliability Monitoring Group was responsible for investigating all functional equipment failures and maintaining the necessary follow-up until satisfactory disposition was concluded. Much progress has been made--but the cooperation of all involved in the program, such as designers, buyers, managers, is needed to develop and maintain high reliability.

REVIEW: In keeping with its title, this is a very brief presentation. It serves to indicate the kinds of steps which can be taken to assure high reliability in the face of cost-related constraints. It may be of interest to those who are concerned with the reliability aspects of similar programs. ##

Serial Number 2581
ASQC Codes 740;770;841

TITLE: Automatic checkout systems for stages of the Saturn V manned space vehicle

AUTHOR: D. M. Schmidt (NASA, Marshall Space Flight Center, Huntsville, Ala.)

SOURCE: 1965 IEEE International Convention Record, Mar 65, Part 4, p. 85-93 (available from IEEE, Inc., 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To describe the automatic checkout systems of the Saturn V.

ABSTRACT: To meet its goal of placing men on the moon by 1970, the United States is developing the Saturn V space vehicle. Exclusive of the spacecraft, Saturn V consists of three liquid-propellant rocket stages and a non-propulsive instrument unit stage. Because of the unprecedented size, complexity and unique test requirements, the design of a checkout system for each stage was a major task. NASA's Marshall Space Flight Center, which is responsible for Saturn V system integration and development of the individual stages, adopted an automation plan which makes automatic checkout and test a requirement for each stage before its shipment to the launch site. Since the Saturn V program is developmental, the checkout systems have not, as yet, been completely proven.

While the automatic checkout systems for the individual stages differ in hardware and in operation capability, the typical checkout scheme consists of a central digital computer and remotely situated test stations. In general, the test stations were designed for electrical, mechanical, control, guidance and instrumentation systems and, since checkout is a system-testing operation, were oriented to meet a progressive, building-block sequence of checkout tests. While designed by different contractors to meet unique test requirements, each stage's checkout system must also meet the overall program goals of high reliability, efficient handling of large volumes of data, and accuracy and speed of operation. Test requirements and automatic checkout equipment are defined for each of the four stages. Block diagrams aid illustration of the computer-test station complex used to control checkout of each stage.

REVIEW: This is a reasonably detailed description of the automatic checkout systems for the Saturn V, and the philosophy on which they are based. This concept is important when high reliability is required, as in the case of an expensive, man-rated vehicle. Other considerations include the avoidance of human error and the meeting of time schedules. The ideas presented in this paper will undoubtedly find application in other programs having similar requirements. ##

Serial Number 2582
ASQC Code 824

TITLE: Probabilistic design tools promise higher levels of initial reliability

AUTHORS: Gerhard Reethof and G. W. Weber (General Electric Co., Large Jet Engine Dept.)

SOURCE: Presented at the National Aeronautic Meeting, Washington, D. C., 12-15 Apr 65, SAE paper 650210, 12p, 17 refs. (*see RATR 2576)

PURPOSE: To present some of the more important tools of design and evaluation that are directed toward arriving at high levels of reliability early in the development process.

ABSTRACT: Many of the modern reliability techniques are not suitable for structural problems. The variability of stresses and strengths causes the most trouble in designing mechanical and structural parts. The probability of failure can be determined from the probability density functions of stress and strength.

REVIEW: The first part of the paper is quite introductory, the middle part explains the simple stress-strength model for failure. There appears to be some confusion about how time enters the failure calculation, but perhaps it arises from trying to oversimplify the presentation. The word "random" is used as a synonym for "Poisson variable"--a practice which should be discouraged since all variables whose uncertainty is not negligible are random. The examples are not too clear since they consist essentially of the introduction and the answer.

While the simple stress-strength model for failure is useful, it is unwise to assume a parametric form for the tails of a distribution and to proceed to calculate small probabilities of failure, especially to several significant figures. The reason it is unwise is that little is ever known about the shape and size of the far tails of a distribution pertaining to any physical situation. ##

Serial Number 2583
ASQC Codes 412;824

TITLE: Tolerance and confidence limits for classes of distributions based on failure rate

AUTHORS: Richard E. Barlow and Frank Proschan (Boeing Scientific Research Laboratories, P. O. Box 3981, Seattle, Wash. 98124)

SOURCE: Boeing Scientific Research Laboratories Document D1-82-0503, Mathematical Note No. 446, Mathematics Research Laboratory, Jan 66, 22p, 16 refs.; also Memorandum RM-4914-NASA, The RAND Corp., Santa Monica, Calif., Feb 66

PURPOSE: To extend the validity of tolerance and confidence limits based on the exponential distribution.

ABSTRACT: Assuming that the sample data arise from a distribution with monotone failure rate or with monotone failure rate average, tolerance and confidence limits are obtained for most reliability parameters of interest. These confidence limits are, in part, derived from the exponential distribution. In many cases these limits are optimum when the failure distribution is exponential. They also have the advantage that they are convenient to compute and are not based on strong, non-verifiable, parametric assumptions. Since these confidence limits are derived in part from the exponential distribution, this paper, in a sense, represents a new justification for the use of exponential confidence limits in reliability theory and practice. (Authors in part)

REVIEW: This is a good paper which justifies (at least conservatively) the use of several confidence procedures based on the exponential distribution in more general situations. As the authors point out, a few of the results will be non-trivial only if certain relations among the constants, i.e. sample size, amount of censoring, confidence coefficient, etc., are satisfied. Fortunately, however, most of the results are applicable in most practical cases.

A related paper was covered by RATR 2283. ##

Serial Number 2584
ASQC Codes 775;815

TITLE: Commonly used specifications and standards for nondestructive testing

AUTHOR: --

SOURCE: Materials Evaluation, vol. 24, p. 158-163, Mar 66 (Society for Nondestructive Testing, 914 Chicago Avenue, Evanston, Illinois 60202)

PURPOSE: To provide a source check list of specifications and standards for nondestructive testing.

ABSTRACT: About 120 specifications and standards are listed according to the codes General, Magnetic, Eddy Current, Penetrant, Hardness, Radiographic, Thickness, Ultrasonic. They are taken largely from ASTM, SAE, AWS, MIL standards, and NBS publications.

Comments, corrections, etc. are requested; they should be addressed to the Society for Nondestructive Testing.

REVIEW: This is a good service and is part of the detail that can improve reliability. Those with an active interest are urged to study the list and send their comments to the authors. Naturally any such project as this requires apparently-arbitrary decisions as to where lines must be drawn. The authors seem to have done well in this respect. ##

Serial Number 2585
ASQC Codes 711;712;837

TITLE: The theoretical deduction of fatigue scatter factor for structures

AUTHOR: I. M. K. Malik

SOURCE: Aircraft Engineering, vol. 36, Jul 64, p. 223

PURPOSE: To show how to calculate a safety factor for safe fatigue life.

ABSTRACT: If a Gaussian distribution of "log fatigue life" with a known variance and mean is assumed, then it is easy to calculate the fraction of the population that will be above a given "log fatigue life." If the mean is estimated from a sample, then a confidence limit must be included and it, too, is easily calculated. A safe fatigue life can then be estimated.

REVIEW: There is an undue faith in the applicability of the Gaussian distribution in this article. While the statistics in it are correct, the assumptions (conceptual model involved) are not likely to fit reality very well in the tail region of the distribution where it will be used. The variance is not likely to be known any better than the mean, and the tail of the distribution is most likely not to be exactly Gaussian. Safety factors (or safety margins as this might be called) are good to use, but to associate an exact low probability with them is misleading at best. ##

Serial Number 2586
ASQC Codes 822;824

TITLE: The determination of laws of distribution on the basis of a small number of observations

AUTHORS: V. V. Chavchanidze and V. A. Kumsishvili

SOURCE: Russian Book, Primeneniye Vychislitel'noy Tekhniki dlya Avtomatizatsii Proizvodstva, Mashgiz, Moskva, 1961, p. 129-139, Translation prepared by Translation Services Branch, Foreign Technology Div., WP-AFB., O., FTD-TT-62 1048/1+2, 8 Mar 63, 18p

PURPOSE: To show how a cumulative distribution function can be estimated from a very small sample.

ABSTRACT: The classical procedure for determining the cumulative distribution function (cdf) is to use nothing but the data themselves and to draw a step function for the cdf. This does not use all the information we have. Assume that the cdf is smooth and is zero at x = a and 1 at x = b. With no data, assume in ignorance that it is linear. Each datum modifies this original assumption a little bit by further assuming that the actual cdf is the average of the original linear estimate of the cdf and of a special cdf for each datum. This special cdf for each datum is quite steep in the neighborhood of that datum and is near 0 or 1 outside that neighborhood. Some success is claimed for the method.

REVIEW: Inferences based on small numbers of observations are particularly important in reliability analyses where data are often scarce. Hence the topic of this paper is of interest. While there is nothing incorrect about the statistics, per se, in the paper, it would seem that the Bayesian approach, where feasible, would be more rigorous and more profitable. Long narrow tails on the distribution are explicitly excluded from consideration in the paper; so if you are looking for that kind of information, this paper will not help. ##

Serial Number 2587
ASQC Code 833

TITLE: Bearings

AUTHOR: --

SOURCE: Machine Design, vol. 38, 10 Mar 66, 230p including advertising (Bearings Reference Issue) (Available from Machine Design, Penton Bldg., Cleveland, O. 44113; Price $2.00)

PURPOSE: To provide general applications information on bearings.

ABSTRACT: The contents are:

Fundamentals
- Lubricants
  - Oils and Greases
  - Solid and Bonded-Film Lubricants
- Lubricating Devices
- Basic Bearing Types
- Bearing Materials and Parts

Plain Bearings
- Cast Bearings
- Strip-Type Bearings
- Powder-Metal Bearings
- Plastic Bearings

Ball Bearings
- Radial Ball Bearings
- Angular-Contact Ball Bearings
- Thrust Ball Bearings
- Instrument Bearings
- Unground Ball Bearings

Roller and Needle Bearings
- Cylindrical and Journal Roller Bearings
- Self-Aligning Spherical Roller Bearings
- Tapered Roller Bearings
- Thrust Roller Bearings
- Needle-Roller Bearings

Premounted and Linear-Motion Bearings
- Premounted Bearings
- Rolling-Element, Linear-Motion Bearings

In addition there is a list of suppliers of the different bearings.

REVIEW: This type of information, while traditional, should not be overlooked as a source for reliability improvement of products. Designers need to take advantage of adequate information on which to base their decisions, whenever such information exists.

This issue provides some good insight into bearing fundamentals which will be valuable to new people in the field. Even old-timers will do well to read it--to keep up-to-date, to refresh a memory here and there, and to erase a few wrong notions that have crept in somehow. The material could have profited by a discussion on methods of estimating life, and the uncertainties thereof, for the various methods. ##

Serial Number 2588 -1
ASQC Codes 711;782;830

TITLE: Mechanical aspects of electronic products

SUBTITLES AND AUTHORS:

1. Which aluminum?, Floyd A. Lewis (The Aluminum Association, 420 Lexington Avenue, New York, N. Y. 10017)
2. Applying fasteners effectively, Technical Information Staff, Industrial Fasteners Institute, Cleveland, O.
3. Countering shock and vibration, Richard L. Lerner and Larry Zide (Contributing Editors)
4. Selection check list for transit cases, Michael C. Presnick (MM Electronic Enclosures, Inc., Hicksville, N. Y.)
5. Selection check list for small metal tubing, John J. Bowe (Superior Tube Company, Norristown, Pa.)
6. How not to specify an enclosure, Andrew Somerville (Bud Radio Co.)

SOURCE: Electronic Products, vol. 8, Mar 66, (1) p. 26-30, 32, 34; (2) p. 36-38, 40-43, 110, 112, 114, 116, 118, 120, 122, 123; (3) p. 47, 48, 50, 51, 160, 162, 164, 166; (4) p. 53-54; (5) p. 54; (6) p. 168, 170, 171, 173, 175 (United Technical Publications, Inc., 645 Stewart Avenue, Garden City, N. Y.)

PURPOSE: To refresh electronics engineers on the problems of mechanical aspects of electronic products.

ABSTRACT: 1. Designations for wrought aluminum and aluminum alloys have been standardized by the Aluminum Association and follow a four-digit index system. The four alloy groups, or series, of most interest to electronic packages--copper, manganese, magnesium and magnesium silicon--and popular alloys within each are discussed. Characteristics and suitable applications of the various metallic and chemical coatings and finishes are summarized.

2. To insure proper selection and effective application of mechanical fasteners for electronic equipment, factors such as strength, material properties, thermal properties, corrosion, torque recommendations and fastener types should be considered. Selection and application criteria are listed; fastener materials, coatings and finishes are discussed in relation to economy, strength, corrosion and temperature resistance; various fastener styles and standards are suggested.

3. Techniques for countering shock and vibration fall into two major approaches: (1) careful initial detailing of the configuration of the electronic package along the lines of classical mechanics--using measures and procedures such as damping, structural shape, balancing, center-of-gravity mounting, mockups; and (2), compensatory or additive measures such as potting, extra rivets or fasteners, or specification of shock and vibration mounts.

4. After deciding the transit case functions essential to a particular application, a check list should be used to insure that all details are specified. The check list suggested covers the shipping hazards of shock and vibration; transportation, handling and stacking, environmental protection; and equipment operation

while in the transit case.

5. Rules for correctly specifying small metal tubing used in electronic applications cover the following areas: determination of fit, cooperation with tubing suppliers, closer-than-commercial tolerances, and telescoping tubing.

6. Lacking practical experience in mechanical design or electronics application, many electronics engineers cannot envisage the mechanical parts or subsystems associated with electronics. In designing the mechanical portion of the electronic equipment, many common mistakes could be avoided by careful physical placement of components and by early choice of a suitable enclosure. Rather than the "forgotten" component in equipment design, housings or enclosures should be the first item considered--for, in addition to the extra cost and time involved, insufficient attention to mechanical aspects affects electrical performance: crowded or poorly positioned components often result in overheating, radio interference and pickup of hum. (Authors in part)

REVIEW: This is a most important subject and the emphasis here is good. Its main value will be in stimulating the electronics engineers to realize that reliability and performance can be violently degraded by poor mechanical design. The factual content is generally good, although far from complete--as would be expected in an issue of this sort. An unmentioned factual point worthy of stress is that strength is an ambiguous word. In mechanical parts it is usually assumed to be ultimate strength, but parts rarely fail that way. Fatigue, corrosion, creep, fretting, etc. and combinations thereof are much more common. So whenever high strength material or parts are advertised, always ask: does that high strength apply to the ways in which my part is likely to fail? You will be surprised at how often the answer is: NO! ##

Serial Number 2589 -1
ASQC Codes 824;838

TITLE: Theory of adjustable switching networks

AUTHORS: S. Amarel, K. R. Kaplan, S. Y. Levy, C. V. Srinivasan, and R. O. Winder (Radio Corporation of America, RCA Laboratories, Princeton, N. J.)

SOURCE: Special Scientific Report No. 2, AFCRL-63-185 (I) and Final Summary Report AFCRL-64-894 (II), prepared for Air Force Cambridge Research Laboratories, Office of Aerospace Research, USAF, Bedford, Mass., under Contract No. AF19(604)-8423, by Radio Corporation of America, RCA Laboratories, Princeton, N. J., 30 Apr 63, 149p, 19 refs. (I) and 30 Oct 64, 19p, 27 refs. (II)

PURPOSE: I, Part 1: To present a survey of the theory of threshold logic; to present some recent work done in this area; to compare the Bayesian approach to the synthesis of very large threshold gates with a geometrical alternative.
I, Part 2: To survey some redundancy schemes for improving reliability; to compare these with the recursive triangle method previously presented; to extend the analysis of that method; to present initial results of the incorporation of memory and feedback to allow the use of fewer gates.
II: To summarize the work done under the contract, to present a list of references, and to list the literature produced under the contract.

ABSTRACT: This covers the second of four special scientific reports and the final summary report under the subject Air Force contract. All of the reports are divided into two sections--one on threshold logic and one on switching network reliability.

I, Part 1 deals with threshold logic, and starts with a survey of the field, augmented by a reading list. It deals largely with the application of threshold gates to artificial intelligence. (An earlier report covered by RATR 1066 dealt with computer applications.) The resolution of the geometric problem of partitioning Euclidian n-space by a collection of hyperplanes is attacked. Upper bounds on the number of incompletely specified functions are computed. An incomplete report is given on the then-current results of a computer-aided investigation of the realization of arbitrary functions with networks of simple three-input majority gates. The last section discusses the authors' approach to threshold gate design, and compares it with the Bayesian approach. An appendix presents the 83 network realizations of four-argument threshold gates discussed previously.

I, Part 2 surveys the work done on the application of redundancy to the improvement of reliability in switching systems, specifically discussing the papers presented at the 1962 Symposium on Redundancy Techniques for Computing Systems, which was held in Washington, D. C. The rest of the report deals with the authors' recursive triangle approach to redundancy, and also with the introduction of self-repair characteristics into the nets. Examples are given.

II gives a short summary of the threshold logic theory covered

under the contract, with conclusions and references, and then discusses the work done by the authors on reliability improvement through recursive networks, feedback, and redundant coding. References are included here also, and the report concludes with a list of the literature the contract has generated.

REVIEW: I, Part 1: The survey of threshold logic is a state-of-the-art summary, and brings this subject up to date. The partition work is well done, but not well explained. The section on realizability of threshold gates is valuable. The investigation of networks of three-input majority gates had "largely negative" results (according to the authors), and was presumably included only to round out the report, although the related appendix has some value. Section VI, on probabilistic vs. switching theory approaches to synthesis, is the most interesting part of the report. The references are excellent.

I, Part 2: Almost half of the second part of this report is devoted to reviews of papers. The thoughts on recursive triangular networks are disorganized. The remainder of this part is devoted to the scheme for organizing nets to "self-repair"--a method being used in which there is a trade-off of slower computation for maintained reliability. This is nothing new as a basic idea in information theory, but the authors use a good approach.

II: The Final Summary Report is much too brief to do more than scan the basic ideas. Naturally, this is a good place to look for some idea of what the whole project is about. Such a look would indicate whether one would want to read the individual reports, which are briefly summarized and indexed. ##

Serial Number 2590 -1
ASQC Codes 711;712;713

TITLE: Experimental details of testing a full-scale structure with random and programmed fatigue load sequences

AUTHORS: A. Nederveen, P. de Rijk, D. Broek and J. Schijve (National Aero- and Astronautical Research Institute, Amsterdam)

SOURCE: NLR-TM S.608, Nationaal Lucht-En Ruimtevaartlaboratorium, National Aero- and Astronautical Research Institute, Amsterdam, 31 Jan 64, 28p, 8 refs.

TITLE: Fatigue loads applied on a full-scale structure in random and programmed sequences

AUTHOR: J. Schijve (National Aero- and Astronautical Research Institute, Amsterdam)

SOURCE: NLR-TM S.609, Nationaal Lucht-En Ruimtevaartlaboratorium, National Aero- and Astronautical Research Institute, Amsterdam, Apr 64, 33p, 9 refs.

TITLE: Strain measurements on eight full-scale wing center sections

AUTHORS: P. J. Sevenhuysen, A. Nederveen and J. Schijve (National Aero- and Astronautical Research Institute, Amsterdam)

SOURCE: NLR-TM S.610, Nationaal Lucht-En Ruimtevaartlaboratorium, National Aero- and Astronautical Research Institute, Amsterdam, 20 Dec 63

TITLE: Fatigue lives obtained in random and program tests on full-scale wing center sections

AUTHORS: J. Schijve and P. de Rijk (National Aero- and Astronautical Research Institute, Amsterdam)

SOURCE: NLR-TM S.611, Nationaal Lucht-En Ruimtevaartlaboratorium, National Aero- and Astronautical Research Institute, Amsterdam, 15 Dec 63, 51p, 11 refs.

TITLE: Crack propagation and residual strength of full scale wing center sections

AUTHOR: D. Broek (National Aero- and Astronautical Research Institute, Amsterdam)

SOURCE: NLR-TM S.612, Nationaal Lucht-En Ruimtevaartlaboratorium, National Aero- and Astronautical Research Institute, Amsterdam, 8 Apr 64

PURPOSE: To study the equivalence of random and programmed loading in the fatigue life of full-scale wing center sections of the F-27 Friendship aircraft.

ABSTRACT: These papers cover fatigue tests on eight full-scale wing center sections of a premodification F-27 wing structure. The specimen included the tension skin and stiffening elements. The purpose of the investigation was to study the equivalence of random and

programmed loads. Topics covered are the following.

1. Manner of establishing load spectrum for
   a) Random loading,
   b) Programmed loading,
   c) Random loading with ground to air cycles added, and
   d) Programmed load with ground to air cycles added.
2. A description of the code-actuated random load apparatus used to apply loads.
3. A comparison of the test results obtained from the tests.

All types of loading are based on a simulation of strain gage records obtained from 96 minutes of flight in turbulent air.

Additional load records were obtained by linear and non-linear development of the original strain gage data in order to represent long-time flying conditions. The records thus obtained were added in various proportions and sequences to obtain 140 different records to form load spectra for fatigue testing. Ground-to-air load cycle data were also included in some of the tests.

Methods used in counting load peaks and coding loads for tape input into the code-actuated test machine are described. The test machine simulated loading on the basis of 32 possible load positions. In the program tests, the load cycles were applied in an increasing-decreasing pattern with the relative frequency of the peak loads equal to those of the random loads. The results were found to have the following trends:

1. Programmed tests gave 24% higher fatigue life than random tests.
2. The addition of ground to air cycles decreased life approximately 50%.
3. Programmed tests with ground to air cycles were 33% higher than equivalent random load tests.

The strain measurements showed a good reproduction of stresses in all specimens.

Cracks of 1 to 2 inches could produce complete failure of the skin at nominal stresses in excess of 35000 psi. Larger cracks caused unstable crack growth at lower stresses, the growth now being stopped by rivet holes and stringers.

REVIEW: These papers should be of great interest to those who have only limited data available from which to predict long-time behavior. The methods used in preparing long-time loading from the strain gage records are the greatest contribution made by these papers.
##

Serial Number 2591
ASQC Codes 715;782

TITLE: Reliability in the space environment

AUTHOR: E. T. Maguire (Avco Corporation, Research and Advanced Development Div., Reliability Data Central Section, Wilmington, Mass.)

SOURCE: Reliability Engineering Data Series, Avco Research and Advanced Development Division, 201 Lowell St., Wilmington, Mass., Jan 63, 49p, 9 refs.

PURPOSE: To abstract and summarize the current literature on the subject of space environments with particular emphasis on the effects of the radiation environment on the reliability of aerospace systems.

ABSTRACT: The influence of the space environment on the reliability of materials, components and equipment contained in aerospace systems cannot be neglected in the design of spacecraft. For definition and summary, the environment of space is broken down into five major effects as follows: magnetic fields, gravitational fields, vacuum, micrometeorites and radiation. Particle radiation, electromagnetic radiation, cosmic radiation, trapped radiation, auroral radiation, solar flare radiation, solar wind, thermal energy atoms, nuclear reactor power source, nuclear propulsion reactors and nuclear weapons, all well-known sources of the penetrating radiation environment of space, are defined and their effects on spacecraft are evaluated. The various types of radiation are then discussed in relation to their effects on the reliability of: metals; organic materials; electronic components; fuels, lubricants, hydraulic and flotation fluids, adhesives and coatings. A glossary is included.

REVIEW: This report is a summary of a number of papers from the open literature dealing with the effects of the space environment on materials, components, and equipment. The information will be of value to designers of missiles and spacecraft. Particular attention is paid to the radiation environment. ##

Serial Number 2592
ASQC Code 821

TITLE: Derivation of reliability formulas for a three-dimensional matrix of equivalent components

AUTHOR: A. V. Pershing (Lockheed Missiles and Space Company)

SOURCE: Report LMSC/A065441, Lockheed Missiles and Space Company, Air Force Contract AF 04(647)-787, 19 Apr 63, 25p

PURPOSE: To develop formulas that describe the reliability of any two- or three-dimensional group of equivalent components.

ABSTRACT: In the design of modern electronic equipment, the ability to establish and predict the reliability of complex groups of components has become increasingly important. Today, designers are asked frequently to determine the reliability of component groups that may contain thousands of components connected in multiple parallel-series arrangements. In these arrangements, various combinations of failed and successful components may be allowed, and the components may be placed in either two or three dimensions. These conditions result in highly complex patterns of successful signal paths, and the methods used previously to determine the reliability of simpler parallel and series arrangements are no longer adequate.

As a result, new methods had to be devised to accurately describe the reliability of these complex component groups. The initial work in this area--the algebra for determining the probability of signal success where signal paths are not mutually exclusive--has laid the mathematical foundation which led to practical formulas that approximated the reliability of multiple parallel-series arrangements of components. In this report, formulas are developed that will accurately describe the reliability of any two- or three-dimensional group of equivalent components.

Matrices are used in this report as mathematical models for complex component groups, and a unique method is employed in developing the equations describing the reliability (probability of signal success) of these matrices. First, equations are derived empirically to give the reliability of any two-dimensional matrix of equivalent components. Then, these equations are expanded in steps to describe any three-dimensional matrix of equivalent components. Finally, the binomial theorem is applied to the resulting equations. This application makes it possible to readily determine the reliability of any matrix with any combination of failed and successful components. (Author in part)

REVIEW: This report presents formulas which describe the reliability of any two- or three-dimensional group of equivalent components. The approach consists essentially of identifying the successful signal paths and the path overlaps, relating probability designations to these, and simplifying the results. It will be useful in the mathematical analysis of the reliability of complex groups of components. ##

Serial Number 2593
ASQC Code 813

TITLE: Apollo reliability control program

AUTHORS: W. K. Warner, D. Amorelli, and R. F. Wadsworth (North American Aviation, Inc., Space and Information Systems Div., Downey, Calif.)

SOURCE: Pub. 542-L Rev. 1/63, North American Aviation, Inc., Space and Information Systems Div., Downey, Calif., 3 Dec 62 (Rev. 1/63), 28p

PURPOSE: To describe the Apollo reliability program of the Space and Information Systems Division of North American Aviation, Inc.

ABSTRACT: Reliability requirements in the Apollo program are extremely high. At the outset a space program demands a level of reliability normally achieved by missiles only after years of test and improvement. The traditional approach to product improvement through lengthy programs of testing and modifications is not compatible with the requirements of the space age. Considered in the practical sense, reliability is the sum of inherent design reliability plus quality--quality in procurement, manufacturing, inspection, testing, and use. Reliability and quality are exploited to the utmost in order to achieve the reliability requirement. The Apollo program concentrates on high-integrity design, stringent control measure, comprehensive ground testing, and the selection, assignment, training, and motivation of all personnel associated with the project. Each of these elements of the program is discussed.

REVIEW: A survey of the reliability program of one of the major Apollo contractors is presented in simplified, straightforward terms in this report. Just about every possible approach to achieving reliability seems to be mentioned. Thus the report should contain some ideas for those who are planning reliability programs. Too often in the past the descriptions of reliability programs and the actual programs as implemented have been quite different; but such gaps are apparently decreasing as the governmental procuring agencies are learning that implementation of high reliability programs costs a lot of money and if they are really desired they must be paid for. Conscientious implementation of the program described here represents just about all that can reasonably be done to achieve the Apollo reliability requirement, but it is indeed a challenging undertaking. ##

Serial Number 2594
ASQC Codes 821;831

TITLE: Mariner B telecommunication system reliability study

AUTHOR: Man K. Tam (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif.)

SOURCE: JPL Technical Memorandum No. 33-146, prepared for NASA under Contract No. NAS7-100, by Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., 15 Aug 63, 120p

PURPOSE: To present mathematical expressions describing the functional reliability of the Mariner B spacecraft communication system.

ABSTRACT: Functional reliability equations of the Mariner B spacecraft telecommunications system were derived using event algebra and a reliability model constructed under considerations of partial successes. These equations were enumerated and given in terms of other factors within the spacecraft. Numerical values for the functional reliabilities were obtained on a parts-count basis. Three-dimensional graphical displays were then constructed for each of the functional equations.

Reliability improvement, resulting from simplification and redundancy, was considered from the standpoint of functional blocks as well as on the basis of individual circuitry. A comprehensive comparison between the results of the Mariner A and Mariner B reliability studies indicated the desirability of Mariner B's command function independence, its improved two-way Doppler function and its flexible data decoder. Specific elements and circuits in the command (decoding unit), radio and telemetry subsystems were designated as targets for redesign, replacement or redundancy due to their low reliabilities. (Author in part)

REVIEW: This is a rather lengthy report--made so in part by the inclusion of some rather elementary material which is readily available in textbooks on set theory and probability. Not all of the equations were checked, but the analysis appears to be of a standard form, based on customary simplifying assumptions. The results of such an analysis are rather gross or "ball-park" estimates, useful chiefly in comparing the reliabilities of similar systems, and in making decisions as to where reliability improvement dollars can be spent to the best advantage. The quoting of final numerical values to more than two significant figures seems unwise since it lends them an aura of precision which the methods do not support.
##

Serial Number 2595
ASQC Codes 352;775;800

TITLE: Quality control and nondestructive testing for the prevention of failures in scientific satellites

AUTHOR: Alfred J. Babecki (Goddard Space Flight Center, Spacecraft Systems and Projects Division, Materials Research and Development Section, Greenbelt, Md.)

SOURCE: Presented at the Sixth National SAMPE Symposium, Seattle, Wash., 18-20 Nov 63, 17p

PURPOSE: To inculcate in the minds of all engaged in the space program a greater feeling of responsibility for the production of a first-class product.

ABSTRACT: The scientific satellite program is, at the moment, the most important means of exploring the solar system. However, compared with the manned space program, less enthusiasm and effort is generated in the creation of a first-class, 100% reliable spacecraft, although the responsibility and need are as great. This article discusses some of the problem areas in scientific satellite manufacture in an attempt to show that, in most cases, costly errors in scientific satellite fabrication due to defective or unreliable hardware could have been avoided by the contractor's early and continued use of qualified materials experts and by exerting adequate nondestructive testing and quality control procedures during component manufacture.

The variety of materials, processes and treatments occasioned by the variety of scientific satellites, the necessity for "custom-made" fabrication, and the variety of space environments in which the spacecraft must operate all combine to make quality control for optimum reliability a formidable, expensive and difficult task. Specifications for spacecraft materials and components are inadequate due to lack of details concerning service requirements; in addition, the contractors building the satellite hardware vary in experience, facilities and access to developmental information.

While problem areas will continue to exist, reliability of satellite components can be greatly increased by complete examination of <u>all</u> items installed on the spacecraft and by environmental tests in vacuum chambers under simulated solar energy conditions. NASA's establishment of spacecraft meterial and component specifications and greater interest exhibited by the nondestructive testing industry itself would eventually increase both quality and reliability. But, meanwhile, the contractors themselves can improve hardware quality by rigorous quality control procedures and by establishing standards for items manufactured in-house and procured from suppliers.

REVIEW: This is a rather general paper which contains some worthwhile thoughts for those concerned with the management of the production of components and systems for spacecraft use. Many of the ideas expressed form part of the "infinite attention to detail" which is so essential to the production of reliable equipment. ##

Serial Number 2596
ASQC Codes 711;716;781

TITLE: Chemical material influence on stress corrosion behavior of high strength materials

AUTHOR: Sara J. Ketcham (U. S. Naval Air Engineering Center, Aeronautical Materials Laboratory, Philadelphia, Pa. 19112)

SOURCE: Report No. NAEC-AML-2174, U. S. Naval Air Engineering Center, Aeronautical Materials Laboratory, Philadelphia, Pa., Problem Assignment No. 12-75 under Bureau of Naval Weapons Weptask RRMA 05 010/200 1/R007 08 01, Apr 65, 14p, 11 refs.

PURPOSE: To determine the sensitivity and reproducibility of test specimens and to establish standard procedures for evaluating the influence of chemical materials on stress corrosion behavior of high strength alloys.

ABSTRACT: Stress corrosion tests on H-11 steel, 18% Ni maraging steel, 17-7PH stainless steel, AISI 301 stainless steel, AISI 410 stainless steel, 7075-T6 aluminum, and 6Al-4V titanium were conducted. Tensile (notched and unnotched), C-ring (notched and unnotched), bent beam, and U-bend specimens were employed for these tests. The electrolyte specifications and mechanical property data for the alloys are included. Visual and metallographic examinations were completed on each specimen at the termination of each test.

Test specimens for the H-11 material did not all have the same life. The RH 950 is the condition most susceptible to stress corrosion cracking for the 17-7PH material. Titanium alloys possess considerable resistance to stress corrosion cracking up to 500F. At approximately 600F titanium alloys become susceptible to hot salt corrosion.

The only sure method of determining whether a chemical/material combination is safe is to test it at the specified strength level. Appropriate specifications should include a screening test to determine the susceptibility of high strength alloys to stress corrosion cracking. Procedures and recommendations for such tests are included.

REVIEW: This paper presents the subject matter in a clear and concise manner. The limited stress corrosion cracking data presented should be useful to the design engineer. The recommendations concerning stress corrosion cracking test procedures and test specimens should be valuable to the test engineer. ##

Serial Number 2597
ASQC Codes 431;612;831;
872

TITLE: Mathematical models for system analysis

AUTHOR: Larry D. Krüll (Capt., USAF)

SOURCE: Thesis presented to the Faculty of the School of Engineering of the Air Force Institute of Technology, Air University in partial fulfillment of the requirements for the degree of Master of Science, Aug 63, 31p

PURPOSE: To derive a basic mathematical model for a system which is stochastic in nature.

ABSTRACT: The modeling of systems which can be considered stochastic in nature has wide application for system analysis. If a system is made up of operational units and repair channels, having time dependent failure and repair rates its basic mathematical model can be written as a differential equation. Both the transient and steady-state solution of the model can be arrived at directly by the use of analog computer simulation. By not requiring constant failure and repair rates, nor the initial inclusion of a model for the full system, stochastic modeling coupled with analog simulation make the basic modeling technique considerably more useful for system analysis. The solution to the system equations provides probabilistic information concerning system operation that is useful for operational and technical evaluation, data input for cost analysis, and spares procurement planning. (Author in part)

REVIEW: This paper will be of interest to those concerned with stochastic modeling and analog computer simulation in the analysis of systems from the standpoints of reliability, maintainability, cost effectiveness, tradeoffs between system configurations, etc. Necessary input information for application of the method includes failure rate and repair rate functions which are realistic for the system under consideration. Applications are discussed only in a general way, and only a simple hypothetical example is given. The value of the report could have been enhanced by including a reasonably detailed description of the application of the method to a relatively complex system. This would have served not only to illustrate its usefulness, but also to point up any pitfalls or difficulties, which may be quite serious in practice. ##

Serial Number 2598
ASQC Codes 412;824

TITLE: Tolerance limits for some life testing distributions

AUTHOR: Lee J. Bain (Oklahoma State University, Stillwater, Okla.)

SOURCE: Dissertation submitted to the Faculty of the Graduate School of the Oklahoma State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Aug 63, 71p, 12 refs. (Xerographic copies may be purchased from University Microfilms, Inc., Ann Arbor, Mich., order no. 64-8895)

PURPOSE: To derive lower tolerance limits for some life testing distributions.

ABSTRACT: The reliability of a product may be determined by conducting a life testing experiment to measure the time-to-failure of the sampled items. In this thesis, tolerance limits are developed for several density functions which have been used to describe time-to-failure data.

A general procedure is given for determining lower tolerance limits for any distribution with a single unknown parameter. This procedure is applied to the generalized gamma, gamma, Weibull, and exponential distributions where one parameter at a time is considered unknown. Tolerance limits based on a single order statistic are derived for all cases and, in most cases, are also given as a function of a sample sum. Tolerance limits based on a sample ratio are given for the generalized gamma and gamma distributions. In each case one-sided confidence levels are given for the unknown parameter and it is assumed that the sampling procedure is simple random sampling without replacement. Tolerance limits based on the number of failures in time T_o are given for the exponential distribution, where truncated sampling with and without replacement is used. A solution to the problem of determining the sample size necessary to give a tolerance limit with a prescribed precision is found for certain cases.

REVIEW: This report is a contribution to the theory pertaining to certain distributions useful in life testing. As such it is concerned with the mathematics rather than with applications, although some scattered examples are found throughout the text. It should be noted particularly that the method presented is applicable only to the case of a single unknown parameter. Some suggestions for additional work which should be done in this area are found at the end of the thesis. ##

Serial Number 2599
ASQC Codes 713;821;822;
824;837

TITLE: The analysis of structural safety

AUTHORS: A. M. Freudenthal, J. M. Garrelts, and M. Shinozuka (Columbia University, New York, N. Y.)

SOURCE: Technical Report No. 12, Institute for the Study of Fatigue and Reliability, Department of Civil Engineering and Engineering Mechanics, Columbia University in the City of New York, sponsored by the Office of Naval Research, Air Force Materials Laboratory, and Advanced Research Projects Agency, Contract No. NONR 266 (91), Oct 64, 61p, 23 refs. (AD-608 607); also Journal of the Structural Division, ASCE, vol. 92, Feb 66, p. 267-325

PURPOSE: To present a discussion, illustrative examples, and recommendations concerning the determination of structural factors of safety.

ABSTRACT: The "factor of safety" of a structure takes on a rational meaning only when it is correlated to the probability of failure of the structure. At this time, it is not possible to give due consideration to all aspects of structural safety by the probabilistic approach; but various phases of the "factors of safety" analysis can be handled by probability techniques. If the probability approach is rejected, safety factors must be selected on the basis of engineering experience and common sense. The development of large computer systems has led to a scientific approach to solutions of the complex "factor of safety" problem and the study of the relationship between the cost of a structure and its safety. Most structural safety studies have been based on probability distributions of either log-normal or extremal type. Examples with material distributions of log-normal, extremal, t, exponential, and Gram-Charlier type are included. Discussions related to multiple member structures and reliability functions are also presented.

REVIEW: The authors of this paper treat a difficult subject with authority. The paper is not easy to read, but it is a worthwhile contribution to the literature since it summarizes the concept of structural safety and presents guidance for engineers concerned with reliability problems. The examples concerning the safety of aircraft wings and trussed towers are applicable to engineering design. The probability interpretation of safety factors has a severe limitation in that the desired maximum probability of failure is so small that no data are even close to being useful for estimating it. Such small probabilities, in addition, are very difficult to interpret in an engineering sense. Statistical independence is too blithely assumed; it must be demonstrated that for all types of loading, including inertia loads, ultimate strength and the load-causing situation are statistically independent. Further, if more than one environmental profile is considered, many events are not statistically independent that were so in the case of just one profile. This paper would be useful to the experienced design engineer with a strong background in mathematics, statistics, and probability theory. A previous progress report, referenced by the authors, may warrant concurrent study for complete understanding. (The mathematics of the paper was not checked in its entirety.) ##

Serial Number 2600
ASQC Codes 612;824;844

TITLE: Sense and nonsense in the application of the Monte Carlo method in reliability theory

AUTHOR: E. G. Pieruschka (Lockheed Missiles and Space Company, Sunnyvale, Calif.)

SOURCE: Technical Report 5-10-63-21, Lockheed Missiles and Space Company, Sunnyvale, Calif., Aug 63, 29p

PURPOSE: To discuss the Monte Carlo method and its applicability in reliability analysis.

ABSTRACT: A discussion of the essence of the Monte Carlo method and its application to statistical and general mathematical problems reveals that, by simulating the probabilistic experimentation underlying the mathematical formulation of a reliability problem, any theoretical reliability problem may be solved by the Monte Carlo method. However, caution is necessary for reasonable application of the method to reliability problems for, in nearly all cases, the classical method gives a more accurate solution with much less effort. The Monte Carlo method requires real numbers leading to a unique solution and not a family of solutions. Solutions by means of the Monte Carlo method are not suitable for general discussion, as is the case when mathematical solutions in closed form are available. In order to obtain even a modest accuracy of the solution, a large number of experiments must be simulated--and these can be handled only by a computer. Nevertheless, the Monte Carlo method may be applied successfully when a classical solution cannot be found and economically when a mathematical solution requiring a capable mathematician may be more costly than a solution by means of sampling experimentation. When there is a limited amount of experimental data on parts of a system being investigated, a simulation of the problem by means of this method is always a reasonable and adequate procedure.

REVIEW: This is a worthwhile paper on the Monte Carlo method as applied to problems in reliability analysis. It does a good job of placing the advantages and disadvantages of the method in proper perspective. Two examples from the paper covered by RATR 998 are used to illustrate cases in which it would be better not to use a Monte Carlo method. ##

Serial Number 2601
ASQC Codes 813;835

TITLE: Microelectronics and space vehicle reliability

AUTHOR: Joseph L. Murphy (Reliability and Quality Assurance Office, National Aeronautics and Space Administration, Washington, D. C. 20546)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 437-449 (*see RATR 2511)

PURPOSE: To summarize the attitude of NASA toward microelectronics.

ABSTRACT: Microelectronic circuit devices have had a considerable impact on the current design and fabrication of space electronic systems. If used within prescribed limits and applications they provide capability over and beyond that of discrete parts in such areas as reliability, space, weight, and power consumption. Adequate sources of reliable circuits are available today, but continued emphasis on improvement will be needed in order to meet future space requirements. Microelectronics has the potential of becoming the most reliable form of electronics packaging. It offers savings in weight and volume, not only in the electronics themselves, but in the structures that carry them; accordingly, the saving in fuel and/or increased payload is a major incentive for extending the usage of microelectronics.

NASA is fully aware of the status of this technology and is actively engaged in developing its potential. Prudent selection of the most reliable circuits and the reduction of different types are being encouraged at the project level. Development and adoption of a NASA-wide program for the qualification of manufacturers, their circuits, and specification documentation are needed to assure that the most reliable product with the lowest possible cost is obtained for NASA and its contractors. Such a system is under development. (Author in part)

REVIEW: This is a general paper, in the nature of a review rather than a quantitative discussion. The program for "vendor qualification" is not given in detail (probably because the detail is not yet available) but will be of major importance to centers and vendors alike. There is some indication that the program will take advantage of the increased capabilities of suppliers and put less emphasis on producing paper work than has been done in the past. ##

Serial Number 2602
ASQC Code 835

TITLE: Reliability of integrated circuits - Analysis of a survey

AUTHOR: William R. Rodrigues de Miranda (Honeywell Inc., Aeronautical Div., St. Petersburg, Fla.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 450-463, 16 refs. (*see RATR 2511)

PURPOSE: To review the results of a survey on the reliability of integrated circuits.

ABSTRACT: A comprehensive survey of integrated circuit manufacturers during October 1964 assessed all aspects of microcircuit reliability. It included data and opinions on failure rates and their temperature and stress dependence, the relation of reliability to circuit complexity, and the prevalent failure mechanisms. Estimates of eventual failure rates for integrated circuits ranged from 10^{-3}%/1000 hr. to 10^{-6}%/1000 hr. Reliability data from various sources are still so diversified as to render generalizations impossible. Integrated circuit manufacturers who have assumed the circuit design role must also assume the responsibilities that go with it, particularly those related to reliability. The low estimates of failure rates are attainable provided that continued efforts are maintained on design, quality control, and failure analysis.

REVIEW: This is a mature, well considered report on integrated circuit reliability. The perspective given for the various testing and analysis techniques is particularly informative. In order to increase the reliability of integrated circuits more emphasis should be placed on process control and on-line tests in comparison to that now given to bonding, interconnections, and packaging. This is not a critique of this paper but rather of the current industry practices. The author has reported and analyzed accurately.
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Serial Number 2603
ASQC Codes 835;844;850

TITLE: Proving integrated circuits reliability

AUTHOR: Phil Holden (Texas Instruments, Inc., Dallas, Tex.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 464-468 (*see RATR 2511)

PURPOSE: To illustrate the problems of determining the life of integrated circuits.

ABSTRACT: The traditional approach to reliability testing estimates the life from a life test on many items--the exponential distribution is usually assumed. A different approach is that of failure mechanism elimination; tests are severe enough to cause failures. The failure mechanism thus brought to light is removed by changes in design or manufacture. These need not be mutually exclusive tools; both have their place. Techniques such as acceleration and step-stressing are also important. Reliability engineers face a severe challenge in using and developing suitable reliability methods for integrated circuits of very high reliability.

REVIEW: This paper presents problems but does not solve them. They are very severe for the long lives encountered in integrated circuits. Part of the problem in the traditional approach lies in the implicit assumptions involved in words such as "proof" and "mathematical." Proof is highly subjective (contrary to some popular opinion) and mathematical merely means that the model is quantitative and the reasoning contains no logical contradictions. Neither says anything, necessarily, about the adequacy of the model. Bayesian techniques may help in solving these problems. Much of the discussion is good, especially the emphasis on accelerated tests (which includes step-stressing) and the analytical and interpretive problems associated with them. ##

Serial Number 2604
ASQC Codes 813;833;835

TITLE: Reliability of integrated circuits for Minuteman

AUTHOR: T. J. Nowak (Data Systems Div., Autonetics, a Division of North American Aviation, Inc., Anaheim, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 469-482, 9 refs. (*see RATR 2511)

PURPOSE: To discuss the physical and the reliability management aspects of the integrated circuits (IC) used in Minuteman II.

ABSTRACT: Integrated microminiature semiconductor circuits are extensively used in the airborne inertial guidance system and associated ground equipments produced by Autonetics for the Air Force's Minuteman II. The IC were designed to minimize the variety of circuits required and to reduce system complexity. The series consists of logic, memory, input/output, linear, and power switching circuits.

Integrated circuit reliability is discussed from two major viewpoints. The first deals with the physical aspects of IC reliability such as technology and inherent problems, applications, reliability growth, major failure modes and corrective actions, and reliability testing. A significant point brought out is that the presence of parasitics and of the conditions disturbing the reverse bias on the isolation junctions of the IC must be accounted for to preclude unwanted electrical coupling effects which may lead to unreliability.

The second viewpoint deals with the management aspects of reliability. The paper describes how reliability assurance programs are reduced to practice by the IC suppliers. It is concerned with such activities as reliability program plans, reliability by direct action, reliability by reaction, and supplier monitoring activities. Significant points brought out on the management aspects are that a disciplined production line is essential for production of high reliability IC and that reliability growth is achieved by closed loops of discovery, analysis, and recurrence control of specific failure modes. (Author in part)

REVIEW: A case history is presented of one of the few high reliability programs for electronic parts which has actually been implemented. This program for Minuteman II bears a strong resemblance to the Minuteman I program which received much publicity. The discussion of the physical aspects concentrates on failure modes. The program aspects are basic and thus are potentially applicable to parts other than integrated circuits; however, significant purchasing power is required in order to implement this type of program and most parts users cannot individually implement such programs. This paper is well written; features such as illustrations and sub-titles combine to make it readable.

Another paper describing the Component Quality Assurance Program (CQAP) used by Autonetics on Minuteman II is [1].

REFERENCE: [1] "A new reliability concept takes off," Electronic Procurement, vol. 6, Mar 66, p. 24-29 ##

Serial Number 2605 -1
ASQC Code 815;850;871

I. TITLE: Reliability and maintainability requirements and Electronic Systems Division (AFSC) applications

AUTHORS: G. H. Allen, R. M. DeMilia, and M. V. Ratynski (Technical Requirements and Standards Office, Electronic Systems Division (AFSC), USAF, L. G. Hanscom Field, Bedford, Mass.)

II. TITLE: AFSCM 375 and reliability

AUTHORS: Robert Katz and Ernest Cupo (General Electric Co., Re-Entry Systems Dept., Philadelphia, Pa.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 483-496, 11 refs., p. 609-627 (*see RATR 2511)

PURPOSE: To discuss aspects of the AFSCM 375 Management System that affect the reliability and maintainability disciplines.

ABSTRACT: The Air Force Systems Command Manual (AFSCM) 375 describes the activities which must be established on new AF systems, to which the systems will be subjected during their life cycle. It has for the first time developed a sequential activity diagram on a relative time phase base beginning with the issuance of military requirements and extending into the operational phase. Management procedures are contained in 375-4 and systems engineering in 375-5.

In I the manual is described; specification of quantitative reliability and maintainability requirements and verification of their achievement are discussed. A correct specification of reliability quantitative requirements includes failure counting ground-rules; otherwise the specification is meaningless. Experience has shown that when specific penalties or rewards in terms of the fees are involved, the tenacity and interest of both parties to quantitative requirements and demonstration ground-rules are refreshing. A flexible position is necessary with respect to demonstration, and the universal demonstration by test in the MIL-R family has been abondoned. In the maintainability area, demonstration experience has indicated that both the exponential and normal distributions of repair time must be rejected. It is recommended that a sequential test of the 50th and 90th percentiles form the basis for verification of quantitative requirements, based on the binomial frequency function.

A model reliability program is analyzed with respect to the 375 manual in II. The model program is first presented, and then it is separately interwoven into the details of the management systems engineering manuals. Reliability is readily woven into the phases of both, as it is basically a program control system using the systems engineering approach.

REVIEW: A conclusion from both papers is that reliability activity readily blends into the AFSCM 375, thus providing another sanctioned entry for reliability. However, there have been many government documents which looked good from the reliability viewpoint, yet progress in reliability remains slow.

The discussion of reliability and maintainability demonstration in I is timely, but seems to have no more or less relation to AFSCM 375 than any particular aspect of reliability would. It is recommended in I that maintainability demonstration be placed on an attribute basis. This means that a larger sample size will be needed to maintain an operating characteristic curve similar to that which would apply if demonstration was based on variables. This is a basic limitation not acknowledged in the paper, and it is a price for the advantages which are cited.

Much detail is developed in II to illustrate compatibility of reliability programs and AFSCM 375; it will be of interest to someone specifically concerned with how a reliability program would comply with the constraints of the 375 manuals, but of no general interest. ##

Serial Number 2606
ASQC Code 871

TITLE: Maintenance strategy diagramming technique

AUTHORS: D. C. Burnstine and W. H. Eppard (International Business Machines Corporation, Systems Development Division, Poughkeepsie, N. Y.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 497-506 (*see RATR 2511)

PURPOSE: To present a technique for the comprehensive study of the total unscheduled maintenance process.

ABSTRACT: The Maintenance Strategy Diagramming Technique (MSDT) is an experimental effort which provides a disciplined approach whereby maintainability engineers can make trade-off decisions during the design of new equipment.

This technique consists of four phases:

Information-Gathering--documenting, in a standard format, the necessary data from which the unscheduled maintenance process for any equipment design can be synthesized into a mathematical model. The procedures followed are: (1) define the problem, (2) establish functional environment, (3) establish physical environment, and (4) define a maintenance concept.

Diagram Construction--synthesizing a mathematical model which represents the unscheduled maintenance process for any equipment. A flow diagram is developed which delineates how specific equipment should be maintained (in respect to unscheduled maintenance) and serves as a vehicle for communicating maintenance problems to the design engineer.

Simulation--solving the mathematical model for statistics that will approximate the field performance in terms of average downtime and the distribution of downtimes.

Analysis and Optimization--examining the model and testing any design changes for their effects on maintenance. The maintenance engineer determines what parts of the model are affecting the parameters which describe the maintenance process. The model is altered and up-dated to reflect any trade-offs documented during information-gathering or realized as a potential improvement during the model analysis.

REVIEW: A general description of the development and use of mathematical models for maintenance analysis is presented in this paper. No mathematical models as such are shown, and it is not apparent what form they will take. It is suspected that timely material exists here which is of interest to others, as the paper notes that the technique has been programmed on a computer and has been applied to a number of equipments. However, additional information will be needed to gain full visibility. No references are given. ##

Serial Number 2607
ASQC Codes 221;831;851

I. TITLE: Identification of inadequate subsystems--development of sampling plans

AUTHOR: R. J. Christie (Bell Telephone Laboratories, Inc., Whippany, N. J.)

II. TITLE: Identification of inadequate subsystems--application to specific systems

AUTHOR: A. Constantinides (Bell Telephone Laboratories, Inc., Whippany, N. J.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 511-530, 531-539 (*see RATR 2511)

PURPOSE: To derive sampling plans for an approach to system reliability verification based on the identification of inadequate subsystems; to present some results of applying the procedure.

ABSTRACT: I. Experience indicates that subsystems are essentially either "good" or very "bad," i.e., the true failure rate of a subsystem is either close to its estimated value or is very much worse than had been expected. From this premise an approach involving a procedure for identifying inadequate subsystems is developed. The derivation and application of sampling plans for discriminating between "good" and "bad" subsystems with a high probability of correct identification are described. As compared to conventional procedures requiring that the entire system be tested as a unit for several times its MTBF, this procedure is a more rational, efficient and economical approach to the system reliability verification problem. It reduces test time by about 50%, furnishes valuable information to the designer or manufacturer, and can be run on individual subsystems, separately or in functional groupings.

II. The approach described in I was applied to two different missile-borne guidance systems. Results obtained were found to be consistent with those from prior conventional reliability demonstrations and actual field experience. Application to the two guidance systems is described in detail.

REVIEW: The first paper is a practical one on reliability demonstration for a system consisting of several subsystems. It is important for the user of the sampling plans to realize that they are designed to identify with high assurance all the inadequate subsystems, i.e., the ones which have failure rates of the order of 20 to 30 times those of the corresponding good subsystems. Underlying assumptions are clearly stated and cautions regarding them are expressed in both papers. Some of the assumptions and parameters are based on experience; the user should consider the examples in his area of application prior to using the plans.

The two examples given in II serve to illustrate the suggested procedure. They indicate that it has a high assurance of correctly determining whether a system can meet a desired reliability level, while affording considerable latitude in application and utilizing prior knowledge to save test time. ##

Serial Number 2608
ASQC Codes 612;831

TITLE: Computer methods for effectiveness evaluation

AUTHORS: Mrs. Suzanne Dobbins (Computer Applications Inc.) and J. Adelsberg (Naval Applied Science Laboratory)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 540-551 (*see RATR 2511)

PURPOSE: To discuss the design of a generalized computer program which evaluates the various effectiveness measures for alternative system configurations.

ABSTRACT: A basic logic for a generalized computer program, capable of evaluating the various facets of system effectiveness, has been developed. Reliability, availability, dependability, mean life and other variables of total effectiveness can be evaluated by means of the System Effectiveness Analyzer (SEA). This generalized program has been designed to accomodate variations in either the system configuration or the type of effectiveness measures which are used. SEA has been developed to accomplish two objectives: system evaluation and system optimization. The generalized program has been divided into two distinct processors. The first, an evaluation processor, generates the mathematical models of the system and performs the evaluation of the variables which contribute to system effectiveness. The second, an optimization processor, performs the optimization procedure which best satisfies the specified objectives. The processors accept problem definitions written in a special problem-oriented English-like language, and based on this input will generate and execute a program which will perform the evaluation procedures necessary to effect a problem solution. Some of the difficulties encountered during the design of these processors and the proposed solutions to these problems are discussed. Possible applications are considered, including trade-off analysis, fault locator placement, the WSEIAC model, and worst-case circuit analysis. (Authors in part)

REVIEW: The program is described in general terms supported by a large number of sample items presented as figures. Thus a general view is given, but the detail is not complete. Appealing features are flexibility in terms of system configuration and the measure criteria, the fact that the user need not be skilled in programming, and, of course, timeliness of the effectiveness subject. Optimization apparently involves the literal comparison of all feasible alternatives, and it is not clear if any formal optimization technique such as dynamic programming is used. No references are cited. ##

Serial Number 2609
ASQC Codes 831;844

TITLE: New methods for predicting electronic reliability

AUTHORS: Eli J. Dworkin (U. S. Army Electronics Command, National Maintenance Point, Fort Monmouth, N. J.) and Raj P. Misra (Newark College of Engineering)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 552-569, 21 refs. (*see RATR 2511)

PURPOSE: To discuss methods of predicting electronic system reliability without relying exclusively on part failure rate information.

ABSTRACT: Current methods for predicting electronic system reliability are reviewed. New methods which do not depend exclusively on component failure rates are explained. They employ part parameter distributions, correlation of reliability with parameters such as noise figure, specific indexes such as sensitivity and pulse repetition rate. A new method for reliability estimation compares indexes and parameters of existing equipment for which reliability is known with the values of the indexes and parameters for the equipment under design. Not all the parameters and indexes need be available for the prediction.

REVIEW: It should be emphasized that some of the procedures discussed in this paper treat performance variation or degradation using deterministic models while others consider reliability life using reliability logic models. Thus the techniques are not necessarily distinct. The idea of using the data on similar systems as proposed in the paper is very good. However, the procedure used is not basically different from that proposed by personnel at Hughes as referenced in the paper and seems less desirable. The procedure for selecting the significant variables or indicators should be made more objective as the appropriate statistical techniques are available. In addition the authors might consider another form of the model such as a multiplicative one. The paper is worthwhile reading for one surveying the techniques. Furthermore, the authors are to be encouraged to look further into the selection of the indicators to be used in the model and the form of the model.

There are several typographical errors with respect to subscripts and superscripts in the Appendices. Furthermore, it is not clear how there are $p!-1$ equations as stated in Appendix II. The number would appear to be 2^p-1. ##

Serial Number 2610
ASQC Codes 770;823;844

TITLE: Accelerated testing of component parts

AUTHORS: H. S. Endicott and T. M. Walsh (Spacecraft Dept., General Electric Co., King of Prussia, Pa.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 570-583, 11 refs. (*see RATR 2511)

PURPOSE: To describe some accelerated tests.

ABSTRACT: A method for the accelerated testing of component parts has been devised as a result of four years of development work. The technique combines the advantages of step-stress testing and constant-stress testing into an integrated testing plan which will, when properly used, provide accurate and reasonable evaluation of the life capability of long-life component part types in relatively short periods of time. The method was developed for electronic parts but it may also be applied to parts other than electronic. (Authors)

REVIEW: This paper gives a generally unfavorable impression, although the program was undoubtedly worthwhile. It begins by implying that the Arrhenius equation is dimensionally incorrect (not true), that the stress factor in the Eyring equation has the same rigorous derivation as the conventional part of it (unlikely to be true--it was probably added on by later investigators), and that because a process is chemical in nature it follows the Eyring relation (also not true). The reaction rate is implicitly presumed to be independent of time with no justification. Many of the curve fitting operations take gross liberties with the data: Figs. 2, 3, 4, 6 at least. The results of step temperature tests are apparently plotted on curves where one axis is test temperature--an anomaly at best. No theory of cumulative damage is given which relates step-stressing to constant-level stressing.

Accelerated tests on many kinds of parts can be most useful; an appreciation of some of the problems involved can be gotten from the paper covered by RATR 2603, which was presented at the same conference.

In a private communication the authors have pointed out that the paper merely stated that the Arrhenius equation was criticized on the basis of being dimensionally incorrect, but did not imply that it was so. ##

Serial Number 2611
ASQC Codes 433;815;850

TITLE: A reliability demonstration plan with incentives

AUTHOR: Paul Gottfried (Booz, Allen Applied Research Inc., Bethesda, Md.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 584-593 (*see RATR 2511)

PURPOSE: To describe a reliability demonstration plan involving economic incentives and Bayesian statistics.

ABSTRACT: The reliability demonstration approach described in this paper is predicated on the following premises: (1) the achievement of improved reliability merits increased profit, (2) reliability prediction accuracy is sufficiently desired by the user to reward accuracy, and (3) it is useful to combine prediction and test results by means such as Bayesian statistics. A minimum acceptable operational reliability is established; it is termed the critical failure rate. The potential contractor is required to prepare a predicted failure rate, which represents a promised improvement. A compromise value which takes both figures into account is taken to be the a priori expected failure rate. The degree of faith invested is represented in the variance associated with the a priori distribution. As test experience is accumulated; the a priori distribution is modified to yield an uncertainty distribution which takes test results into account and can provide a continuously updated description of the acquired reliability distribution. The basic test plan is defined. Failing of the test results in reduced fee, passing results in interim qualification for higher fee levels which are paid upon successful completion of additional operational experience. Normal fee is paid if the additional operation is not successfully completed. The inherent power of the test plans to discriminate against relatively high failure rates is limited by the test times which are to be available. However, the economic incentives compensate for these statistical limitations. The key concepts are the tying of requirements to predictions and the payoff strategy. The concepts which have been developed here should be adaptable to a wide variety of conditions involving differing production cycles and available test times. (Author in part)

REVIEW: Two topics which are timely in reliability, Bayesian statistics and incentive contracting, provide the theme of this paper. In addition, other realistic considerations are injected, the lack of which relegate some reliability approaches to a useless status. Examples are (1) the program will continue even if the formal reliability demonstration test is failed, and (2) it (usually, under conventional procurement conditions) behooves the bidder to be as optimistic as possible in his proposal as he may gain a competitive advantage. The plans appear exceptionally realistic. This paper is mainly a presentation of results and is well illustrated. Derivations are not presented and no reference documents are identified. ##

Serial Number 2612
ASQC Codes 612;822;838

TITLE: Reliability of non-exponential redundant systems

AUTHORS: R. A. Hall, H. Dubner, and L. B. Adler (Computer Applications, Incorporated, New York, N. Y.) and F. N. Stehle (Bureau of Ships, Washington, D. C.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 594-608 (*see RATR 2511)

PURPOSE: To develop and evaluate reliability formulas for non-exponential redundant systems.

ABSTRACT: This paper consists of five parts, the first of which is the development of the general mathematical models for determining the reliability of parallel branches in active and standby redundancy. For the standby redundancy the final mathematical model is expressed in operational equations, while for the active redundancy the model is a system of differential equations.

The second part is numerical procedures for evaluating the general mathematical models for determining the reliability of parallel branches in active and standby redundancy. The numerical methods make extensive use of the Laplace transformation.

The third part is the derivation of the limiting values of the coefficients required for the system of differential equations in the active redundancy model. It is shown that after long periods of time all redundant systems behave as if their individual components had exponential failure and repair times.

The fourth part is an example illustrating the use of Fourier series for evaluating the inverse Laplace transformation. Actual results and a FORTRAN program are included.

The fifth part gives a sample of curves of systems reliability as a function of time for a system with parallel branches in active and standby redundancy. (Authors in part)

REVIEW: This is a clearly written paper which gives some useful results and techniques. A knowledge of the "operational calculus" and of Laplace transform methods is required for the full understanding of the theory. The authors indicate that a comprehensive series of reliability curves similar to those given in the paper is being prepared and will be available shortly. ##

Serial Number 2613
ASQC Codes 221;771;823

TITLE: The necessary tests for reliability

AUTHOR: Charles A. Locurto (General Electric Co., Re-entry Systems Dept., Philadelphia, Pa.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 628-640 (*see RATR 2511)

PURPOSE: To discuss reliability testing in aerospace and missile R&D programs.

ABSTRACT: When systems are designed, manufactured, and delivered in small lots and in a short time, the kinds and amounts of testing must be specially considered. Infant mortality, constant failure rate, and wearout periods require different treatment. The number of tests can be kept small and yet provide reasonable assurance of acceptable performance and life. The necessary tests for a minimum assurance of reliability are operability assurance tests on all prime equipment, a minimum demonstration of reliability in an environmental qualification program, and a demonstration of endurance life within the useful life range. The paper presents a discussion of why these tests are needed within the constraint of a minimum test program. An example is sketched.

REVIEW: Many of the points about testing are very good (although the justifications given for them tend to be inadequate). The adjusting of sample size so that the reliability and statistical confidence are about the same has much to recommend it. In the case of small samples, the author properly suggests that one need not use the hypergeometric distribution. There is even more justification for not using it than is indicated, largely because the inadequacies in the other assumptions in any sampling system far outweigh the differences between the binomial and hypergeometric distributions.

The use of the term "random" to describe failures in the constant hazard rate period is poor practice since they are random even in the wearout period. Again, the assignment of causes to failures in the different periods is awkward because most failures in any period are due to defects of some kind. The wearout period does not necessarily mean that anything is physically wearing out, becoming depleted, etc., but only that the hazard rate is monotonically increasing. ##

Serial Number 2614
ASQC Codes 612;837;844

TITLE: Improved reliability circuit analysis techniques

AUTHOR: Harold V. McConnell (General Dynamics, Pomona Division, Pomona, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 641-653 (*see RATR 2511)

PURPOSE: To describe a circuit analysis computer program.

ABSTRACT: A practical and economical circuit analysis computer program has been evolved by combining the IBM Electronics Circuit Analysis Program (ECAP), and the Propagation of Variance Technique (Moment Method). The Moment Method relates part values and tolerances to circuit output variables through the propagation of variance equation. Solution of the equation yields the variance for the circuit output variable which can be interpreted in terms of probability of circuit success. The ECAP program has some extremely attractive features which include simple computer input methods and economy of operation. The program features a unique algorithm which allows the user to obtain the necessary computer inputs by encoding only the connections and elements of the network. Knowledge of computer programming is not required and all aspects of the program are based on standard engineering practices. However, the ECAP program provides only a mean value solution to the circuit equations.

Combining the best features of each program results in an efficient and economical tool for design or analysis which is "user oriented," and, therefore, attractive to the engineer who has little or no previous programming experience. Integration of ECAP and the Moment Method, particularly integration of the partial derivative solution into the program, is outlined. Innovations for failure effect analysis and temperature drift solutions to the two programs results in a new approach to circuit variable definition where circuit variables can be related directly to part values, part tolerances, temperature coefficients, and time end-point values of parts. Flow diagrams illustrate subroutines required to perform these computations. (Author in part)

REVIEW: Electronic circuit reliability analysis techniques which are suitable for practical applications are brought together in this paper. All of the analysis pieces are here--deterministic circuit, performance variation, failure effect, stress, and reliability prediction. Each technique is introduced and discussed from the viewpoint of computerized applications, which serves to emphasize the realities of applications. The detailed analysis techniques are not new, although there may be aspects to some of them which for some persons will represent fresh material. What is new is that a few pages cover the essence of material which occupies a significant portion of the accumulated reliability literature. Sufficient bits from real-world applications are given to inject a flavor of actual applications. This paper should not have been put in the category of those not presented at the symposium. ##

Serial Number 2615
ASQC Codes 821;872

TITLE: Modified long term system reliability models for maintained systems considering imperfect failure detection, repair and sparing

AUTHOR: Irwin Nathan (Aerospace Systems Div., General Precision, Inc. Wayne, N. J.; present affiliation: Anathon Inc., 11 East 36th St., New York, N. Y. 10016)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 654-669 (*see RATR 2511)

PURPOSE: To derive fairly realistic models for the reliability of maintained systems which take into account the effects of imperfect failure detection circuitry, time-to-repair, time-to-locate a failure and limited, imperfect sparing.

ABSTRACT: Some simple models for the reliability of a redundant system do not consider the effects of imperfect failure detection and switching, non-instantaneous replacement time, and standby failure rates. When these factors are considered the models become complex, but significant differences appear between the more realistic estimates of reliability and the simpler ones, particularly when the probability of failure is not low. The hazard function for a system with failure detection and switching is time dependent. Therefore, the estimate of system reliability is dependent on both the mission operating time interval and the age of the system.

The paper is organized into two main areas. The first area considers the effects of non-zero constant rates for replacement and for standby failure, and of non-instantaneous failure detection. Failure detection is assumed to be without failure. Such models are realistically applied to the reliability analysis of communication equipment, electronic sensors, and digital computers with continuous and extensive self-check capability. The second area considers the effects discussed above plus the added effects of imperfect and limited failure detection circuitry and switching.

The simple model introduces enough error for long-time "manned" missions to justify the additional mathematical complexity. Furthermore, these factors can be traded off to permit engineering optimization between test thoroughness, failure detection-switching circuit complexity, system reliability goals, and system weight and power consumption, etc. (Author in part)

REVIEW: The set of equations looks quite formidable; they were not checked in detail, but on the basis of a spot-check they appear reasonable. The justification of these more complex models instead of the simpler ones pertaining to the "ideal" case will depend on the use to which the end results are to be put, as well as on the precision of the input data. It may very well be, too, that the assumption of underlying exponentiality when it is not completely justified introduces significant error. However, the more complex models should not be overlooked by those who are concerned with the realistic design of manned spacecraft systems. ##

Serial Number 2616
ASQC Code 844

TITLE: Quantitative reliability prediction

AUTHORS: R. A. Owens and T. J. Dolcimascolo (North American Aviation/ Autonetics, Anaheim, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 670-677 (*see RATR 2511)

PURPOSE: To present a method that can be used to predict system reliability in the early proposal and feasibility phases of a program.

ABSTRACT: During the proposal and feasibility phases of a program there is usually short preparation time and lack of well-defined configurations and mission profiles; therefore, the guiding criteria in the evolution of this reliability prediction method were its applicability within the limitations imposed by proposals, conservatism, and ease and speed of computation. The basic element in the prediction method is the predicted component failure rates. Equipment configuration is defined to the part level; the applicable future failure rates (based upon procurement period, quality, and program considerations) are then determined using point estimates of achieved component failure rates in the field. An applicable mathematical model relating those component failure rates and system reliability is then established. Predicted failure rates are given for three component quality levels over three component procurement periods--allowing application to both high- and low-reliability programs and providing for time-dependent reliability growth. The predicted failure rates for the various generic categories of components (resistors, capacitors, transistors, etc.) are based on actual system experience obtained primarily from the Ships Inertial Navigation System (SINS) used on Polaris-carrying submarines and Minuteman I systems under operational use in a controlled benign environment, thus providing system reliability predictions that are attainable with a high degree of confidence. The basic mathematical model, based on exponentially-distributed times-to-failure, provides a prediction model generally easy to apply under the conditions occurring in proposal work. Since the failure rates utilized in the basic predictions apply to use in a benign environment, it is necessary to apply degradation factors to estimate mission success in more severe environments. When subsystems or modules are redundant, classic modeling techniques are utilized to determine the system's reliability with the basic prediction model being used at the subsystem or lower level. Comparison with actual performance data for three guidance systems verified the success of the method in providing conservative reliability prediction.

REVIEW: Development of failure rates from actual experience as described in this paper represents a sensible approach to and a necessary part of reliability prediction. The technique of summing failure rates is old-hat, but will continue to be a part of reliability analysis; it can be reasonably accurate. A significant influence on the failure rates is the level of reliability effort, which is an influence not explicitly considered in some of the standard failure-rate reference sources. ##

Serial Number 2617
ASQC Code 814

TITLE: Semiconductor costs, yields and reliability

AUTHOR: James N. Perry (Fairchild Semiconductor, San Rafael, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 678-683 (*see RATR 2511)

PURPOSE: To demonstrate the unifying interdependence of yield, cost, and reliability--topics often discussed independently of each other.

ABSTRACT: The existence of semiconductor device manufacturing lines capable of producing units of high reliability at low cost is due more to improved manufacturing methods than simply to better screening methods. Reducing the number of defects introduced during manufacturing has increased yields, reduced costs, and enhanced reliability. These goals are always interrelated--a high-yield process obviously reduces costs and can reasonably be expected to produce devices with fewer undetected defects than a low-yield process; an inherently high-reliability process reduces costs by eliminating the need for screening and confidence testing.

REVIEW: The promise of an honest, frank discussion of the unity of cost, yield, and reliability, leading to new insights into the intricacies of product improvement, is not fulfilled. In its place is rather common-place stuff; nothing really very new is said. There are some interesting data in Table 1, correlating reliability test results with production yields, and a short list of typical defects in manufacturing operations.

Apparently the way to achieve profitable production is to set up a defect-free manufacturing line. As in belling the cat, the details of how this is done are as elusive as ever. ##

Serial Number 2618
ASQC Codes 614;831

TITLE: Optimum system analysis by linear programming

AUTHORS: Victor Selman (System Sciences Corporation, Falls Church, Va.) and Nelson T. Grisamore (School of Engineering and Applied Science, The George Washington University, Washington, D. C.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 696-703, 6 refs. (*see RATR 2511)

PURPOSE: To show how linear programming may be utilized to solve reliability engineering problems.

ABSTRACT: Since reliability is a design parameter, it is difficult in the early stages for the reliability engineer to determine the effects of simultaneous perturbations of cost, maintenance, weight, volume and other constraints on maximum system reliability. Linear programming, a mathematical optimization technique, can be used to great advantage in obtaining a solution to this problem, for it allows maximization of system reliability subject to certain kinds of constraints and requirements on parts, equipments and subsystems. In effect, a linear programming problem arises whenever two or more candidates or activities are competing for limited resources and when it can be assumed that all relationships within the problem are linear. Since most of reliability engineering mathematics is based upon random failures which assumes additivity (and thereby linearity) of failure rates, it is readily seen that linear programming is particularly apropos to the reliability discipline. After a mathematical statement of the general linear programming problem, practical applications are shown in quality control cost minimization, optimum spares provisioning, and reliability apportionment. Threshold values and parametric analysis techniques are illustrated. (Authors in part)

REVIEW: The mathematical statement of the general linear programming problem is concisely presented in this paper, and the manner in which it is presented could well be adopted by others writing for the reliability literature. Although linear programming has been a well developed technique for some time, it has not found general application in reliability. Four examples along with the general mathematical statement comprise this paper. The examples apparently are hypothetical and are simple ones; however they are suggestive of more complex problems which might be handled by linear programming. In particular, the examples on spares provisioning and on reliability least cost apportionment might be extended into real-world problems. Although the paper does not treat computer aspects, it is worth noting that computerization would be a requirement for actual applications, and should not be a problem. This paper would be useful to those wanting precise introduction to linear programming, and also to those who are already familiar with it but are seeking hints on applications. The limitation to linear relationships may be important in some cases. ##

Serial Number 2619
ASQC Codes 431;821;831

TITLE: Reliability computations for systems with dependent failures

AUTHOR: Martin L. Shooman (Department of Electrical Engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 712-718, 7 refs. (*see RATR 2511)

PURPOSE: To derive reliability formulas for certain systems with dependent failures.

ABSTRACT: Reliability theory has been concerned to a great extent with the formulation of mathematical models to describe the behavior of rather complex physical mechanisms. In most cases components in the system are assumed to fail independently so that a relatively simple model can be postulated. Experience and good engineering judgment suggest that there are many situations in which the independence assumption leads to poor answers and conceals important details concerning the reasons for failure. This paper describes a technique for the formulation of system models which include Markov-type dependence between components. The results are illustrated with two practical examples. (Author in part)

REVIEW: This is a good paper and can be recommended to all reliability engineers. The problem of dependent failures is well-motivated by the examples given and explicit solutions are obtained for certain reliability configurations. Extensions to other situations are indicated. The numerical examples given show that the dependency assumption can make substantial changes in the calculated reliability of the system. The author points out that the models considered depend upon Markov-type assumptions. These models will not fit situations where the transition to a new state depends on more than the last previous state. ##

Serial Number 2620
ASQC Code 814

TITLE: The optimization of systems reliability

AUTHOR: Jack E. Wylie (Missile & Space Systems Div., Douglas Aircraft Company, Inc., Santa Monica, Calif.)

SOURCE: Proceedings 1966 Annual Symposium on Reliability, San Francisco, Calif., Jan 66, p. 719-725 (*see RATR 2511)

PURPOSE: To derive a relationship between reliability and program time and dollars, and to present an associated scheduling methodology.

ABSTRACT: Two related premises are put forth:

1. Given a design of a certain excellence, holding dollar expenditures constant, reliability will grow as a function of time; holding that same design excellence and time constant, reliability will grow as a function of the program dollars expended. All other variables are to be held constant.
2. The ability to differentiate between the effects of time and those of dollar expenditures on the growth of reliability is a paramount consideration on both the customer and contractor levels.

A network is developed that represents the interaction of work tasks which might otherwise be presented in the form of a bar chart. Superimposed upon the work task network is a series of cost-time relationships developed for each of the tasks in the network. By combining the task network, time information and cost-time relationships, the investigator can generally arrive at better cost-time solutions than he can by using the standard critical path techniques. Costs can be minimized while holding reliability and time constant, or conversely, reliability can be increased while holding time and cost constant. Although not presented, a simple algorithm exists to facilitate the inspection of relationships leading to a better solution. The approach presented becomes unwieldy as the number of tasks to be considered increases.

REVIEW: A description of the optimization methodology, illustrated by a hypothetical example, comprises this paper. The approach appears reasonable, and most likely the limitation will be in the accuracy with which the detailed relationships can be established, such as the cost-time relationship for a given task. No mathematical descriptions or theory are presented, and it is suspected they will not be in the references which are given. There is also no mention of real-world applications. Those interested in the cost aspects of system effectiveness will want to read this paper. ##

Serial Number 2621
ASQC Code 844

TITLE: Functional failure mode analysis from the component to the system level

AUTHORS: V. E. Denietolis and A. C. Spann (Sylvania Electronic Systems, a Division of Sylvania Electric Products, Inc.)

SOURCE: Presented at the IEEE Group Meeting, Boston, Mass., 12 Mar 64, 5p

PURPOSE: To describe a technique for determining the failure characteristics of a system in terms of the failure characteristics of its parts.

ABSTRACT: Functional Failure Mode Analysis is a technique for determining the failure characteristics of a functional system in terms of the failure characteristics of its parts. This analysis considers only singly-occurring catastrophic failures. Failure rates versus environment and stress, and the probabilities of various modes (open, short, etc.) are evaluated for each part. The effects of these part failure modes on the circuit functions are then assessed. When all the circuits in the system have been analyzed for each of their failure modes, the functional blocks are analyzed and the same procedure is repeated from subsystem to system level. Resultant data are widely applicable to maintenance and fault analysis problems and have been used to illustrate the feasibility of, and provide guide-lines for, the performance of a gross maintainability study of a complex electronic system. (Authors in part)

REVIEW: The procedure described here is part of the attention to detail that is necessary for high reliability. In general, it should be a valuable part of a system analysis. ##

Serial Number 2622
ASQC Codes 220;822;824

TITLE: Random fatigue test sampling requirements

AUTHORS: S. C. Choi and L. D. Enochson (Measurement Analysis Corporation, 10962 Santa Monica Blvd., Los Angeles, Calif. 90025)

SOURCE: Technical Report AFFDL-TR-65-95, prepared for Air Force Flight Dynamics Laboratory, Research and Technology Division, AFSC, Wright-Patterson AFB, O., under Contract AF 33(615)-1314 by the Measurement Analysis Corporation, Los Angeles, Calif., Aug 65, 67p, 14 refs. (AD-622 086)

PURPOSE: To discuss the determination of sample sizes necessary for various statistical tests and estimates in random fatigue testing.

ABSTRACT: Basic considerations are discussed for determining sample sizes and record lengths for various statistical tests and estimates which are important to random fatigue testing. Methods for determining minimum sample sizes when comparing means and variances of normally (Gaussian) distributed random variables are described. Procedures for reducing a relatively large sample to a smaller sample are presented. Elimination of outliers and systematic resampling are two methods given.

An explanation is presented of the requirements and problems involved in the determination of record lengths necessary for an estimate of a given accuracy for autocorrelation functions, ordinary power spectral density functions, cross-correlation functions, cross-spectral density functions, frequency response functions, and probability density functions.

Due to its importance in random fatigue testing applications, the basic properties of the Weibull distribution in terms of its parameters and the failure rate are summarized. Estimation and statistical testing problems related to the Weibull distribution are presented. Methods of estimating the parameters are described. Methods of determining sample sizes needed for various analyses are developed. Some problems of reliability analysis applicable in fatigue testing are discussed. New decision techniques for comparing two or more systems are proposed in terms of reliability. The report concludes with an example of the application of the Weibull distribution to actual fatigue test data. (Authors in part)

REVIEW: This report is presumably directed to engineers concerned with sampling requirements who have little knowledge of statistics. Thus one would expect it to be quite clear as to what assumptions are being made, definitions of terms, etc. Unfortunately this is not always the case. Even in the simplest section on testing or estimating means and variances of normal distributions, several misleading or unclear statements are made. Section 3 on the reduction of the sample size is also not clear. For example in equation (11) the left-hand side is a constant whereas the right-hand side is random. The results on estimation of the covariance function and various spectral densities depend upon the definition of the bandwidth but may, as the authors point out, give at least rough guides to be used in planning. ##

Serial Number 2623
ASQC Codes 413;844

TITLE: Sequential reliability tests applied to checkout equipment

AUTHOR: Ben Norman Theall

SOURCE: Thesis presented to the Faculty of the School of Engineering of the Air Force Institute of Technology, Air University in partial fulfillment of the requirements for the degree of Master of Science, Aug 63, 90p, 23 refs.

PURPOSE: To discuss sequential probability ratio tests in reliability applications.

ABSTRACT: This paper discusses the sequential probability ratio test (SPRT) as applied to reliability tests of mission support aerospace ground equipment such as checkout equipment. The discussion is aimed primarily at testing for the mean time between failures (T) when the life distribution can be assumed exponential. Other distributions are mentioned. No specific checkout equipment is considered.

The following subjects are discussed: considerations in setting acceptable test risks, conditions under which SPRT's are appropriate, the theory of SPRT's and the resulting relationships used in SPRT's of T, and the expected qualitative variations in an SPRT when different test parameters are varied. It is pointed out that the average failure number (AFN) characteristic yields incentive for the contractor to submit equipment with T well above the two values of T, T_1 and T_o, selected as the decision limit parameters of the test. As the true T increases above those test-establishing parameters, the AFN and the expected waiting time decrease.

Under specific assumptions it is shown that a simple exponential relationship may be established between the expected test time and the ratio T_1/T_o. It is indicated that such a relationship could be used in conjunction with cost considerations to lead to a simple method for selecting the ratio yielding lowest cost. A flow chart suggesting one iterative procedure for selecting an appropriate SPRT for a particular problem closes the paper. (Author in part)

REVIEW: This is a good paper for the reliability engineer who wants to gain familiarity with sequential probability ratio tests in general and, in particular, for those wishing to apply such tests in reliability situations where the exponential distribution is appropriate. The discussion is well-motivated and the practical aspects of using the tests are considered. Much of the work is summarized in tables and graphs. It does bring to mind the paradox of being sure that the equipment has several times the required T, but being unable to use that information in a test. Bayesian statistics may help to resolve this situation. ##

Serial Number 2624
ASQC Code 844

TITLE: Reliability in advanced development programs

AUTHOR: M. M. Yarosh

SOURCE: Nuclear Safety, vol. 6, Winter 64-65, p. 160-164, 10 refs.

PURPOSE: To discuss the role of reliability in advanced development programs.

ABSTRACT: The initial emphasis in the work on reactor space power plants is primarily on the development of a system having a high probability of operating continuously and satisfactorily without external maintenance for at least one year. In this and other advanced systems, reliability and not performance is the outstanding requisite. To meet the unconventional demand for high reliability without the crutch of interim maintenance, prime consideration must be given in the conceptual design to obtaining a simple system composed of highly reliable components and to recognition of potential sources of trouble. In advanced development programs, it is impractical to obtain extensive test data on life-expectancy of such systems and, using traditional methods, a reliability level cannot be calculated with high confidence. In addition, the development program is beset with peculiar requirements which will not be present in the final system. The solution to this dilemma appears to lie in the field of reliability physics--in the study of fundamental processes of system failure. Through an understanding of the detailed modes and mechanisms of failure in developmental components, the engineer can determine--and thereby sharply reduce--the number of failures. Systems capable of varying degrees of maintenance by self-repair are also under study, but this technique is currently limited to electronic circuit repair and generally requires additional equipment.

REVIEW: This paper is brief, clearly written and well documented. Its principal message--that the solution to the reliability dilemma lies in the physics of failure--is conceptually sound. The problem of new failure modes being introduced unwittingly when changes are made is not a negligible one, however. The paper goes into no real detail on the implementation of the idea. One of the references prominently quoted is the paper covered by RATR 976. The reader should see also the critical and lengthy review of that paper as an aid in placing this topic in focus.

The author, in a private communication, has commented as follows: "There is a need to understand more specific details on the mechanisms of failure so that we can predict reliability with greater confidence without extensive applicable life expectancy data. To do this we should embark now on studies of the fundamental processes of failure such as those suggested in the article. This is suggested as a longer term, but more permanent solution to the present dilemma on predicting system reliability. The implementation of this suggestion must, I believe, result from an impetus given by those agencies providing the support for the advanced development programs. How in detail a program of study on the mechanisms of failure would be implemented and carried through, I did not intend to cover in this article." ##

Serial Number 2625
ASQC Code 800

TITLE: Safety-system reliability vs. performance

AUTHOR: E. P. Epler

SOURCE: Nuclear Safety, vol. 6, Summer 65, p. 411-414

PURPOSE: To discuss performance versus reliability in relation to reactor safety-system ineffectiveness.

ABSTRACT: A reactor safety system must perform in an accident environment which cannot be simulated and which ordinarily is unwillingly produced for purposes of performance evaluation. Unscheduled emergencies have therefore been depended upon to disclose failures to perform as needed (i.e., to shut down the reactor in case of control-equipment failure), to establish the true causes of safety-system ineffectiveness and determine the rate of arrival of uncontrolled excursions. Oak Ridge National Laboratory (ORNL) experience with safety systems has shown that a very high degree of reliability (less than one component failure per year) can be obtained by employing redundant channels properly maintained and carefully isolated--for, in spite of imperfect testing and imperfect isolation, safety-system ineffectiveness results not from component failure but from performance failure. By citing the record of excursions and major catastrophies in which the reactor safety-system was ineffective, it is pointed out that the majority of reactor accidents to data can be attributed to failures in safety-system performance resulting from design errors. A few are due to excessive delay in safety-system response, but none to component failure or to random sticking of rods--yet safety-system logic and sticking rods continue to receive major attention in disregard of the historical causes of reactor accidents. After making a probabilistic comparison of the effect of performance failure with that of component failure, it must be concluded that much time and effort is being wasted in toying with safety-system logic and probabilities based on random component failures that the record shows not to be a factor in excursions to date. Much effort must be expended in improving the performance of reactor safety systems that have been ineffective in preventing one destructive excursion for each 100 years of reactor operation (10^{-6} per hour). (Author in part)

REVIEW: This is a brief presentation which will be of interest to those concerned with the reliable performance of reactor safety systems. While the problems involved with such systems appear different from those encountered with space vehicles and military equipment, they have much in common. The approach to problems and the message are worthwhile--solve the ones you have rather than those you think you should have. ##

Serial Number 2626
ASQC Code 830

TITLE: Malfunction detection for Gemini

AUTHORS: J. J. Miller, Jr. and R. C. Weaver, Jr. (Martin Co., Baltimore, Md.)

SOURCE: ISA Journal, vol. 12, Jun 65, p. 59-64

PURPOSE: To describe the Malfunction Detection System for the USAF/Martin Co. Gemini launch vehicle.

ABSTRACT: Man-rating of the Titan II ICBM for boosting the two-man Gemini spacecraft into orbit required the inclusion of a Malfunction Detection System (MDS). This system is installed in the Titan and connected to a Warning-Abort system in the Gemini. During boost, the MDS monitors Titan performance parameters concerned with crew safety, and provides the astronauts with visual early warning of malfunction. For failures causing loss of thrust vector control, the MDS automatically switches flight control from the primary to the secondary system, because insufficient time is available, before a catastrophe, for malfunction detection, display, crew observation and reaction, and escape.

From the outset the MDS was conceived and designed to provide maximum safety for the crew and to far exceed the reliability of the systems monitored. These aims resulted in: simple design, painstaking care in evaluating and selecting both components and systems, and thorough testing. Block diagrams illustrate the design, relationship and location of the various MDS components. The guidance-flight control systems, sensors, rate switches and other circuits are all redundant. During evaluation of the design, various environmental and reliability tests were performed on the major MDS components. After carefully controlled fabrication, the complete MDS was subjected to overall system tests that allowed inducement of all known launch vehicle malfunctions while monitoring MDS for detection capability and response. MDS has functioned successfully through the test, countdown, launch, and flight of the first two unmanned Gemini launch vehicles and the first manned launch vehicle.

REVIEW: This paper is a concise description of the design, fabrication, and testing of a specific system with a high reliability requirement. As such it will be of interest to those concerned with the corresponding aspects of similar systems. ##

Serial Number 2627
ASQC Codes 831;844

TITLE: Power system network reliability

AUTHORS: F. E. Montmeat (Public Service Electric and Gas Company, Newark, N. J.) and A. D. Patton (Westinghouse Electric Corporation, East Pittsburgh, Pa.)

SOURCE: Presented at the American Power Conference, 27th Annual Meeting, Chicago, Ill., 27-29 Apr 65, 11p

PURPOSE: To present a method for predicting power system network reliability.

ABSTRACT: A newly developed analytical method employing probability theory now permits calculation and evaluation of important measures of reliability in power system networks from basic system component parameters. Measures of system reliability (or service goodness) which can be calculated include the average number of service interruptions per customer, the average customer restoration time, and the average total interruption time per customer--measures indicative of the system's ability to supply satisfactory service. Measures also calculated to indicate poorest system reliability are maximum number of interruptions for any one customer, maximum expected restoration time, and the probability that any customer will be out of service longer than a specified time. Outage rates and average repair or switching times, the two basic types of circuit and equipment data required, can usually be obtained from existing records. The first step is the preparation, or at least visualization, of reliability diagrams for each bus or point in the system at which service reliability is to be calculated. These diagrams show how components are connected, in the reliability sense, to form series and parallel paths of supply from the source to the bus in question. Once the series and parallel paths of supply to a bus have been established, the mathematical methods which have been developed can be applied to determine the service reliability of that bus. A computer program has been developed to facilitate power system calculations. Input data consist basically of component outage rates and repair times, weather statistics, and "success" expressions (reliability diagrams) for the buses. The program calculates measures of reliability as seen at each load bus specified for a system; it then calculates measures of reliability which are descriptive of the average reliability provided to all customers served by the system. This method can be used to compare the reliability of alternate system designs, to analyze the reliability of existing and future systems, and to determine the most economical methods of improving reliability.

REVIEW: This paper describes the application of relatively standard reliability analysis techniques to power system networks. An interesting feature is the need to consider two distinct environmental states--normal weather and stormy weather. The analysis has been programmed for the IBM 7094, but no details of the program are given in the paper. Additional details may be found in two references which are cited. ##

Serial Number 2628
ASQC Code 830

TITLE: How to boost reliability of industrial servo systems

AUTHOR: Willard M. Walthall (Hurletron Incorporated, Electric Eye Equipment Division, 1938 E. Fairchild St., Danville, Ill. 61834)

SOURCE: Hydraulics & Pneumatics, vol. 18, Sep 65, p. 91-93

PURPOSE: To describe the developments necessary to upgrade the lateral controls of a high-speed rotary printing press.

ABSTRACT: In 1956 Hurletron Incorporated began using electrohydraulic servovalves on hydraulic cylinders and motors for register controls on high speed rotary printing presses. When servovalves were introduced in the original central hydraulic systems they were quickly jammed by contaminants (paper fibers and coating, starch, moisture, and oil oxidation products generated by fixed-volume pumps and associated pressure-relief valves). As a result, a unitized system was developed for the new type lateral web controls but, in time, this system was found to have the same problems. To cope with the problem of contamination and reduce high operating temperature, the system was further modified to utilize a variable volume pump and a revised filtration system to catch built-in contaminants and provide continuous filtering. Because no external relief valve was necessary, a major source of oil oxidation was eliminated. In addition to these circuit refinements, step by step procedures were outlined to the customer for placing the system in operation. This new system requires less maintenance, has lower operating costs, increased filter life, and provides visual indications when the filters need changing. Furthermore, excessive oil temperatures or plugged filters will automatically stop the pump motor. Consequently, the assurance of longer life and greater reliability is given to servovalves and hydraulic actuators.

REVIEW: This paper describes refinements in design which resulted in improvement of the reliability of a particular system. The ideas may well have applicability to other systems. They serve to illustrate steps which can be taken to cope with sources of failure once these sources have been identified. Many of the problems turn out to be rather prosaic. Much reliability improvement can be obtained just by the actual use of standard engineering techniques which it is ordinarily but incorrectly presumed that everyone uses anyway. ##

Serial Number 2629
ASQC Code 831

TITLE: The methodology of modeling

AUTHOR: A. R. Teasdale, Jr. (Martin Company, Friendship International Airport, Md.)

SOURCE: Presented at the Systems Engineering Conference, New York Coliseum, 8-11 Jun 64, 47p, 10 refs.

PURPOSE: To review some of the fundamental concepts in the methodology of modeling and its relationship to systems engineering.

ABSTRACT: In systems engineering, engineering models varying in size and complexity have been used for many years to aid in analysis and gain physical insight into many systems problems. The fundamental approach is to identify and think in terms of the three basic entities: the system to be modeled, a mathematical model of the system, and a physical model of the system. Definition and description of the system is the first important step; properties of the system must be well understood and definition must be quantitative as well as qualitative. The mathematical model brings together in a formal and orderly manner all the pieces of information describing the system. The physical model must be derived from the mathematical model and, in some special cases, parts of the system may be substituted directly into the physical model. The programmed digital computer is becoming more and more heavily applied to dynamic physical models. A specific example, making use of a digital computer as a dynamic physical model to simulate the characteristics of a given filter, is described in detail in Appendix I. Before the model is subjected to its role in the solution of the systems problem, it must be tested and interrogated from many angles, for the fidelity of the solution derived from the model is determined by the fidelity of the form and numerical makeup of the model. In problem solution, the mathematical model and the physical model play a major part in the interplay between (1) problem statement, (2) conceiving ideas (systems synthesis), and (3) idea evaluation (systems analysis)--the three basic components of system problem solving. Examining the character of the mathematical models through analysis and exercising the physical models stimulates the thought processes and aids in establishing a rapid convergence toward optimal solutions to a systems design requirement.

REVIEW: This paper will be of interest to those who are concerned with modeling for systems reliability analysis. The discussion does not deal with reliability per se, but with some basic considerations regarding modeling, and contains some worthwhile ideas. The concept of physical model is not too clear since simple means for finding the logical implications of the mathematical model are included in the concept. While the body of the paper is pitched at a rather general level, the appendix goes more fully into some of the specifics. ##

Serial Number 2630
ASQC Code 801

TITLE: Reliability

AUTHOR: C. A. Ranous (University of Wisconsin, Dept. of Electrical Engineering, Madison, Wis.)

SOURCE: IEEE Transactions on Education, vol. E-7, Jun-Sep 64, p. 52-54, 6 refs.

PURPOSE: To present an exact definition and some applications of "reliability" in an attempt to prevent misunderstanding and misapplication of the term.

ABSTRACT: Reliability is not simply predictable performance, longevity, or accuracy. Reliability is not simply an assurance that a machine will start up when power is applied, nor availability, that is, readiness to perform its functions when wanted; it is equivalent neither to freedom from repair (low failure rate) nor to good inoperational to operational ratio (low "down time" or quick maintenance). Reliability does not necessarily equal high quality nor is it always the supreme, or a major, criterion of value of a product. Rather, reliability is the probability that a given machine will fulfill selected performance parameters under specified environmental and operating conditions for a certain number of hours.

Prerequisites for mathematically deriving a statistical probability that a machine will work without failure for h hours (mission time) are the following: (1) the mission time, (2) the specified environmental and operating conditions, and (3) selected performance parameters. In initial reliability determination, applicable tables are consulted to determine actual and potential failure rates of materials under the specified conditions of application. When the failure rate of each discrete part in the proposed machine has been determined, a reliability figure can be arrived at for the proposed mission time. During development, production, shipping, installation and field use, each part, tool, assembly process, inspection and test must have reliability scrutiny and approval in order to maintain the reliability figure. Terms associated with reliability--specifically, MTTF (Mean Time to Failure), Average Repair Time, Availability, Maintainability--are defined.

REVIEW: This paper is a brief, general, and largely semantic discussion which will be of most interest to the engineer not already familiar with the essentials of reliability engineering. The material presented is correct, as far as it goes; the reader interested in the details should seek them from competent references, some of which are cited in the paper. The term "reliability" is, of course, often used with meanings other that that associated with probability of success as defined by the author. Even the author's definition is not always applicable in its context since the initial conditions are not specified and various degrees of performance may be worth different amounts to the user. ##

Serial Number 2631
ASQC Codes 512;824

TITLE: "...with 60 per cent confidence..."

AUTHOR: Phil Holden (Texas Instruments, Inc., Dallas, Tex.)

SOURCE: Electronic Communicator, vol. 1, Mar/Apr 66, p. 5

PURPOSE: To discuss the usefulness of 60% confidence limits.

ABSTRACT: The 90% confidence limit is useful for lot acceptance because the maximum economical confidence is desired on each lot. The 60% confidence limit is useful for estimates of system reliability because of the way confidence limits combine. This is true where the number of failures is small and the number of types of components is large. It is better to use the 60% upper confidence limit on component failure rates rather than the best estimate because the 60% confidence level: (1) is the "worst case best estimate" for zero failures, (2) effectively "adds" one failure to the best estimate, and (3) results in the system failure rate being at 90% confidence or greater. But at the same time, the 90% confidence level is the only logical choice for lot acceptance purposes. (Author in part)

REVIEW: The conclusions are probably reasonable--there is no absolute basis for decision--but the justification is not always clear. For example, exactly the same reasoning used for 60% confidence limits for system estimation could be applied to lot acceptance since one usually uses more than one lot of a single part type in constructing a system. Some considerable attention has been given to system vs. component confidence limits, but the problem is not very tractable and success is slight. The use of the term "best estimate" implies the existence of criteria for "best"; there are many such and they should be stated. For example, the author discusses reasons why the "best" one is not best and another one is; he also says "The true best estimate for zero failures is somewhere around the 40% upper confidence limit; ..."--just what the criteria are for "true best" is not at all clear. It should be noted that unbiased estimates of failure rate will give biased estimates of MTBF and reliability. The case for 60% confidence is probably reasonable, but just as reasonable a case could be made for 50% or 70%. There are no absolute guide lines; it is all engineering judgment. ##

Serial Number 2632
ASQC Codes 820;831

TITLE: Reliability analysis using flowgraphs

AUTHOR: Thomas F. Oltorik (1/Lt., USAF)

SOURCE: Thesis presented to the Faculty of the School of Engineering of the Air Force Institute of Technology, Air University in partial fulfillment of the requirements for the degree of Master of Science, Aug 63, 45p

PURPOSE: To demonstrate the usefulness of flowgraphs in reliability analysis.

ABSTRACT: Reliability analyses of various integrant structures are performed using flowgraphs. The flowgraph representation of the reliability and effectiveness of a multimoded system is demonstrated. This solution provides a concise, pictorial illustration of the mathematical elements of the system. A Markov analysis of the multimoded system is performed by means of a Markov graph. This technique yields the transitional probabilities of moving from one mode or state to another. Flowgraphs are used for a resource allocation problem to determine the cost and sensitivity of the system to changes in various parameters. (Author in part)

REVIEW: This thesis presents an elementary introduction to the use of flowgraphs in various reliability problems. As such it is potentially useful to reliability personnel who wish to become familiar with this technique. However the exposition is flawed by lack of precision in certain basic probability statements (although the correct meaning can usually be detected) and by lack of definitions (especially in Chapter III). Other papers on this topic were covered by RATR 711 and 1507. ##

Serial Number 2633
ASQC Codes 813;814;844

TITLE: Optimizing product reliability

AUTHORS: Dimitri B. Kececioglu and Roy C. Hughes (Allis-Chalmers Mfg. Co., Research Div.)

SOURCE: Automotive Industries, vol. 130, 15 Jun 64, p. 66-69

PURPOSE: To suggest a program to attain optimum levels of product reliability.

ABSTRACT: The increasing reliability-consciousness of product users, both industry and the public, is making it imperative that the producer understand and use the science of reliability. For both producer and user there exists an optimum level of product reliability, a specific level of reliability that assures for each a minimum "total cost" of the product. By utilizing an aggressive integrated reliability program which coordinates reliability efforts affecting all phases of a product's life, the producer can attain higher reliability at lower cost--thereby raising the optimum level of reliability, while further reducing the minimum total cost to the customer. Fundamental to the program is a "reliability collective action and data feedback plan" to investigate failure rates and ensure corrective action. Reliability prediction and testing, reliability design reviews, the use of value engineering to convert designs to hardware at minimum cost with no sacrifice of reliability--all contribute considerably to cost reductions. Ensuring that measures are taken toward attaining the target reliability during design, engineering, manufacturing, purchasing, sales and service plus cooperation with, and reliance on, the customer for valuable reliability data should lead to minimum cost for mutual benefit.

REVIEW: This paper describes conventional reliability analysis techniques which will be familiar to the experienced reliability engineer. For the newcomer to the field, the paper would be useful for orientation purposes. It should be noted, however, that limitations and potential difficulties have not been emphasized. For example, the system failure rate can be determined by arithmetically summing the component failure rates only when component failures are statistically independent events. To ignore this fact could lead to misleading results. Similarly, "bath-tub" curves for each component may not be readily available. It is not necessarily true of all components that one can identify a time period during which the hazard rate is essentially constant; nor is it true in practice that an optimum level of product reliability can always be identified--due to the dynamic nature of trade-offs. Some reference to these and other limiting considerations would have made for a more realistic presentation. ##

Serial Number 2634
ASQC Codes 830;870

TITLE: Modular concept in design and maintenance

AUTHOR: Warren N. Kemnitz (Scovill Manufacturing Company, Hamilton Beach Div., Racine, Wis.)

SOURCE: Presented at the ASME Design Engineering Conference and Show, New York, N. Y., 17-20 May 65, Paper No. 65-MD-41, 5p (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th St., New York, N. Y. 10017)

PURPOSE: To stress the use of the modular concept in design.

ABSTRACT: Today, in designing products, ease of maintenance should be foremost in every designers thoughts. The easiest way of staying out of trouble with the service department is to keep the design and construction simple, to utilize interchangeable parts, to select materials known to be satisfactory, and to isolate potential trouble spots. Use of the throwaway or modular concept of design, coupled with reviews of the design with the engineering, sales, manufacturing and service departments to utilize their knowledge of problems in their areas, will result in a product requiring a minimum of service. If maintenance should be required, it will be handled easily in any service department.

These points are discussed briefly and several examples are cited.

REVIEW: The points made in this paper are certainly worth the attention of designers of maintainable equipment, at least of those who do not already have them in mind. Other factors, such as reliability and cost, must also receive proper consideration--very often this is more than they are currently receiving. On the details pertaining to specific equipment, the implementation of the ideas will call for ingenuity and judgment on the part of the designer. ##

Serial Number 2635
ASQC Codes 770;844;851

TITLE: A review of step-stress testing

AUTHOR: D. S. Peck (Bell Telephone Laboratories, Inc.)

SOURCE: Bell Laboratories Record, vol. 42, p. 327-329, Oct 64

PURPOSE: To review step-stress testing

ABSTRACT: Step-stress testing--subjecting a sample to increasing stress levels until all, or most, of the sample fails to meet prescribed limits--can provide information for reliability prediction and control in a relatively short time. The failure distribution pattern developed by the step-stress aging method approximates the Normal or Gaussian distribution with stress plotted on a linear inverse absolute temperature scale for storage or operating-junction temperature. While one test can provide considerable failure rate data, the performing of several such tests, using different times for application of stress, allows extrapolation to estimate a life distribution at a lower stress level. References to actual applications indicate that considerable experience confirms the validity of this extrapolation. In addition to providing an estimate of the median failure-stress, such tests can show the percentage of failures occurring earlier than expected from the stress time. Other advantages are that the entire time involved in applying the test can be defined fairly closely and a reasonable failure percentage obtained in a small sample. Failure due to weaknesses of the materials involved in the device assembly can also be indicated.

The step-stress technique is not effective with all alloy transistors because of the temperature limitation of the structure. Although effective for diffused germanium transistors, with silicon transistors, however, the stress-time reliability curve has now improved to such a degree that much longer times are required to obtain sufficient failure data. In transistor manufacture, "freaks" with some temperature dependence, tend to raise the failure rate. Therefore reliability testing must be aimed at measuring the "freak" rate in addition to assuring that quality does not degrade drastically. In the interim, step-stress testing and product improvement have been remarkably effective.

REVIEW: This is a very brief paper, serving to present the essentials of step-stress testing based on experience with it at Bell Telephone Laboratories, Inc. This is a method which has much potential for saving time in yielding reliability information on components relatively quickly. Not all of its limitations are given here. For example the interpretation of results generally depends on the model assumed for cumulative damage. The publication of accumulated experience for various types of components will serve a useful purpose. ##

Serial Number 2636
ASQC Codes 770;844

TITLE: Control systems reliability myths

AUTHOR: Dorian Shainin (Rath and Strong, Inc., Boston, Mass.)

SOURCE: IEEE Transactions on Industry and General Applications, vol. IGA-1, Jan-Feb 65, p. 2-3

PURPOSE: To describe a reliability testing strategy aimed at coping with the increasing degree of complexity of automatic control systems.

ABSTRACT: Moves toward automation are often blocked by misconceptions that say one has to accept some reliability troubles along with production-unit cost savings. The combining of engineering knowledge with statistical planning and statistical tools for analyzing variation provides new methods of coping with the increasing degree of system complexity. One such method, overstress testing, is currently helping engineers to accelerate their accumulation of knowledge about product weaknesses. However, the time-proven, classical method of solving problems by considering hypotheses and testing each one cannot adequately cope with all unsatisfactory distribution results revealed by overstress testing. Too often the width and the unsatisfactory position of such failure-mode distributions come from the dependent actions of multiple causes (called statistical interactions) or from a cause that simply escaped consideration. It has been found necessary to develop skill in a "process of elimination" strategy--combined with statistically designed experiments--for discovering the unknown and unsuspected variables. This form of research with variations has shown quickly and powerfully in hundreds of cases that causes quite different from those strongly suspected have been the culprits. Many costly and comparatively ineffective system design changes have thus been avoided.

The proposed method consists of gradually and continuously increasing the stress which the product experiences from combined environmental stresses during certain time periods of the entire test. At least six supposedly similar units are taken to the stress level which causes the first failure or malfunction mode in each. These individual stress results are plotted on Weibull probability paper. A lower 0.90 confidence limit stress position on the statistical distribution of failures is calculated to see if any margin of safety exists between it and the maximum expected operational stress. (Author in part)

REVIEW: Contrary to its title, this brief paper has little to do specifically with control systems, other than that they tend to be complex and less reliable. Rather than simplifying their design, the concern here is with the special method of overstress testing described in the second paragraph of the above abstract. It would seem to have good potential for forcing the revelation of failure modes in components and systems. However, a more convincing case for the method could have been made by presenting one or more case histories in reasonable detail, or at least by referencing them. The details may vary from one analysis to another. ##

Serial Number 2637
ASQC Code 800

TITLE: Whither reliability?

AUTHOR: John de S. Coutinho (Grumman Aircraft Engineering Corp., Bethpage, L. I., N. Y.)

SOURCE: Presented at the 1st AIAA Annual Meeting, Washington, D. C., 29 Jun - 2 Jul 64, AIAA Paper No. 64-249, 30p, 74 refs. (*American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N. Y. 10019)

PURPOSE: To present a state-of-the-art review on reliability control and to make some observations on the task ahead.

ABSTRACT: Engineering work has been done on the methods of measurement of the reliability of existing aerospace system designs and hardware, and thought has been given to quality control procedures. A start has been made on procedures to assist the designer in developing a design which meets, on paper, specified reliability requirements. However, except for the airframe, engines, and other devices involving safety of life, there is almost a complete lack of management understanding of the use of these techniques, and very few companies have developed a sound application philosophy. Practically no systematic work has been done on designing and organizing manufacturing methods, processes, and facilities to assure that a product of specified minimum reliability will result.

This paper is intended as the first in a series of annual reviews sponsored by the AIAA Technical Committee on Reliability and Maintainability, and it seeks to provide a framework for future reviews. The various sections establish the need for reliability control, both from the military and the civilian viewpoint; describe the development of statistical reliability concepts and of the more comprehensive system effectiveness concept; discuss the implementation of this concept by defining the scope of reliability assurance engineering with respect to the product development cycle; analyze where we stand today with respect to major subsystems and prime causes of unreliability; discuss the administration of reliability programs, particularly from the viewpoint of incentives and subcontractor control; and conclude with some observations on the task ahead. (Author)

REVIEW: In keeping with its nature as a state-of-the-art review, this paper covers a lot of topics, but treats none of them in great detail. The discussion is well documented, being keyed to some 74 references. The reader wishing to follow the discussion closely will find it useful to have at least some of these at hand. In the section on statistical concepts it should have been pointed out that the product rule is applicable only when the individual failure events are statistically independent. Also, the second equation from the bottom of the second column on p. 3 should read $R_s = (1-Q_s) = 1 - (1-R_1)(1-R_2)$. On p. 5 it is implied that the term "random" uniquely characterizes failures occurring under a constant hazard rate; this is not correct although the same implication occurs frequently in the reliability literature. ##

Serial Number 2638
ASQC Code 838

TITLE: Practical applications of redundancy

AUTHORS: Carl M. Bird and Bartholo T. Colandene (International Business Machines Corporation, Owego, N. Y.; now at IBM Systems Manufacturing Div., P. O. Box 1900, Boulder, Colorado 80301)

SOURCE: Presented at the AIAA Second Annual Meeting, San Francisco, Calif., 26-29 Jul 65, AIAA Paper No. 65-349, 21p (*see RATR 2637); also IBM Report No.:65-825-1431, IBM Federal Systems Division, Space Guidance Center, Owego, N. Y., May 65, 21p

PURPOSE: To present a progress report on actual cases where redundancy has been implemented.

ABSTRACT: Discussion in this paper centers on three specific redundancy techniques--duplex, triple modular, and multiple component redundancy--as they were employed in the development of the data processor for the Orbiting Astronomical Observatory (OAO) and the guidance computer for the Saturn V launch vehicle. Advantages and limitations of each technique, problems encountered in the design, and deviations from the theoretical reliability model are summarized.

In the OAO data processor, extensive use was made of multiple component redundancy techniques (more specifically, components were employed in quad configurations). Quad components and circuits applied the redundancy at the lowest possible level, leading to the greatest reliability gain; however, engineering problems of design, tolerance and testing restricted its application. Duplex redundancy was used in the power supply and memory sections of the Saturn V Launch Vehicle Digital Computer (LVDC) and was preferred where practical as it produced a greater reliability gain and used fewer parts than triple modular redundancy. In addition, it had the least weight and power increase for the redundancy techniques discussed and was capable of retaining simplex operational speed--all factors of considerable importance in these two areas. However, additional hardware, plus a test program, were required for fault detection, isolation and switching. Due to problems in providing error detection and switching circuitry, triple modular redundancy (TMR) was used in the LVDC logic sections. By employing TMR voter circuits, errors were voted out without interrupting machine operation. As shown by these studies, previously unattainable reliability gains can be achieved through the use of redundancy; however, improperly applied, redundancy can result in cost penalties in other parameters or even a degradation of reliability.

REVIEW: This is a good case-history paper, illustrating two cases in which redundancy has been applied. The material is presented clearly and concisely, and the disadvantages of the use of redundancy are mentioned as well as the advantages. As the authors have pointed out, to apply redundancy properly in any given case, detailed studies of the actual application must be made. An approach to high reliability without redundancy is that used on MIT/Apollo--see RATR 2467. ##

Serial Number 2639
ASQC Codes 715;782;833

TITLE: Degradation of n-p-n silicon planar transistors with bombardment by high-energy neutrons

AUTHOR: J. A. Hood (Sandia Corporation, Albuquerque, N. M.)

SOURCE: Semiconductor Products and Solid State Technology, vol. 8, Jan 65, p. 13-16, 6 refs.

PURPOSE: To discuss a model describing the degradation of n-p-n silicon diffused planar transistors when exposed to bombardment by high-energy neutrons.

ABSTRACT: To determine the effects of high-energy neutron irradiation on transistor circuits, it is necessary to know the degradation of the transistor's characteristics with the neutron dosage. The transistor parameter most affected is the forward current transfer rate or current gain. Based on the assumption that its falloff is dependent only on the loss of carrier lifetime with neutron dosage, this gain degradation can be predicted by electrical measurements. A one-dimensional transistor model is used to determine the equation and electrical measurements necessary to predict this gain variation after neutron irradiation. The equation may be applied to a particular circuit application by relating the minimum gain required in the circuit, the allowable neutron dosage, and the base transit time of the device. By establishing any two of these factors, the required value of the third can be determined by using the nomogram given in the paper. (Author in part)

REVIEW: The theory (model) appears to be satisfactory and conventional--it contains nothing new. The agreement of the data with the theory is quite reasonable. Thus the article seems to fulfill its purpose well. ##

Serial Number 2640
ASQC Codes 782;833

TITLE: Effect of vacuum environment on thin film component reliability

AUTHOR: Donald J. Santeler (Aero Vac Corporation)

SOURCE: Semiconductor Products and Solid State Technology, vol. 8, Jan 65, p. 17-22, 6 refs.

PURPOSE: To discuss the effect of the vacuum environment on the properties of thin film components.

ABSTRACT: New applications such as rapid switching devices, memory elements, semiconductors, and microminiature electronic components have created a need for research and development activity to determine the properties and to improve the reliability and reproducibility of thin films. Among the factors affecting the electrical and magnetic properties of thin film components are the impurity conditions prevailing in the vacuum chamber during deposition. The total pressure, amount of water vapor and presence of hydrocarbon impurities will affect the reliability and reproducibility of thin films. This article surveys the sources and amounts of different contaminants which may exist in the system, and the interaction of total system pumping speed with the total outgassing. The vacuum environment parameter is as important to control for insuring best film results as factors such as substrate material and cleanliness, temperature, rate of deposition and purity of the melt. Unlike the other factors, the vacuum environment is often not carefully controlled due to the great expense involved. Determining the extent of the interaction of vacuum system impurities with the films and the degree of vacuum or level of trace impurities which can be tolerated to reliably obtain satisfactory components will allow the establishment of realistic requirements of vacuum systems for economical manufacture of thin film components. (Author in part)

REVIEW: This article reviews sources of vacuum system contaminants and does not explicitly deal at all with the life of components. No test results of any kind are presented. This is an article on vacuum systems for engineers who need the knowledge; as such it is satisfactory. ##

Serial Number 2641
ASQC Codes 770;838;844

TITLE: Research on failure free systems

AUTHOR: --

SOURCE: NASA Contractor Reports CR-105 and CR-343, prepared under Contract No. NASw-572 by Westinghouse Electric Corporation, Baltimore, Md., for National Aeronautics and Space Administration, Washington, D. C., Nov 64, 229p (OTS: $3.50) and Dec 65, 170p (CFSTI: $5.00)

PURPOSE: To describe research aimed at advancing the state-of-the-art in the design of highly reliable electronic systems for use in the space effort, with emphasis on insensitivity to the effects of failures of individual internal components or subsystems.

ABSTRACT: Research on failure free systems included the development of new techniques for organizing and implementing systems which more effectively use redundant equipment and the development of procedures for testing a variety of redundant systems. In Phase I the research was divided into the following major tasks: (1) Implementation--concerned with developing suitable circuits, systems and testing techniques for use with currently-available redundancy techniques; (2) Advanced Voting Techniques--to develop new restoring circuits for use in redundant systems; and (3) Self Repair Techniques--to compare various switching strategies employed in self-repairing systems using a computer simulation program. Expanding and implementing Phase I studies, Phase II consisted of: (1) Statistical Measure of Quality--the development and analytical derivation of techniques for optimally allocating test points within redundant systems and estimating system reliability based on results obtained from testing only parts of the system; (2) Implementation of an Adaptive Voter--to design, construct and use a practical adaptive voter; (3) Failure Responsive Systems Organization--to develop design rules for systems capable of partially reorganizing their redundant subsystems in response to internal failures and to design a study vehicle with such capability; and (4) Medium Communication for Module Reorganization--the initial investigation of structures which can easily be reorganized through the use of a medium communication channel. The two reports are divided into sections describing in detail the work performed and conclusions reached in each major task area.

REVIEW: These reports reflect competent and comprehensive study on the design and testing of redundant electronic systems. They are well organized and clearly written. Summaries at the beginning of each enable the reader to identify particular topics, the details of which are found in the later sections (or appendices in NASA CR-105).
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Serial Number 2642
ASQC Code 802

TITLE: Syllabus for the reliability training course: "Statistics for Reliability"

AUTHOR: Benjamin Epstein (Consultant to Philco Western Development Laboratories, Palo Alto, Calif.)

SOURCE: Technical Operating Report WDL-TR1999, prepared for Air Force Space Systems Division, Air Force Systems Command, USAF, Inglewood, Calif., by Philco Western Development Laboratories, Palo Alto, Calif., under Contract No. AF04(695)-278, 28 Mar 63, 67p

PURPOSE: To present lecture notes and class handouts for the Philco WDL reliability training course, "Statistics for Reliability."

ABSTRACT: The material in this report represents the first course of a series developed to cover the basic probability and statistical concepts essential to the practice of reliability. Topics covered include the following.

- Introduction to reliability, probability, and statistical inference, the sample space
- Combinatorial techniques; rules for computing probabilities
- Bayes' theorem; applications of rules of probability to reliability of various system configurations
- Random variables; probability and cumulative distribution functions
- Empirical frequency distribution; computation of measures of location and dispersion
- Binomial and geometric distributions; applications to reliability problems
- Poisson and hypergeometric distributions; applications
- Exponential and Gamma distributions; reliability applications
- Normal distribution
- Normal approximation to binomial
- Sampling and estimation of parameters
- Point estimation; properties of estimates and estimators
- Confidence estimates and limits
- Significance tests
- Nonparametric techniques
- Testing hypotheses; applications of confidence to reliability

REVIEW: This is a good concise treatment of the material indicated in the above abstract. It will be useful to those who wish to get a grasp on the fundamentals of probability and statistics pertinent to reliability analysis. While these topics are covered in a variety of statistics textbooks, this presentation has the advantage of being slanted toward the reliability analyst, emphasizing the things which he needs to know. ##

Serial Number 2643
ASQC Code 838

TITLE: The case for redundancy...redundancy...

AUTHORS: J. W. Nicholas and R. N. Dallas (Lockheed-California Co., Burbank, Calif.)

SOURCE: Machine Design, vol. 37, 18 Mar 65, p. 170-173

PURPOSE: To discuss redundancy as a means of improving system reliability.

ABSTRACT: Whether the redundancy is active or passive, whether parallel units are alike or dissimilar, redundancy offers one obvious advantage over nonredundant design--it can markedly improve reliability. Reliability gains are demonstrated by considering the effects of standby units upon system unreliability.

Unfortunately, redundancy has hidden penalties: it adds weight, increases complexity, and increases cost. Sensing, switching and fault-isolation components required by redundant systems may function prematurely or fail to function; redundant systems must be as completely checked out as nonredundant systems prior to each mission--therefore, redundant design requires more complex checkout equipment and increased checkout time, increasing both maintenance time and cost. (Authors in part)

REVIEW: This paper is a good brief presentation of the advantages and disadvantages of redundancy. Redundancy can improve reliability, but there may be constraints (such as cost, weight, or available space) which make its implementation impossible. Similarly, the improvement in reliability may be offset by a deterioration in some other parameter such as cost effectiveness. The improvement that redundancy offers depends vitally on the assumption of statistical independence of failures; physical independence is not enough. An unexpectedly severe environment can result in statistical dependence, even with physical independence. These factors must be kept in mind by the designer who is considering the use of redundancy, and a paper such as this is helpful in this connection. ##

Serial Number 2644 -1
ASQC Codes 711;712

TITLE: Fatigue in textile fibers
(Covered are five parts (IV through VIII) of a series of papers. These parts deal with fatiguing by cyclic tension under the headings: Effects of stroke on the statistics of lifetimes, Probability-strain-lifetime relationships for a polyester sample, Effects of frequency on the statistics of lifetimes, Considerations of creep and force data, and Fiber properties and behavior after cyclic loading.)

AUTHORS: Dusan C. Prevorsek and W. James Lyons (Textile Research Institute, Princeton, N. J.)

SOURCE: Textile Research Journal, vol. 34, Oct 64, p. 881-888, 6 refs.; Dec 64, p. 1040-1044, 6 refs.; vol. 35, Jan 65, p. 73-78, 8 refs.; Feb 65, p. 110-118, 8 refs.; Mar 65, p. 217-220, 5 refs.

PURPOSE: To discuss the effects of stroke, stroke frequency, and creep on the fatigue life of several textile fibers.

ABSTRACT: In Part IV, lifetime distributions have been determined as functions of the total displacement of one end of a fiber specimen (stroke) for nylon 6, nylon 66, Dacron 52 and 420, viscous rayon and acrylic fibers. The frequency of stroke and temperature were kept at 250 cpm and 21^{o} C. Results are plotted in terms of cycles to failure, % stroke and probability of failure (assuming a Normal distribution). None of the results displayed any great conformity to a Normal distribution, particularly the acrylic fibers which had a bimodal characteristic indicating two different mechanisms of failure. The latter was also indicated to a lesser extent for the other five groups; since the two modes were not clearly separable, the distribution was considered unimodal and the results were analyzed for various strokes using the third asymptotic or Weibull distribution. Tests on the acrylic fiber have indicated that the probability of failure plots linearly with % stroke for a given life. All such plots for various life values intersect at a point which reveals the stroke which may be considered the endurance limit. Stroke vs. cycles to failure are given for all six fibers tested. Above 10 cycles to failure nylon appears to show higher results than Dacron while rayon showed the poorest results. If an endurance limit exists, it is at a stroke giving life greater than 10^6 cycles to failure.

In Part V a relationship between survival probability, strain amplitude, and time to failure is obtained for Dacron 52 using the data obtained in Part IV and assuming a Weibull distribution.

In Part VI the effect of frequency on the distribution of lifetime is determined for an acrylic sample and types 52 and 420 Dacron fibers. For acrylic tests at 72, 250 and 600 cpm the results show a bimodal distribution at 250 cpm but unimodal at 60 and 600 cpm. Recent studies by Prevorsek and Whitwell conclude that a bimodal distribution can result from a healing process at some favorable frequency.

Dacron 52 and 420 fibers both had a unimodal distribution at all

frequencies and seem to follow a Weibull distribution. In general, longer lifetimes are more affected by frequency than shorter lifetimes. The average number of cycles to failure seems to increase with an increase in frequency in all cases. Fatigue scatter was much greater for the acrylic fibers at a given frequency than for the Dacron sample.

In Part VII, acrylic, Dacron 52 and Dacron 420 fibers are studied with respect to creep during cyclic loading at various strokes. For the acrylic fibers, the average increase in specimen length per cycle due to creep decreases with increasing frequency. For both Dacron fibers and acrylic fibers the rate of creep decreases with an increase in frequency; however creep extension for the Dacron fibers increased with time which is opposite to the results from the acrylic tests. When force and creep are measured simultaneously, changes in cyclic force and creep extension predominate only in initial periods on cycling from which it is concluded that failure results from crack formation rather than as a result of creep.

In Part VIII tests on acrylic fibers are discussed that are designed to determine whether fatigue is a localized phenomenon or a general process of progressive failure that occurs throughout the entire specimen. From these tests it was concluded that fatigue in fibrous polymers is not due to progressive damage but instead is catastrophic. This conclusion was based on:

a. Tensile tests on fatigued and unfatigued specimens in which breaking tenacity of fatigued specimens was higher and breaking extension lower than in unfatigued specimens.
b. Fatigue tests on segments of previously fatigued specimens which showed no appreciable difference in life from the original values.
c. Fatigue tests of mildly precycled specimens that showed no effect due to precycling on fatigue life.
d. Measurements of the breaking tenacity of fibers made immediately after a cyclic loading treatment and others made 18 hours after the treatment which indicated that the "rest" period had no detectable effect on this property.

REVIEW: This is a very comprehensive and interesting work on the fatigue strength and the effects of cyclic tension on the properties of textile fibers. If one could take exception to any of the conclusions reached or results obtained it would have to be with the conclusion that fatigue failure in fibrous polymers is catastrophic rather than progressive. Fatigue failure is generally considered to be a two-step process that includes crack initiation and crack propagation. Perhaps in specimens that have extremely small cross sectional areas crack initiation plays a far more important role than crack propagation which could lead to the conclusion reached. In any event the papers are examples of excellent reporting on the data and the manner in which the data were analyzed. ##

Serial Number 2645 -1
ASQC Codes 711;712;770;
782;844

TITLE: Reliability and performance of aircraft transparencies in civil airline service

AUTHOR: E. G. Barber (British Overseas Airways Corporation)

TITLE: Reliability and performance of aircraft transparencies in military service

AUTHOR: W. E. Pryor (Central Servicing Development Establishment, Royal Air Force, Swanton Morley, Dereham, Norfolk, England)

TITLE: Test methods to establish strength and reliability

AUTHOR: P. W. Taylor (Royal Aircraft Establishment, Farnborough, England)

SOURCE: Aircraft Engineering, vol. 36, Dec 64, p. 384-385, 386-387, 388-391

PURPOSE: To discuss failure rates of windows in civil and military aircraft as well as methods for establishing reliability and improving performance.

ABSTRACT: Windows are limited here to windshields and bomb aimer panels; failure is due to cracking or delamination.

In the paper on military windows the discussion is limited to the R.A.F. which has approximately 11,000 such windows in its aircraft. Failures reduce the number of operation-ready aircraft at any given time, and once launched there is the probability that additional failure could affect the success of a mission. Problems associated with window failures include flight safety, availability of spares, and maintenance costs. The mean operational time between window defects is given for bombers, transports, coastal, fighter and training aircraft. They range from 178 hours for bombers to 2000 hours for training aircraft. The time required to change a windshield may be as long as 64 hours. Investigations of failure have not led to any specific shortcoming being found in design or material. Improvements in the last 10 years have not increased reliability.

With respect to window failures in civil aircraft, the data used were obtained from Boeing 707, Comet 4, and Britannia 412 aircraft. Only cockpit heated window panels were examined since these present the greatest problems. The biggest problem has been the inability to predict life since there are no known rates of wear or deterioration. To prevent inconvenience of untimely failures, it is suggested that replacement should be rapid and simple. Average operating time between failures in these civil aircraft ranged from 670 to 910 hours.

Several approaches with respect to test methods are discussed for providing design data for glass panels. The fact that glass strength deteriorates with time and then recovers makes it necessary to know

the age of glass test specimens before a test program is attempted. Beam and disk tests are discussed for providing design data for sustained and cyclic loading. These tests are designed also to determine the effects of temperature and pressure. Temperature effects stem from kinetic heating and cooling, deicing and demisting systems, and hot air rain removal systems. Methods are described for thermal testing, contraction and expansion tests, simulation of supporting structural restraints and edge conditions, and measuring strain.

REVIEW: It appears that the greatest need in solving the problem of reliability in aircraft windows is to relate failure to its cause. Perhaps measurements of stress amplitude, stress frequency, and temperature made in actual flight could be used to establish this relationship. Failures should also be analyzed as to type and location of point where crack or delamination initiated. The problem may be one of either design or material and new design must be based on which of these problems predominates. Window failures in other fields could also be analyzed to shed light on the problem. The papers serve mainly to emphasize that window failures greatly affect aircraft operations and that these problems must be alleviated in order to increase safety in air travel. ##

Serial Number 2646 -1
ASQC Codes 810;871

TITLE: Program management in design and development

AUTHORS: J. R. Dempsey (General Dynamics/Astronautics), W. A. Davis (Maj. Gen., Ballistic Systems Div., Norton Air Force Base), A. S. Crossfield (Space and Information Systems Div., North American Aviation, Inc.), and Walter C. Williams (Manned Spacecraft Center, NASA)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 1-22 (*cosponsored by Society of Automotive Engineers, Inc., American Society of Mechanical Engineers, Inc., and American Institute of Aeronautics and Astronautics; Proceedings published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N. Y. 10017; Member price: $12.00; Nonmember price: $15.50)

PURPOSE: To present the responses of a panel of experts to a set of questions pertaining to reliability and maintainability program management.

ABSTRACT: This paper is in the form of responses to a set of standard questions put to the various panel members concerning a number of significant program management problems. The responses reflect the authors' experience in management of the test and assurance aspects of aerospace vehicle development and production. Emphasis is placed on the need for analysis and identification of the critical areas in design, manufacture and operation, for control of all the significant factors affecting product effectiveness, and for testing to verify the suitability of the product for its intended use. The questions were as follows.

1. Do you believe that all bidders on new development proposals are submitting reliability/maintainability programs on a comparable basis? If not, what must be done to provide this assurance?
2. What are the basic elements necessary to define a reliability/maintainability program? That is, percent of overall cost, design reliability effort, test, development or demonstration effort, organization, etc.
3. Is it possible to specify order of magnitude improvements in reliability/maintainability for design and development contracts? If so, what constraints must also be included? (weight, schedule, cost, confidence, etc.)
4. How best can advancements in reliability/maintainability state-of-the-art be attained and used with compressed schedules?
5. Is it practical to require high-confidence demonstration of the equipment reliability for all types of aerospace equipment? At what level of assembly?
6. Should we continue to use the same specifications to define reliability/maintainability requirements for both airborne and ground support aerospace equipment?
7. Does the organization structure have an effect on the reliability/maintainability attained in design and development contracts? Does management understand and support have any effect?
8. Is reliability being considered out of proportion to the overall cost-effectiveness picture for manned space programs? For weapon systems?

9. Should we design and develop new products which require no testing after factory functional testing and what type of products will they be more advantageously used in?
10. Based on past performance, how can the higher-priced, more reliable component manufacturer compete with the lower priced, less reliable component manufacturer? i.e., at what level of reliability/cost can a valid decision be made. For example; Contractor X met only 1/2 of the specified reliability at a cost of $X. Contractor B met the specified reliability at a cost of $1.2X. On what basis should the award of new business be made?
11. On incentive type contracts, how should schedule, cost, reliability, and maintainability be apportioned? How and where should it be measured and incentives awarded? How does it vary with different types of contracts (Space, Aircraft, GSE)?
12. What qualifications must personnel possess (background and education) to effectively function in reliability/maintainability organizations?
13. How has the recent trend to integrated "product effectiveness" organizations worked out?
14. What problems have been created by the Air Force's growing insistence to specify numerical reliability requirements to be achieved by the contractor?
15. What progress has been made on developing economically feasible methods for demonstrating reliability of parts, components, subsystems and systems?
16. An increasing number of Air Force contracts contain performance incentives. What problems have arisen and what methods have been developed to demonstrate reliability performance to determine the appropriate incentive award?

REVIEW: The replies of the four authors to the 16 questions listed above are presented clearly and concisely. Thus any attempt to summarize them is not likely to be worthwhile--it will behoove those interested in management for reliability and maintainability to read and compare them in order to gain their own impressions. The panelists collectively represent a wealth of experience from both industry and government organizations, and the paper merits the careful attention of those concerned with the topics covered. ##

Serial Number 2647
ASQC Codes 814;815

TITLE: The dollars and cents aspect of reliability

AUTHOR: H. W. Nevin (United Air Lines, Inc.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 62-64 (*see RATR 2646)

PURPOSE: To discuss the need for improved reliability of aircraft components as a means of reducing the investment in spare parts.

ABSTRACT: As a result of less than 100 percent reliability United Air Lines carries a $122,000,000 spare parts inventory and employs thousands of maintenance personnel. A major problem in determining spare parts requirements is the uncertainty of reliability forecasts. There are significant differences between manufacturers' laboratory-derived reliability forecasts and actual airline experience. Of particular concern is the incompatibility of interdependent units and the difference between "true" and "apparent" failures. The sophistication used in component reliability work should now be applied to component-to-aircraft compatibility and troubleshooting techniques.

The following ideas for solving these problems are presented:
1. Component manufacturers must be stimulated to increase efforts towards total system reliability through increased competition.
2. During the selection of a system, the airframe manufacturer should coordinate and concentrate efforts on component to system and system to aircraft compatibility in order to assure better reliability to the ultimate consumers - the airlines and the passengers.
3. Airlines must demand better product warranties to promote more complete and realistic reliability estimates. At present most warranties do not adequately represent the reliability claims of manufacturers. One way would be to require product warranties that better relate financial guarantees to reliability claims. The vendor would lend the airline additional units needed to compensate for his over-estimating the reliability until such time as he is able to improve the reliability. Conversely, he would buy back excess parts purchased by the airline when he under-estimated the reliability. (Author in part)

REVIEW: This is a clear and concise paper addressed to an important problem. The ideas for effecting a solution, presented in the above abstract, are reasonable. However, as the author has indicated, a concerted effort will be required for implementation. The result would be increased first cost for components and systems, which would hopefully be offset by a lower investment in spare parts and lower maintenance costs to an extent producing lower total cost. The implementation of the ideas should also result in improvement in safe and reliable operation--of paramount importance to the airlines and their passengers. The idea of better expressed warranties is a good one and should be further explored in many commercial and military areas. ##

Serial Number 2648
ASQC Code 810

TITLE: The role of effort classification in system design and evaluation

AUTHOR: Vernon L. Grose (Ventura Div., Northrop Corp.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul, 64, p. 71-81 (*see RATR 2646)

PURPOSE: To describe the management tool known as "effort classification."

ABSTRACT: Northrop Ventura has implemented, as part of their internal management control, six categories, similar to those in the Department of Defense, for various types of development. This implementation required that (1) the DOD development categories to be expanded and interpreted in terms of Northrop Ventura's product interests, and (2) levels of appropriate effort within each of the development categories be defined for all functions involved in the development process. These latter levels constitute what is called "effort classification." Effort classification has been credited with reducing the time required to prepare and negotiate proposals, simplifying program management, and achieving product maturity. (Author)

REVIEW: This is a concise description of a worthwhile management idea and the advantages accruing from its implementation. From the point of view of reliability, the most important part of the paper is Appendix C, in which graduated work statements for various reliability tasks are illustrated. As the author has pointed out, these are illustrative only, and must be adapted for the particular program to which they are to be applied. ##

Serial Number 2649
ASQC Codes 820;844

TITLE: Reliability--the science of analysis

AUTHOR: John W. Hughes (Thiokol Chemical Corp., Wasatch Div.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 82-93 (*see RATR 2646)

PURPOSE: To discuss the definition, purpose, and effective application of the reliability function.

ABSTRACT: Reliability is invariably treated as a statistical probability and only to a limited degree is it considered an analytical science. Considered as a scientific discipline, however, reliability can make important contributions to every phase of product development, from design conception to management systems, tool design, process engineering, quality assurance, and maintainability. Recognizing the existence of problems of definition and application in the reliability field, Thiokol reliability engineers re-evaluated the subject in relation to their position within the company. First consideration was given to defining reliability and the reasons and purposes of a reliability program. The following definition was proposed to identify reliability as a science of analysis--rather than simply "the probability of success"--and to deter the possibility of misconception: Reliability is the science of analytically defining every conceivable way in which a product can fail, isolating the causes, and developing changes or controls to prevent the occurrence of these failures. The next step was a review of the reliability function accomplished by drawing a parallel between the following sequence of events in an engineering effort and the reliability concepts coincident to them: (1) definition of system concept, (2) preliminary design, (3) equipment design, (4) development equipment fabrication and test, (5) analysis of test results, (6) redesign and re-evaluation, (7) release to production and (8) liaison. If a reliability function is well understood and effectively applied, there is no doubt that in most cases the company's capability for conducting a profitable and successful program can be enhanced.

REVIEW: The message in this paper, that reliability analysis should be primarily concerned with assurance by identifying failure modes and then eliminating them, coincides with current attitudes. The paper is mainly a general survey type of description of a design process for rocket propulsion equipment and how reliability engineering fits into this process. Most of the detail which appears is contained in the illustrations covering aspects of reliability analysis; otherwise the contents are general. In the portion of the paper on page 87 covering mathematical models, reliability probabilities associated with various performance parameters are obtained individually for each parameter by considering an acceptable range for each, and then they are multiplied to obtain an overall reliability estimate. This approach assumes complete independence among these parameters, which may not exist because of functional interrelationships and uncertainty in the knowledge of common environments. Nothing is mentioned concerning this assumption. ##

Serial Number 2650
ASQC Codes 615;817;863;
871

TITLE: Increased reliability through spare parts optimization

AUTHOR: D. J. Davis (Douglas Aircraft Co., Inc., Missile and Space Systems Div.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 94-99 (*see RATR 2646)

PURPOSE: To describe a method developed to determine the effect of spare parts on reliability and mission success.

ABSTRACT: As part of a NASA study of a manned orbital research laboratory, a computer method was developed: (1) to select an inventory of spare parts that provide the greatest protection against mission failure for a given weight, and (2) to establish a relationship between mission success probability and the level of spares provisioning. Input data were provided by reliability prediction and failure mode and effects analysis. Four different criteria of mission success were used to rank the value of spare parts: crew safety, laboratory survival, experimental return, and degradation. The computation program, in its barest essentials, accepts a list of potential spare parts and, for a given weight, determines for each class of failure effects the selected spares which provide more protection against failure than any other set within the weight constraint. In the actual computation, provisions for redundancy and multiple usage, kit approximation, and non-repairable parts were introduced into the simplified model in order to provide a more realistic representation of the spacecraft under study. When the probability of survial was plotted against the weight of critical spares, a "knee" shaped curve resulted. In addition to satisfying an immediate need, the spares optimization technique proved practical, valid, and effective in improving design reliability and maintainability. Although presently used only in the preliminary design phase, it should prove equally useful in the detail design phase and in the optimization of inherent system reliability. Certain limitations of the method are also indicated.

REVIEW: The basis of the approach is only briefly treated, and involves dynamic programming. The method apparently draws on a spares optimization procedure which has been treated extensively in operations research procedure and is referred to there as "fly-away kit." Those persons who are not already familiar with this will need to consult the references; some are cited in the paper. Much of the paper is an excellent discussion of the limitations, practicality, and validity of the approach with respect to its space-oriented application. The computations have been mechanized for the 7094 computer. Those persons who are interested in logistics and reliability trade-offs can benefit from this paper. ##

Serial Number 2651
ASQC Codes 771;813

TITLE: More efficient testing and data utilization in a large development organization

AUTHOR: M. R. Seldon (General Dynamics/Astronautics)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 100-106 (*see RATR 2646)

PURPOSE: To describe a unified test plan and give its advantages.

ABSTRACT: A Unified Test Plan (UTP) combines all tests of various departments such as Central Test Control, Design, Reliability Control, and Test Laboratories. This UTP begins in the proposal stage. It eventually brings all test plans together in one book, for maximum coordination and effectiveness. The UTP reduces the number of tests, saves time and specimens, and requires fewer people. The test results are much more useful to more people, and corrective action is surer because of the increased discipline.

REVIEW: This is a short paper and gives only the barest outline of the UTP. Its advantages appear to be many; no disadvantages are mentioned. There surely is some lower limit on a test size such that the test is not included in the UTP, although the description is very general. The author undoubtedly felt there were some obvious lower limits.

Some sort of unification, especially of the more formal required tests, can be most beneficial. Each organization should check its own needs in this regard. ##

Serial Number 2652
ASQC Codes 813;815

TITLE: Report on an incentive/penalty reliability program

AUTHOR: C. W. Russell (Republic Aviation Corp.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 107-114 (*see RATR 2646)

PURPOSE: To discuss some of the problems, results, and benefits that accrued during an incentive/penalty reliability program.

ABSTRACT: A reliability program established for specific subsystems of the F-105 aircraft included an incentive/penalty approach. Added profits would be obtained if acceptable MTBF values were achieved. Penalties, associated with reworking and retesting each lot in which the sample failed, rather than a reduction in fee, were assessed if low MTBF values were obtained. Although difficulty was encountered in the early negotiation, the program accomplished its objectives. Other benefits which resulted from these programs were: (1) an increased knowledge of the contractual requirements, (2) an increased knowledge of the control of such programs, (3) a bi-monthly conference promoting free exchange of information, (4) design information, (5) improved manufacturing and quality control techniques, and (6) savings in repair costs. As a result of these programs, it is recommended that special attention be devoted to the following areas: (1) a representative environment cycle, (2) early involvement of all departments, (3) the use of highly reliable test equipment, (4) more detailed test specifications, and (5) a more equitable relation of incentive to penalty. It is strongly recommended that industry should not generally accept a penalty on a rework basis due to the unassessable financial risk involved.

REVIEW: This paper is a sequel to the one covered by RATR 2263, and the complimentary remarks made in that review are also appropriate here. It is noted that the majority of reliability improvements were achieved in manufacturing and quality control, which is an observation being made with increased frequency, yet--generally and aside from this paper--there does not seem to be much effort for improving manufacturing techniques for reliability, but rather emphasis remains on improving further the design techniques. At the beginning of page 109 and elsewhere there are some remarks to the effect that the consumer's and producer's risks as calculated by statisticians are not the risk management is interested in. Extensive developments have been made on applications of statistics to financial risks. RATR 2430 and 2480 are specifically on reliability tests and financial risks, and the references in the publications covered by them are indicative of other applications. The author strongly recommends that industry not accept the type of contract, as used here, where the penalty is a firm rework requirement instead of a reduction in fee. This is indeed a strong recommendation, and if applied literally would say do not accept any firm requirements at a fixed price. Surely there are situations in reliability, as with other characteristics, where this recommendation would not apply. The above remarks pertain to only one area of the paper; in the main it is timely, pertinent, and informative. ##

Serial Number 2653
ASQC Codes 815;832

I. TITLE: USAF military specification for safety--MIL-S-38130

AUTHOR: Jay T. Robbins (Norton Air Force Base, USAF)

II. TITLE: Air Force safety practices

AUTHOR: Mack W. Eastburn (American Airlines, Inc.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 129-132; p. 360-363, 386 (*see RATR 2646)

PURPOSE: To show how accidents arise and what is being done to reduce the causes.

ABSTRACT: I. The Air Force experiences many accidents, although the number is not increasing as fast as the exposure. In the final analysis, most accidents are due to some person: pilot, mechanic, designer, manufacturer, etc. The organization of the manufacturer needs to be set up, at all stages, so that identification and elimination of hazards is an integral part of the operation. To this end, the USAF MIL-S-38130 on safety has been promulgated. It requires that all contractors (prime and sub) apply safety engineering to all phases of weapon system design, development, test and operation. Each contractor must file a system and safety engineering plan which details his organization and planning for safety, analyses of all components for hazards, and proposes reduction of the hazards.

II. It is important that everyone in the chain understand his responsibilities and be able to use properly the information at his disposal. Pilot errors and design errors alike are caused by improper use of information.

REVIEW: The first paper gives a very sketchy outline of the safety specification and is worthwhile for that. Since many of the same tasks need to be done for safety, reliability, and maintainability, perhaps some method of combining and integrating them can be worked out. This, of course, tends to lead back to the science of engineering as opposed to the sub-disciplines.

The effectiveness with the new specification, as with most others, will depend on the vigilance, resourcefulness, and knowledge of contract officers as well as on how seriously the manufacturers take it.

The second paper is an essay on doing things right. It probably made a more effective speech than it does a written paper. ##

Serial Number 2654
ASQC Code 824

TITLE: Some problems in reliability estimation

AUTHOR: Gerald J. Lieberman (Stanford University)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 136-140 (*see RATR 2646)

PURPOSE: To discuss three important problems in reliability where complete solutions are unavailable.

ABSTRACT: This paper discusses the following three areas of interest.

1. The government requirement of assurance of high reliability of complex items where the cost of sampling is extremely high.
2. Confidence intervals for a system in series where component data are available, and
3. Estimation of the parameters of the Weibull distribution when sampling terminates after the r th failure is observed in a sample of size n.

It is shown that to obtain a lower confidence bound on reliabilities of interest (i.e., $\geq .9$) with high confidence coefficient (90-95%), an inordinately large sample must be used. A Bayesian approach is suggested. In dealing with the second area it is noted that when the reliabilities of individual components are high and fairly large samples have been used, then a Poisson approximation may be used to obtain a lower confidence bound for system reliability. The maximum likelihood estimation method is used for the third problem area. The resulting equations are not solvable explicitly and some approximations are given. A Generalized Weibull-Gamma distribution is defined and proposed as a new time-to-failure distribution. It is shown that, for certain values of the parameters, the hazard function associated with this distribution can be of the important "bathtub form."

REVIEW: This is a brief paper with some good ideas on the stated problems. The Poisson approximation used to obtain a solution for the second problem seems especially useful. The proposed Generalized Weibull-Gamma distribution is also of interest--especially since its hazard function can be of many different shapes. Perhaps it should have been pointed out that the random variable $Y = X^{1/\beta}$ will have the Generalized Weibull-Gamma distribution if X has a Gamma distribution with scale parameter α and shape parameter γ. It is also easy to obtain $E(Y^n) = \alpha^{-n/\beta}\,\Gamma(\gamma + n/\beta)/\Gamma(\gamma)$. ##

Serial Number 2655
ASQC Code 800

TITLE: Reliability prediction--an engineering appraisal

AUTHOR: James T. Koppenhaver (Consultant in Reliability and Quality Assurance)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 147-152, 8 refs. (*see RATR 2646)

PURPOSE: To reflect on reliability activities.

ABSTRACT: This paper examines some of the history of reliability prediction and, in the context of the progress achieved over the past eight to nine years, finds it lacking in several important respects, e.g., accuracy as related to the requirements for it, and in precise basic failure rate data.

Major areas wherein effort should be initiated or greatly expanded to correct the existing situation include establishment of a standard "benchmark" for failure rate data, a new approach to prediction for mechanical items, evaluation of process variations, and application of quality data.

In view of the highly project-oriented thinking in military and aerospace activities today, reliability and quality organizations must assume an innovative role if progress is to be made.

REVIEW: About one third of the paper is history of the reliability effort and the rest is essay material about reliability. The signal-to-noise ratio seems rather low. There is a lack of clear-cut ideas, so that the impression is one of not quite knowing precisely what is good or bad and what should be done about it. The history is interesting and perhaps some will be able to filter out the essential points without too much trouble.

The author, in a private communication, has commented as follows: "In a field which has been noisy for many years, one should not be surprised to find the signal-to-noise ratio low. I regret (referring to the lack of clean-cut ideas etc.) that I could not offer a recipe to follow. I did offer a few ideas and suggestions whose long-term worth is indeed difficult to measure at the onset; I judged them to be worth-while points of departure." ##

Serial Number 2656
ASQC Codes 817;821;831

TITLE: Probabilities associated with launch-on-time, weather, and rendezvous for a space station system

AUTHORS: D. R. Jackson, A. H. Ramquist, and R. A. Holtz (Martin Co., Denver Div., Denver, Colo. 80201)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 166-178 (*see RATR 2646)

PURPOSE: To define the probability interrelationship of operational factors affecting the probability of rendezvous for a space station.

ABSTRACT: A space station must be periodically resupplied with spares and vital materials, both to keep the crew alive and to maintain the station in an operable status to fulfill its mission. Furthermore, it is contemplated that crews must be rotated at specified intervals for psycho-physiological reasons. Resupply and crew rotation missions must meet severe performance, logistics, and reliability constraints.

This paper concerns the probabilities associated with the many parameters that control successful rendezvous for space station logistic missions. These variables are: (1) launch-on-time (probability of completion of countdown at a precise time), (2) length of resupply interval, (3) synchronism (repetitive cycle) of station orbit, (4) launch stand turnaround time, (5) number of committed launch vehicles, (6) number of stands, (7) countdown and flight (through rendezvous) reliability, (8) length of "launch-window" time, and (9) acceptable launch weather probability during a specified time period. All these parameters are combined in a mathematical model that provides system operational design criteria. The model involves a unique application of binomial expansions relating number of vehicles, stand turnaround time, orbit synchronism, and weather probability. These expansions generate the probability of having acceptable weather on required number of launch days. This probability is then multiplied by the functional redundancy factor of the overall probability-to-rendezvous model. This factor relates number of vehicles committed to achieve the overall probability of rendezvous requirement. Parametric presentation of variable reliabilities dependent upon precise and "wide-window" launch times and orbit phasing time are discussed.

The system integration of these parameters and constraints by means of a straightforward and precise model demonstrates the criticality of variable weather and the need for a wider tolerance in acceptable launch-weather criteria. The technique is a means for providing probability tradeoffs for number of vehicles and launch stands in system operational cost effectiveness studies. (Authors)

REVIEW: This is a clear and concise description of a straightforward approach to a problem of relating system operational constraints to system design and effectiveness studies. The model proposed is really quite simple, but it should be adequate for the purposes of tradeoff studies and some mission simulation investigations. ##

Serial Number 2657
ASQC Codes 871;881

TITLE: Improved effectiveness through availability models

AUTHOR: G. C. Henry (General Dynamics/Fort Worth)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 198-206 (*see RATR 2646)

PURPOSE: To discuss the detailed structure of models developed to predict and measure aircraft availability.

ABSTRACT: General Dynamics has developed models to (1) measure quantitatively the contribution of reliability and maintainability to aircraft availability, (2) measure quantitatively the support assets to achieve the inherent availability of a fixed quantity of aircraft, (3) measure airborne effectiveness as a function of reliability, operational concept and mission requirements, (4) isolate major problem areas, and (5) predict the improvements in operational capability for corrective action decisions. Omitting the detailed structure of the models, this paper shows how the models are used with specific results that have been obtained, how they are related, and how they can be used at various stages in the life of a weapon system. The four models (used with an IBM 7090 computer) are as follows:

(1) Subsystem Maintenance Model--to measure the expected frequency and downtime required for maintenance.

(2) Network Analysis Model--to determine the distribution of total weapon system downtimes and to measure the contribution of each subsystem to the mean downtime.

(3) Base Maintenance and Operations Model--to measure the operational capability of a squadron or combat wing of aircraft in its operational environments. This model utilizes the outputs from the above models and combines them with flight schedules and other maintenance and operations policies to simulate activities of an aircraft base.

(4) Effectiveness Simulation Model--to measure the airborne effectiveness in terms of aircraft performance, operational concepts, reliability of the airframe, engines, and mission systems, and availability of the aircraft to fly (from other models); also accepts cost inputs for the computation of cost effectiveness.

The models were developed for the B-58 program in 1962 and are now being used effectively for the F-111.

REVIEW: A case report on effectiveness modeling for a large system is presented in this paper. Very little of a mathematical nature is given. Emphasis is on the approach and the results. Real-world experience is reflected throughout the discussion. Note that the work reported here is an actual application which predates the current efforts to formalize these concepts by the reliability discipline under the system-effectiveness label. The paper is well illustrated; no references are given. ##

Serial Number 2658
ASQC Code 836

TITLE: Design methods tools and documentation to assure reliability

AUTHOR: W. W. Reaser (Douglas Aircraft Co., Inc.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 212-218 (*see RATR 2646)

PURPOSE: To review tested design procedures.

ABSTRACT: There are three design periods: conceptual, preliminary, and final. Check lists and design reviews are valuable during each period. Preliminary designs and calculations should be kept for reference--they are especially helpful when something has gone wrong. Reliability engineers can assist the designer by providing data and analyses that he needs. Several check lists are given.

REVIEW: This is a rather general paper, but one that designers might wish to glance over for new ideas. The check lists can prove valuable--a designer should certainly have his own and compare them with others. Design reviews are important but their potential benefits can be lost if the company and the individuals involved do not give them their best. ##

Serial Number 2659
ASQC Codes 612;850

TITLE: A practical method of reliability demonstration

AUTHORS: E. D. Karmiol, W. T. Weir, and J. S. Youtcheff (Re-Entry Systems Dept., General Electric Co.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 219-225 (*see RATR 2646)

PURPOSE: To describe a practical reliability demonstration procedure.

ABSTRACT: Present government specifications, exhibits, and directives state that quantitative reliability requirements must be established in procurement specifications, work statements, and especially in incentive contracts. Without a practical means of demonstrating reliability in the developmental program, this requirement is of doubtful value.

Current ballistic missile contracts state definite reliability numbers that must be demonstrated by a specific calendar time usually associated with operational site activations. The General Electric Re-Entry Systems Department has developed a potent method for measuring and demonstrating equipment reliability using a proven analytical model. The analytical model provides the necessary means for simulating the entire operational and environmental profile. Detailed data from all levels of hardware test are fed into a computer through the mechanized data system. The output from the computer shows the probability of equipment survival under any desired combination of conditions. Equipment Reliability Status Reports generated in this manner have been used to successfully demonstrate contractual reliability numerical requirements on major Re-entry Vehicle Systems.

This paper describes the reliability demonstration plans and their successful implementation on typical re-entry vehicles for ballistic and space systems. (Authors)

REVIEW: A general discussion of a very real problem area, that of reliability demonstration, is presented in this paper. The method has been computerized for an IBM-7094. The effectiveness of such a procedure depends heavily on the quality of the data inputs. It would be of interest to know something concerning the availability of the computer program and the input data.

The mathematical details of the procedure are omitted in the paper. However, the second author in a private communication has suggested that NAVWEPS OD 29304, "Guide Manual for Reliability Measurement Program," prepared by GE-RSD under contract to the USN-SPO, be consulted for the details of the practical reliability demonstration procedure. Those persons interested in applying the techniques would necessarily have to consult the manual. The approach is a logical one subject to stated assumptions; the paper and the manual will be of interest and value to personnel interested in reliability demonstration techniques. ##

Serial Number 2660
ASQC Code 837

TITLE: An activation-energy index as a criterion for design excellence of a go, no-go system

AUTHOR: Dan Bloom (Missile & Space Systems Div., Douglas Aircraft Co., Inc.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 273-280, 286 (*see RATR 2646)

PURPOSE: To show how safety margins can be applied to a system characterized as good or bad.

ABSTRACT: When the results of a test are only success or failure, it is impossible to apply the theory of safety margins. It is also difficult to assess the impact of system changes. The way around this is to modify the system (for test purposes) so that some pertinent variables can be measured. These variables are then associated with success-failure of the system and the original difficulty has been overcome. If there are several modes of failure, the set of variables must be inclusive enough to account for all of them. An example is treated extensively.

REVIEW: The principle, which has been distilled from the paper and shown in the abstract above, is certainly very sound and deserves to be brought to the attention of engineers again (the principle certainly is not new). The detailed treatment in the example can give a misleading impression in spots of how experiments should be conducted. Further, the details are probably of interest only to someone on a very similar type of project. The choice of the term "activation energy" is poor since it has a previously-staked-out meaning in chemistry and physics. Two examples of poor advice are the following.

1. "Ideally, the optimum ... weight is that which makes the reliability with respect to either failure mode equal." This is false under the assumptions in the text of constant standard deviations, Normal distributions and failure occurring when a process becomes too high or too low. The ordinary methods of calculus readily yield the correct result which comes out in terms of the ordinate of a distribution, not its tail area.

2. "Furthermore, it should be clear that design changes have to be investigated one element at a time." That statement will give statisticians a fit; they have been impressing us with the benefits of statistical design (with consequent ability to detect interaction effects) for years. ##

Serial Number 2661
ASQC Codes 841;844

TITLE: SCORE: A versatile effectiveness tool

AUTHOR: John C. LaSharr (Denver Div., Martin Co.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 287-291 (*see RATR 2646)

PURPOSE: To discuss the development of a reliability evaluation technique which supports the functional analysis approach to system design.

ABSTRACT: SCORE is a data system developed by the Martin Company's Denver Division for the Ballistic System Division of the USAF. The data system is derived from the event-function structure of the Titan II weapon system. SCORE is an attribute data system, with the yes-no or go-no go data bits resulting after the event sequence has been defined and the various system tests have been observed for attempt and achievement of each required event-event sequence. Reliability and other parameters can be evaluated for any sequential operation.

The Titan II weapon system operational countdown was examined to derive a flow diagram which related subsystems and events. The flow diagram was converted into a matrix format which related the event-event sequence to the subsystems used to accomplish the event. Existing data forms were reviewed as possible sources of attribute data for each of the matrix intersections, but they were not adequate and a primary data system for SCORE was initiated. The SCORE system has proven to be an effective management tool for the Titan II weapon system, due to the simplicity of operation and versatility in retrieving results, e.g., by location, date, missile, or failure type. Other possible applications of SCORE include any creative process that is logically accomplished by some established set of rules.

REVIEW: Emphasis here is on the concept of an attribute measurement system and on the approach used to implement it for a particular weapon system. There is very little given on the statistical techniques which are used and if the few elementary equations shown are the extent of those used, then there is probably some room for more sophistication here. Some readers may find it difficult to "get the point" of this paper by trying to read more into it than it contains; conceptually this data system is simple, and undoubtedly this is one reason why it has proven effective.

RATR 1613 covers a paper with a similar title (SCORE: An effective reliability aid), but there is no relationship between the subjects of the two papers. ##

Serial Number 2662
ASQC Codes 773;775

TITLE: Nondestructive test equipment for predicting and preventing failure

AUTHOR: Paul Dick (General Electric Company, Spacecraft Dept., Valley Forge Space Technology Center, King of Prussia, Pa.)

SOURCE: Presented at the ASME Design Engineering Conference, New York, N. Y., 17-20 May 65, Paper 65-MD-26, 8p (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To describe some nondestructive in-process test equipments and systems used by spacecraft manufacturers to predict and prevent failure.

ABSTRACT: Nondestructive testing is an absolute must in the manufacture of missiles and space vehicles. (Failure analysis after a field failure is seldom possible and, in addition, the quantities produced are too small and too costly to test destructively.) The testing must also be "in-process" for high costs demand that a unit be proven "acceptable" in all prior operations before moving to the next manufacturing operation. The combination of nondestructive testing and in-process testing methods not only expedites manufacture, results in a quality part, but usually yields substantial savings for manufacturers. Nondestructive test equipments and systems described in this paper are as follows:

A low-voltage x-ray measurement system developed to determine the quality and performance of basic electronic parts and components before, during, and after tests simulating space environments;

Test equipment used to quickly and accurately measure the thickness of materials and coatings by use of eddy current instrumentation;

A flaw detection measurement system using the pulse-echo method of ultrasonics to scan and record the quality and uniformity of the complex honeycomb panels used in missiles and space vehicles; and

Ultrasonic inspection instruments using ultrasonic energy to evaluate the quality of the bonds used in metal-nonmetal type assemblies such as re-entry capsules and ballistic-missile nose cones.

REVIEW: This paper presents a good brief description of a number of nondestructive testing methods useful in the development and manufacture of spacecraft. As the author has pointed out, the importance of nondestructive testing techniques is increasing. It will be worthwhile for the designer to be aware of these techniques and their capabilities, and to use them to his greatest advantage. ##

Serial Number 2663
ASQC Codes 414;433;824

TITLE: Design, testing and estimation in complex experimentation
II. Reliability growth processes: estimation theory and decision-theoretic formulations

AUTHORS: Bernard Sherman and Mitchell O. Locks (Rocketdyne, a Division of North American Aviation, Inc., Canoga Park, Calif.)

SOURCE: ARL 65-116 Part II, prepared for Aerospace Research Laboratories, Office of Aerospace Research, USAF, W-P AFB, O., by Rocketdyne, a Division of North American Aviation, Inc., Canoga Park, Calif., under Contract No. AF 33(616)-7372, Jun 65, 66p (AD-618 516)

PURPOSE: To consider maximum likelihood and Bayesian approaches to the estimation of parameters in reliability growth models.

ABSTRACT: This report consists of two separate papers. The first, which deals with estimation in reliability growth models, was written by the first author. The second, by the second author, is concerned with decision theory studies.

Properties of maximum-likelihood estimators of parameters of reliability growth processes are investigated. It is shown that the maximum-likelihood estimator for a simple process involving a single failure mode is not consistent. For a modification of this process, a proof of consistency is sketched.

Decision-theoretic studies of reliability growth are considered and include investigations of the minimum-loss redesign policy, single-stage improvement models, and optimum effort for reliability growth. (Authors in part)

REVIEW: These papers are highly technical and require a fairly substantial background in statistics (especially Bayesian statistics) for their comprehension. The two extensive appendices on Bayesian analysis of reliability growth models are particularly interesting. Not all of the detailed mathematics of the report was checked. An earlier paper by the second author, in the nature of an interim report on the same problem, was covered by RATR 1125. ##

Serial Number 2664 -1
ASQC Codes 612;831

TITLE: Comparison and evaluation of three automated circuit analysis programs: PREDICT, NET-1 and CIRCUS

AUTHOR: R. H. Dickhaut (The Boeing Company, Aero-Space Div., Seattle, Wash.)

SOURCE: The Boeing Company, Aero-Space Div., Seattle, Wash., May 65, 12p (AD-623 963)

PURPOSE: To summarize the results of a study for comparing and evaluating existing automated circuit analysis programs.

ABSTRACT: This report summarizes the results of a study sponsored by the Air Force Weapons Laboratory to obtain an objective comparison and evaluation of the existing automated circuit analysis programs as of early 1965. The goal was to discover what significant differences existed in actual usage and what accuracies were obtainable with each program. As a result, improvements might be suggested that should be incorporated in the PREDICT program, which will be the ultimate program for use on Air Force problems.

The three digital computer programs are capable of analyzing any arbitrary circuit in the time domain, and are, therefore, of great assistance in the analysis of radiation effects on circuits. Special efforts have been made in the design of each of these programs to insure ease of use, and simplicity in the input required by the program. In brief, all that is required of the user of a given program is that he: (1) supply a topological description of the circuit, i.e., specify the kinds of circuit elements with their values, and the manner in which they are interconnected to form the circuit, and (2) supply parametric information on the active devices in the circuit. With this information specified to a program in an appropriate manner, it is capable of producing the dc steady-state conditions and the transient response of voltages and currents of interest in the circuit. The latter may be obtained in both printed and plotted forms.

The general features such as inputs, active device characterization, outputs and program solution are first compared. Each can treat circuits of similar complexity (minimum of 100 nodes and 300 branches) but each has certain advantages and disadvantages which are tabulated and discussed. Evaluation of the programs for comparative cost and accuracy is aided by computing the transient response of three moderately complex circuits to a radiation transient. PREDICT is the slowest of the three because of the greater number of derivative evaluations it is required to perform but is more impressive for its flexibility in handling arbitrary mathematical expressions. NET-1 is slower than CIRCUS but has the advantage of giving more information such as whether a part electrical rating has been exceeded and the effects of power-supply failure on devices. CIRCUS, the fastest, has capabilities uniquely fitted to production radiation effects work but the format arrangement for tabular data is awkward to set up and read off the input list.

REVIEW: Automated circuit analysis by computers has proved to be a definite asset for design. Several programs (more than these three, e.g., ECAP and SCAN) are being promoted, with each possessing distinct salient features. The major problem faced by a user is which program to select. The prime considerations from the user viewpoint are cost, ease of use, required data inputs, type of outputs, and accuracy of analysis; program selection involves comparison and tradeoff among these.

This report, even though brief, presents many pertinent and useful facts for comparison of the three programs and is very worthwhile reading for someone faced with the problem of selecting a circuit analysis program. It does not, however, cover all facets to be generally considered. For example, there is only slight reference to treating non-linear circuit elements other than transistors and dividers and the capabilities of investigating parameter variations is not fully explored. The examples are informative for comparing computing time but adequate information is not presented for comparing the convenience of using the program. More information would have been welcomed on how the radiation transient is introduced, which circuit parameters are affected, how they are changed, etc.

The accuracies, i.e., comparison of computed response to observed response of the actual circuits, was never discussed even though stated as a goal in the study. Accuracies depend on validity of input data and the program content (inherent models and computing schemes); the latter varies among different programs. The user is warned against relying on such programs without discretion, and considerable confidence and basis for judgment can result from knowing what the program does.

This report is a definite contribution to reliability literature; more reporting of user experience with circuit analysis programs is needed. ##

Serial Number 2665 - 1
ASQC Codes 612;831

TITLE: CODE-AN IBM-7094 program for writing circuit matrix equations

AUTHOR: (Prepared by Design Analysis Group, Test and Quality Assurance, North American Aviation, Inc., Space and Information Systems Div., Downey, Calif.)

SOURCE: Pub 543-J North American Aviation, Inc., Space and Information Systems Div., Aug 65, 100p

PURPOSE: To review the fundamental concepts of generating circuit matrix equations and to provide necessary background for engineering use of the CODE Matrix Generating program.

ABSTRACT: In the past few years, computer programs have been developed which perform analyses of electronic circuits to a degree far greater in scope and accuracy than heretofore had been practicable using manual methods. Common to all of these programs is the requirement that the analyst or programmer furnish the circuit matrix equations as part of the input data. In general, the engineer will draw the equivalent circuit, write the matrix equations, and present this information to the programmer. As the size of the matrix increases the time spent in developing, checking, and coding the matrix expressions increases rapidly. A definite need exists for a computer program which permits the computer to develop the circuit matrix equations. The CODE program, described in this report, has been developed to satisfy this need.

CODE, revised, is a computer program developed originally by the Autonetics Scientific Programming Unit for the IBM 7094. This program develops the node voltage admittance matrix outlined above. In addition, it can handle controlled current or voltage sources, and punch a set of matrix equation cards which are compatible with other analysis subroutines; the handling of controlled voltage and current sources enables the user to form an equivalent model for active elements. Finally, the new CODE deck is capable of generating AC- as well as DC-circuit matrices. (Author in part)

REVIEW: This report describes the CODE program well, but is intended primarily for those having direct user access to it. The analysis is discussed in enough detail to be of benefit to others preparing a similar program.

Most automated circuit analysis programs being widely promoted (e.g., NET-1, ECAP, and PREDICT) accept a topological circuit description and circuit parameter values, then provide, as printouts or plots, the computed response (either DC, AC steady-state, or transient) of the circuit. The CODE program differs in that it accepts only the topological description and provides an analytical model of the circuit in the form of circuit equations (in matrix format). The report states that the CODE output is compatible with other in-house routines for solving the equations. This approach seems less efficient than the other programs mentioned; however, possible advantages immediately recognized are (1) an interim analytical model that the designer can see, and (2) savings in computer compiling time during reruns of the identical circuit configurations.

Notable disadvantages are (1) inability to perform transient analysis and (2) required use of linear equivalent circuits for active circuit elements. The latter is not necessarily detrimental when precision requirements for analysis are not stringent and can even be an asset for certain design analyses where data are limited. CODE is probably only one of several capabilities in automated circuit analysis within this organization and could serve a very useful supplementary role in an overall design program.

For other papers on automated circuit analysis see RATR 1818, 2018, 2513, and 2664. ##

Serial Number 2666
ASQC Codes 830;844

TITLE: Failure-effect analysis

AUTHOR: John de S. Coutinho (Grumman Aircraft Engineering Corporation, Bethpage, Long Island, N. Y.)

SOURCE: Transactions of the New York Academy of Sciences, vol. 26, Mar 64, p. 564-584

PURPOSE: To explain the application of failure-effect analysis, a design control procedure.

ABSTRACT: Design plays a most critical role in the development of advanced aerospace systems. Designers have always been concerned with equipment reliability in a quantitative and intuitive sense and non-statistical methods such as failure-effect analysis represent an intensification and more systematic approach to what the designer has always been doing.

Properly applied, the failure-effect analysis can be a powerful design control technique for assuring reliable aerospace systems. Intimate cooperation between designer and reliability analyst is required. A reliability engineer prepares the failure-effect analysis and monitors the design development to insure compliance with the reliability requirements. The analysis is an independent critical review of the system, involving a systematic examination of all conceivable failures from a systems viewpoint and an evaluation of the effects of these failures on the mission capability. The details of failure effects analysis are given and are illustrated by some examples.

REVIEW: Failure effects analysis is a valuable part of the design of any system and is vital for good reliability; the author describes it well. The details may vary from one place to another, but the principles stay the same. The paper can be read and understood by the non-expert, but some knowledge of engineering is essential.
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Serial Number 2667
ASQC Codes 833;844

TITLE: National Association of Relay Manufacturers Relay Conference Papers, 1966

SOURCE: Proceedings of the Fourteenth Annual National Relay Conference cosponsored by Oklahoma State University and the National Association of Relay Manufacturers, 26-27 Apr 66 (Copies available from National Association of Relay Manufacturers, P. O. Box 7765, Phoenix, Ariz. 85011; price $5.00)

PURPOSE: To present an exchange of ideas and problems between users and manufacturers of relays.

ABSTRACT: Most of the papers are on design of relays and their parts. Two of them deal with life per se (Military Relay Reliability, Paper 3; Life Expectancy of a Form C Dry Reed Switch ..., Paper 7); and one with physics of failure (The Internal Atmosphere of Hermetically Sealed Components, Paper 22). The first lists and discusses some of the factors which affect the life of various relays. It suggests that relays can be very reliable when manufactured and used properly, but very unreliable otherwise. The second involves the design and construction of a reed relay and describes some of the experimental life-test plans; the program is not complete. The third reviews the contents actually found in back-filled hermetic relays; many had improper fill because they were not sealed prior to being disconnected from the fill gas.

REVIEW: This year the conference seems to be less concerned with life of relays, per se, than in years past. The applicable papers are satisfactory and should help to demonstrate that relays can be the optimum components in some situations. All the papers have an indirect bearing on reliability because they deal with the design, materials and construction of relays. ##

Serial Number 2668
ASQC Codes 813;844

TITLE: Modern reliability technology for electronic components

AUTHOR: George V. Browning (Autonetics, Research and Engineering Division, North American Aviation, Inc.)

SOURCE: Proceedings of the NSIA/AFSC Microelectronics Conference, Washington, D. C., 8-9 Dec 65, p. 83-93, 8 refs. (National Security Industrial Association, 1030 15th Street, N.W., Washington, D. C. 20005)

PURPOSE: To illustrate the applicability of the physics-of-failure concept as a means of achieving improved reliability of electronic components.

ABSTRACT: The application of a limited physics-of-failure approach can significantly improve the reliability of electronic parts. Some of the efforts on Minuteman II are an example of success under such a program. To be economically effective and timely, the analysis of failures and behaviors goes just far enough to learn what is wrong and how it might be fixed. There is neither time nor money to learn everything about the problem. Several examples on semiconductors are given.

REVIEW: This is an article with appeal to managers and those not directly involved in intensive physics-of-failure programs. The approach is tutorial and the paper is both readable and reasonable. At first, there are trite irrelevant statements about getting complete mathematical models of a device and then solving all the device's problems by solving the model; but later the practical approach mentioned in the abstract is emphasized. ##

Serial Number 2669
ASQC Code 825

TITLES: Reliability apportionment and optimization techniques
Mathematical optimization techniques for reliability and maintainability apportionments

AUTHORS: G. J. Mroz and E. A. Yerman; A. C. Shershin (Autonetics, A Division of North American Aviation, Inc. 3330 E. Anaheim Rd., Anaheim, Calif.)

SOURCE: TM-31-024-43-ORA-10, 29 Apr 63, 44p; TM-31-024-43-ORA-014, 4 Nov 63, 74p, 10 refs., Autonetics, A Division of North American Aviation, Inc., Quality, Reliability, and Standards Div., Reliability and Engineering Standards Dept., Reliability Analysis Group, Operations Research and Analysis Unit, 3330 E. Anaheim Rd., Anaheim, Calif.

PURPOSE: To summarize mathematical methods for reliability and maintainability apportionment.

ABSTRACT: The four most prominent mathematical techniques for optimizing the apportionment of reliability and maintainability are linear programming, dynamic programming, Lagrange multipliers, and the calculus of variations. The first three techniques are discussed, with emphasis on dynamic programming. The Lagrange method would seem to be the most desirable because it is analytical, but it tends to be impractical except in simple cases. Linear programming is limited to maximizing or minimizing a linear function, subject to a set of linear constraints. Dynamic programming is perhaps the method least limited by its mathematical formulation, but its application is restricted by the computational techniques available to the user.

In the second report two cost problems are considered. The first has as its aim the minimizing of cost while satisfying reliability and maintenance requirements under the assumption that an unlimited ceiling exists for the cost. The second problem concerns maximizing reliability and maintainability under a fixed budget.

The second report summarizes the first one, indicates a new approach to Lagrange multipliers, and applies the multiplier method to trade-off apportionment of availability parameters; it describes the reliability and maintainability apportionments, both separately and simultaneously, primarily using the method of dynamic programming. (Authors in part)

REVIEW: These summaries are good (not all the mathematics was checked, but it appears to be of high quality), but a knowledge of differential calculus and/or matrix notation is needed for understanding. The dynamic programming technique is carefully explained and illustrated with examples. References are cited for further reading. The reports do not deal at all with the formulation of equations for reliability/maintainability allocation--just their solution once they have been derived (thus the title of the first is a little misleading). ##

Serial Number 2670 -1
ASQC Codes 543;824;844

TITLE: A new reliability prediction technique

AUTHOR: Harold Balaban (ARINC Research Corp., 2551 Riva Rd., Annapolis, Md. 21401)

SOURCE: Presented to IEEE P. G. Reliability, Baltimore Chapter, 31 Mar 64, 15p (based on the reports cited below ([1], [2]), which were reviewed together with subject paper)

PURPOSE: To describe the approach used in developing a new reliability prediction technique and to present the prediction equations.

ABSTRACT: A technique for predicting reliability of ground electronic equipment and systems during the early design stage is based on knowledge of required system functions and associated general system design parameters. In addition to affording an early assessment of achievable reliability, the technique quantitatively indicates the reliability penalty associated with increased functional sophistication.

System failure data were obtained from 27 Air Force systems and 23 Navy shipboard systems; the data analysis that followed included MTBF estimates, comparisons of Army vs. Navy systems, and tests for exponentiality. Concurrently, research was performed on identifying and quantifying engineering or prediction characteristics. Preliminary studies were then made, correlating the engineering characteristics with the observed reliability characteristics. Finally, regression analysis yielded four prediction equations--each using a different set of prediction parameters and having different accuracy. The four equations predict both point estimates and confidence intervals. The procedure was verified and necessary refinements were made. For illustration, the procedure is applied to a small receiver. Application to equipment and systems dissimilar to those used in the study would lead to results of questionable value. The main value of the effort has been to demonstrate the applicability of regression analysis to the task of reliability prediction in terms of functional information. Although the equations are useful, of greater importance are the refinements that may be made in the future. The MTBF estimates are presumed to be accurate within a factor of two or three.

The results of the study described in this paper were presented in a two-volume report [1]. A set of revised equations for ground system reliability prediction were presented in a supplementary report [2].

REFERENCES: [1] System reliability prediction by function: Volume I--Development of prediction techniques, Volume II--Prediction procedure, RADC-TDR-63-300, Vol. I, 115p, Vol. II, 43p, Aug 63, prepared under Contract No. AF 30(602)-2838 by ARINC Research Corporation, Washington, D. C., for Applied Research Laboratory, Rome Air Development Center, Research and Technology Div., AFSC, Griffiss Air Force Base, N. Y.

[2] System reliability prediction by function, by Harold Balaban, Technical Report No. RADC-TDR-63-300, Supplement 1, Mar 65, 21p,

Serial Number 2670 -2
ASQC Codes 543;824;844

Reliability Branch, Rome Air Development Center, Research and Technology Div., AFSC, Griffiss Air Force Base, N. Y. (AD-614 227)

REVIEW: This appears to be a good piece of work. Many details are reflected upon and discussed in the reports. As in most engineering problems, decisions had to be made with inadequate information, but the results certainly are reasonable. Considerable effort was devoted to the problem of correlations between various pieces of information and these are of interest per se. There is also a caution that the resulting equations do not necessarily reflect engineering cause and effect--merely the observed correlations. Two highly correlated variables may have a common cause that is not very obvious, e.g., conscientious designers tended to do both things, poor designers tended to do neither.

The creation of "quick and dirty" estimating methods which are reasonably effective is most worthwhile. A lot of the time, engineers do not bother with any other kind of methods. Blind application, without good sense, of this or any other estimating procedure is likely to lead to a sad state of affairs. ##

Serial Number 2671
ASQC Codes 612;837;844

TITLE: A mathematical technique for automatic fault isolation in a complex system

AUTHORS: S. I. Finkel, R. N. Nilsen, and E. St Clair (Vitro Laboratories, West Orange, N. J.)

SOURCE: Technical Documentary Report No. ASD-TDR-63-409, prepared for Directorate of Aeromechanics, Aeronautical Systems Division, AFSC, Wright-Patterson AFB, O., under Contract No. AF33(657)-9184 by Vitro Laboratories, West Orange, N. J., May 63, 113p, 7 refs.

PURPOSE: To investigate and develop mathematical techniques for automatically isolating faults in complex equipment.

ABSTRACT: This report describes the theory and application of a mathematical technique for fault isolation which is applied through the use of a general-purpose digital computer. The theory develops the construction of a recognition matrix which, when premultiplied by a vector whose components are functions of selected test measurements, yields another vector whose components identify the system element which is out of tolerance. This fault isolation process is applicable to any equipment level. The technique has been applied successfully to fault isolation for a portion of the reference system--the Setchell-Carlson Model 159 television receiver--and this report presents the results. The necessary computer programs have been written in FORTRAN for an IBM 7090 computer and can be readily adapted for any general-purpose digital computer.

REVIEW: The mathematical aspects of the technique described in this report are quite elementary. Simply stated, we are given several parameters, each with given tolerances which describe boundaries for acceptable operation. Boundary values are also given which describe various failure regions. The problem is to decide in which region a given set of parameter values is contained. To apply this or any similar technique of automatic fault isolation to a given system or piece of equipment one must first set up these tolerance regions--this will probably be a very difficult job for complex systems. Much of this report is devoted to defining these regions for the reference system under study. It is not at all clear that the extension of the method can be accomplished by means of matrix theory or factor analysis as suggested by the authors. ##

Serial Number 2672
ASQC Codes 553;822

TITLE: Exponential reliability tables

AUTHORS: L. G. Dion, D. J. Gimpel, and J. W. Thomas (General Electric Co., Spacecraft Dept., Valley Forge, Pa.)

SOURCE: General Electric Technical Information Series, No. 63 SD 261, May 63, 58p

PURPOSE: To present a set of negative exponential tables for use in determining a confidence interval on reliability.

ABSTRACT: If times to failure have an exponential distribution, and a test to T_o hours (given) is run with r failures (random variable) it is possible to calculate the reliability for some mission time at a particular confidence level. Using T_o as a unit of time and r from 1 to 20, 21 and lower bound confidence levels of 50%, 70%, 80%, 90%, 95%, and 99%, the reliability has been calculated as a function of mission time from 0.01 to 20.

REVIEW: The theory section in this report is accurate. The tables can be a convenience for anyone who has continually to make these specific calculations. While a copy of this document is available through STAR, the numbers in it are quite illegible. ##

Serial Number 2673
ASQC Code 838

TITLE: Redundant equivalent linear passive networks and stability

AUTHOR: Bobby L. Buchanan (Air Force Cambridge Research Laboratories, Office of Aerospace Research, United States Air Force, L. G. Hanscom Field, Mass.)

SOURCE: Research Report AFCRL-63-140, Air Force Cambridge Research Laboratories, Office of Aerospace Research, USAF, L. G. Hanscom Field, Mass., May 63, 23p

PURPOSE: To introduce the concept of redundant equivalent network and to analyze a few special cases.

ABSTRACT: This theory is concerned only with linear passive two-terminal networks. A "redundant equivalent network" (REN) is made only from copies of the original network and has the same impedance as the original network. Some general properties are defined but the equations are virtually impossible to solve in general. Explicit solutions for two and three meshes are given, however. It is shown that if each unit varies randomly, the REN has a smaller variance than individual units. The probability of failure caused by opens and shorts can be made to approach zero by a sufficiently large number of meshes.

REVIEW: The paper appears to be a good treatment of the subject although not all the mathematics was checked. The theory is interesting in itself and the author makes a few suggestions concerning applications, but little if any specific reference to it has been made in the literature. The hammock network is a special case (two meshes) which of course has received considerable attention in its own right.

The author in a private communication has made the following comment. "One point which I perhaps did not make clear in the paper is that unlike the Moore Shannon 'Crummy Relay Theory' the REN theory provides a 'beginning' for considering redundant combinations which have probabilistically a continuum of possible states and unlike numerous 'Majority Logic Theories' the REN theory does not require a 'decision' element." ##

Serial Number 2674
ASQC Codes 711;712

TITLE: Fatigue behavior of materials under strain cycling in low and intermediate life range

AUTHORS: Robert W. Smith, Marvin H. Hirschberg, and S. S. Manson (Lewis Research Center, Cleveland, O.)

SOURCE: NASA Technical Note D-1574, National Aeronautics and Space Administration, Apr 63, 56p, 12 refs. (OTS: $1.50)

PURPOSE: To discuss the stress-strain vs. life relation during fatigue.

ABSTRACT: A series of constant strain range tests was made for a wide variety of materials producing fatigue lives varying from a few cycles to about one million cycles. The specimens were subjected to axial, compression-tension, low-frequency fatigue about a zero mean strain. Load range was measured periodically throughout each test, enabling an analysis of fatigue results in terms of elastic, plastic, and total strains. Materials tested were AISI 4130 (soft and hard), AISI 4340 (annealed and hard), AISI 52100, AISI 304 ELC (annealed and hard), AISI 310 (annealed), AM 350 (annealed and hard), Inconel X, titanium (6Al-4V), 2014-T6, 5456-H311, and 1100 aluminum, and beryllium.

During strain cycling, load range generally changes during the very early part of the test and then settles down to a fairly constant value for most of the fatigue life. Cyclic strain hardening or softening causes the observed load change and produces cyclic stress-strain relations that often differ substantially from the virgin tensile flow curve. These comparisons are made for each of the test materials.

Fatigue-life relations between elastic, plastic, and total strain components were established. For metallurgically stable materials, straight-line fits of the logarithmic elastic strain-life and plastic strain-life data produce a relation that agrees well with the total strain-life data. The strain-life data are also used to explain changes in susceptibility to stress concentrations over a large life span and to rate correctly the relative notch sensitivities of the four test materials that experienced non-test section failures in comparison with the other materials.

A fair correlation was obtained between the degree of cyclic strain hardening and softening and the ratio of ultimate strength over yield strength. Hardening always took place when this ratio exceeded 1.4, and the softening occurred when the ratio was less than 1.2. In general, the materials with the better total strain-absorbing capacity at low life (100 cycles or less) were among the poorest at high life (100,000 cycles or more). Titanium (6Al-4V), which had good performance throughout the entire life span, was an exception to this behavior. (Authors)

REVIEW: This is apparently a good piece of work and is well reported. The results are of more use to research engineers at present than to designers. This type of effort is most useful however in providing the basis for design information. ##

Serial Number 2675
ASQC Code 815

TITLE: Are your semiconductor reliability specs obsolete?

AUTHOR: --

SOURCE: Evaluation Engineering, vol. 5, Jan/Feb 66, p. 28-29

PURPOSE: To bring reliability engineers down to earth relative to semiconductor reliability specifications.

ABSTRACT: Inapplicability of existing reliability testing methods has led to expensive over-testing of semiconductors and "fudged" or "escalated" reliability specifications. A step toward improvement of this situation is found in in-house testing programs that perform a double duty by combining thorough testing and feedback information to the manufacturer for his own use in monitoring the manufacturing processes affecting reliability.

When drawing up reliability specifications, evaluation engineers should give careful consideration to "escalated" specifications, supplier's in-house programs, and requirements concerning the supplier's process. High-reliability semiconductors not meeting specific military specifications can be obtained if the customer's choice is based upon his own sampling and reliability testing.

REVIEW: There certainly are many good points in this article. Perhaps an implicit one is that if you need more reliability than offered here, do not trust the manufacturer--do the screening and testing yourself. Many reliability specifications need examination and revision; this paper can improve one's outlook on the situation tremendously.
##

Serial Number 2676
ASQC Codes 612;844

TITLE: Failure effect and failure mode analysis using a digital computer

AUTHOR: Harold V. McConnell (General Dynamics/Pomona Division)

SOURCE: Evaluation Engineering, vol. 5, Jan/Feb 66, p. 30, 31, 34, 36, 37

PURPOSE: To show how the IBM ECAP program can be used to determine some of the effects of component failures.

ABSTRACT: One popular approach to the use of a digital computer for failure effect and failure mode analysis is the IBM "Electronic Circuit Analysis Program" (ECAP) utilizing a network topology input to derive and solve circuit equations. The ECAP program provides a simple means of obtaining iterative network solutions for part value changes; thus general network solutions, drift effect, and catastrophic failure effect can be determined with only one treatment of the circuit. The inputs to the ECAP program consist of circuit configuration, in terms of branch and node descriptions, and part values. The pertinent outputs available from the program are: node voltages and element voltages, currents, and power dissipation. These outputs are obtained concurrently, and provide insight into secondary effects of failures by comparison of the outputs to rated stresses of the parts. The program has a DC, AC, and transient solution capability for circuits consisting of up to 50 nodes and 200 branches. The basic procedure for conducting a failure effect analysis with the ECAP program is outlined; for illustration, a video amplifier circuit is analyzed. Equivalent circuits for non-R-L-C elements must be provided by the user. (Author in part)

REVIEW: The computer program is a good one in that it performs easily calculations that ought to be done, but are undoubtedly often neglected. Care should be exercised to ensure that when "failed" parameters are inserted the non-linear elements still have the proper approximate equivalent circuit. For example, a shorted resistor may cut off a usually conducting transistor, but ECAP will not know it. Careful checking can show it up and appropriate revisions can then be made. The slight drawbacks should not deter anyone from using these tools when they are economically feasible. (No mention is made of costs.) Also note that equivalent circuits must be provided for many elements; this may be a disadvantage.
##

Serial Number 2677
ASQC Codes 813;844

TITLE: Gemini rendezvous radar--a closed loop reliability program

AUTHOR: R. E. Carder (Westinghouse Electric Corp., Aerospace Division)

SOURCE: Evaluation Engineering, vol. 5, Jan/Feb 66, p. 46, 48, 50

PURPOSE: To show that failure analysis is a vital part of a practical reliability program.

ABSTRACT: Five examples are given of parts which failed due to poor manufacturing practices: a resistor with loose end caps; an internal short from a part to its case; a motor commutator with epoxy spots on it; a broken cathode line (aluminum tube); and a transistor with an extra length of lead inside. By changes in production and inspection, all these troubles were cured. A sixth failure, breakdown of an RF high-power switch, required respecification. The original reliability efforts were not enough in this program; they had to be extended to all hardware phases.

REVIEW: All these failures were the shoddy slips, the horrible hardware, the foolish failures. No refinements of the state-of-the-art or fancy statistics were required to fix them. Any program which does not include provisions for shoring up fallible humans all along the line is doomed to failure. ##

Serial Number 2678
ASQC Codes 512;837

TITLE: Safety margin confidence limits--the non-central "t" distribution (reliability mathematics corner)

AUTHOR: John E. Lupo (Reliability Engineer, Martin Orlando)

SOURCE: Evaluation Engineering, vol. 5, Jan/Feb 66, p. 51, 52

PURPOSE: To give tables of confidence limits for safety margins.

ABSTRACT: When Lusser's safety margins are estimated from sample data instead of true population values, there is an uncertainty in the estimate. If the population is Normal the safety margin has a non-central t distribution. Equations are derived and tables presented for confidence limits.

REVIEW: The tables presented in this paper should be of benefit to those using safety margins in specifications. The derivations of the equations on which they are based, as presented in Appendix A, are straightforward (the subscript r is missing on S_{mr} in the last line). It should be emphasized that the method is valid only if the population is Normal (the author mentions this only in passing in the Appendix). It is not known how robust the method is with regard to non-Normality, but safety margins beyond three or four involve tail regions where the actual distribution is anyone's guess. ##

Serial Number 2679
ASQC Code 833

TITLE: Connectors--1966

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 5, Mar/Apr 66, p. 6-8, 12, 14, 16, 19-22

PURPOSE: To report on an Industry survey on electrical connectors.

ABSTRACT: This reference report gives details on the newest connectors, connector reliability information, plus 19 operating characteristics to use when specifying connectors. It is based upon a nationwide survey, personal interviews and detailed analysis of feedback from connector users. People problems--from design engineer to production-line-employee to maintenance personnel--and standardization continue as the biggest challenges to connector users and manufacturers. Mishandling (causing some 50% of connector failures), communications, plating, outdated literature, agreement on reliability measurements, and contamination are considered the major obstacles to connector reliability.

REVIEW: This article and discussion are pointed enough to make good reading; they contain more than the usual clichés about connector problems. Customers bear a lot of the burden for lack of standards and not having the increases in reliability that standardization can bring. The people problem vs. ruggedness is quite similar to the controversy about auto safety (drivers vs. car design). Both sides can quote scripture in defense of their positions but it does not help connector problems at all. If the attitude that BOTH are problems and need attention, rather than the "I'm not, you are" philosophy, could prevail, progress would result.

Specific connector configuration is an area out of which any sane reviewer will stay, of course, lest he be caught in the clash between the giants in the field. ##

Serial Number 2680
ASQC Code 871

TITLE: Are elapsed time indications worthwhile?

AUTHOR: R. L. Williams (Westinghouse Electric Corp., Baltimore, Md.)

SOURCE: Evaluation Engineering, vol. 5, Mar/Apr 66, p. 28, 29, 32, 33

PURPOSE: To give suggestions on the proper and profitable use of elapsed time meters.

ABSTRACT: It is wise, in all instances, to consider the nature of the equipment and the conditions under which it will be monitored and maintained before loading an equipment with time meters. First of all, there must be elements in the equipment that are known to have a wear-out or degradation with time or cycle characteristic, such as in a variable resistor or inductor, a motor or mechanical relay, an actuator or any item having a rotating or sliding action. Other items for consideration are electron tubes, when subject to cathode depletion within the normal service life of the equipment. Maintenance of semi-conductors and purely electrical or electronic equipment will not benefit by time measurement except perhaps for calibration purposes. Second, it must be known, or there must be a means of obtaining, the distribution of times to the end of useful life of the item of interest. If the time at which the failure rate curves sharply upward is known, preventive maintenance can be planned. Third, there must be a workable plan to monitor the indicators and take the required action at the proper times. Record keeping must be accurate and consistent--and the data readily available. Fourth, the indicator must represent the status of the element under wear or degradation; therefore, it is highly desirable that an indicator be an integral part of the assembly or major item it monitors. Available in both electromechanical and electrochemical types, elapsed time or event counters should be chosen on the basis of need for accuracy, resettability, weight, space, cost, environmental conditions, etc. Several pitfalls to avoid in meter choice are indicated.

REVIEW: This is a readable and realistic discussion of the uses and misuses of elapsed time indicators. It will be of value to those who have occasion to use these devices, or who are concerned with the design of equipment in which they must be included. ##

Serial Number 2681
ASQC Code 770

TITLE: Reliability techniques used in converting the Thor tactical system to an R & D space booster

AUTHORS: Erwin Mahr (TRW Systems) and Marvin A. Newby (Douglas Aircraft)

SOURCE: Evaluation Engineering, vol. 5, May/Jun 66, p. 14, 37, 38

PURPOSE: To show how a missile booster was modified for a different mission.

ABSTRACT: Some deactivated Thor missiles were converted to boosters for R & D space missions. The requirements for these boosters were more severe than for the Thor missile. Since time was short, analyses were made of each existing subsystem and the subsystem was assigned a criticality number. This number denoted the risk that would be assumed if the subsystem were used as is without acceptance testing to the new and more severe requirements. Only the higher risk items were tested, thus saving time and money. Many parts, such as fittings, that were familiar to ground crews were used to minimize human errors.

REVIEW: The article seems to put forth a good practical philosophy, although some of the details are not at all clear. In particular it is difficult to decipher from the paper exactly the nature of and reasoning behind the risk factors. Undoubtedly the authors can supply more detailed material to those who are interested. ##

Serial Number 2682
ASQC Codes 775;844

TITLE: Infrared detection reveals microcircuit metalization failure mechanisms

AUTHOR: William Berger (Philco Corp., Lansdale Div., Lansdale, Pa.)

SOURCE: Evaluation Engineering, vol. 5, May/Jun 66, p. 15, 16, 19 (based on a paper delivered by the author at the Spring Convention of the Society for Nondestructive Testing, 8-11 Mar 66)

PURPOSE: To describe problems that can arise with aluminum conductors in silicon integrated devices.

ABSTRACT: An appreciable percentage of reported microcircuit failures are attributed, either directly or indirectly, to phenomena related to the aluminum metalization between the individual microcircuit components and the bonds leading to the external terminals of the device. Failure modes observed on devices subjected to operating and storage stress included distortion or disappearance of metalization, formation of intermetallic compounds, and/or loss of adhesion between aluminum and SiO_2 surfaces. Because increased temperature accelerates the failure mode, and because the physical appearance of the metalization is changed, it was concluded that these failure mechanisms are chemical in nature. Certain areas of devices subject to power stress testing were more suspectible to failure than others; it is likely that these areas are regions of localized high operating temperature.

To determine if localized heating does occur in small areas, the Thermal Plotter which measures temperature by detecting the infrared radiation emitted from a given surface area is the type of instrument required, since any contacting method of temperature detection may seriously disturb thermal equilibrium. The spatial resolution of the Thermal Plotter can be varied and is dependent upon which interchangeable Cassegrainian lens system is used. The resolution is an important consideration where a hot spot on the narrow metalization of a microcircuit is concerned because the Thermal Plotter integrates and averages the radiation emitted from the area within the circle of resolution.

REVIEW: The discussion of problems in aluminum metalization is worthwhile though rather general. It is suitable for a wide class of readers who are not booked up on the subject. The use of infrared testing can be of great help in uncovering defects due to design and also in uncovering vagaries in the production processes. ##

Serial Number 2683
ASQC Codes 552;844

TITLE: Some reliability studies on silicon planar transistors

AUTHORS: F. F. Roberts, R. Sanvoisin and Patricia M. Morgan (Post Office Research Station, Brook Road, Dollis Hill, London, N.W. 2, England)

SOURCE: Reprinted from The Post Office Electrical Engineers' Journal, vol. 57, Jul 64, 8p

PURPOSE: To discuss failure modes in silicon planar transistors and the result of a gain-change test.

ABSTRACT: Submerged repeaters require very reliable transistors. In particular, very little gain degradation can be tolerated for 20-30 years. Catastrophic mechanical failures can be screened by centrifuging, mechanical shock and thermal cycling (fatigue). Accelerated tests were run on some silicon planar transistors. Both step-stress and constant temperature runs were made on small samples. The results were plotted and cross-plotted to give a curve for 1% failures on time vs. temperature coordinates. A 25-year life at 100°C (for 1% failure) was predicted.

REVIEW: In general the article is reasonable and treats the problem adequately, but not in depth. As with most graphical analyses there seems to be some hocus-pocus. For example, "... a linear relationship between log t and 1/T, and for this reason it is usual to assume a Normal distribution ... for log t and 1/T." Just what the linear relationship has to do with the Normal distribution is not clear. In estimating the parameters of the line, the low-percentile points are weighted less (no reason given). The reasoning may come out in the correlations between successive points; but one might wish, initially, to weight the low-percentile data points more heavily since the results are to be extrapolated in that direction. In one of the figures, the points are pretty crooked to come even close to Normality. In the step-stress method here, it is implicitly assumed that all stresses below the one at which failure occurred did negligible damage.

There is no absolutely-correct way of constructing tests and analyzing the results, because we do not know enough about nature. Decisions have to be based on not-unreasonable presumptions. It is important, though, to have as many of the assumptions as possible in explicit form. Implicit assumptions can cause no end of trouble. ##

Serial Number 2684
ASQC Codes 835;838

TITLE: Reliability of redundant integrated circuits in failure dependent application

AUTHOR: Philip Lawson (Advanced Associates, Richardson, Tex.)

SOURCE: Proceedings of the IEEE, vol. 53, p. 505, May 65 (correspondence)

PURPOSE: To point out the feasibility of using redundant integrated circuits in a failure dependent application.

ABSTRACT: To achieve the highest degree of reliability within the space-weight limitations of space vehicle work, it is advantageous to give consideration to providing redundancy at the component level rather in system design. This can be accomplished using the integrated circuits technique of duplicating circuit functions on the same silicon substrate. It is asserted that complexity has no effect on the reliability of the integrated circuit. For illustration, two gates diffused into one monolithic chip of silicon are to be redundant. It is assumed that upon failure of one of the gates there is a finite probability that the other gate will fail simultaneously because of a common cause. The reliability of the two redundant gates is $R_{system} = R_{gate} (1 + I - I R_{gate})$ where 1 - I is the conditional probability that there is a common cause for the failure. The result shows that it is feasible to improve the reliability of a system by designing in redundancy at the integrated circuits level. (Author in part)

REVIEW: This is an interesting calculation and is rather straightforward. When I = 0, 1 obviously we have the case of no real redundancy and ordinary redundancy, respectively; the author goes through some calculations to show it. The reference to Bayes' theorem is out of place, since Bayes' theorem is never used. Nor is the first concept about complexity used in the derivation. Mean time between failures is not usually a suitable figure-of-merit when redundancy is involved. The hazard function (conditional failure rate) is better. There are several misprints and the omission of Q_s in Eq 2 is rather disconcerting. ##

Serial Number 2685
ASQC Codes 821;831

TITLE: On a new calculation method for the overall system reliability

AUTHOR: Emilio Greco (Vitroselenia, Rome, Italy)

SOURCE: Proceedings of the IEEE, vol. 53, p. 1227, Sep 65 (correspondence)

PURPOSE: To present a method of finding all possible paths through a system.

ABSTRACT: In the case of complex systems, the difficulty of finding all possible paths may be overcome by relating the equipment network to a graph with oriented arcs whose vertices represent the signal output or input points. In this way, it is possible to find easily all the circuits and elementary paths by applying the rules pertaining to the graph theory.

In the most common case where all elementary paths between vertices x_i and x_j (where x_i is the signal input point into the network and x_j is the signal output point) are to be determined, the method may be simplified by using the graph connection matrix with the arc qualifiers in place of the matrix elements and assuming all the elements of the main diagonal equal to one. All possible elementary paths x_i and x_j will be found by developing the determinant associated with the matrix obtained from the connection matrix, in which the j th line and the i th column have been deleted. If the element failure events are statistically independent from each other, the method will be further simplified by substituting in the connection matrix the qualifier elements with the element nonfailure probability. In this case the result obtained from the determinant calculated for all pairs of vertices to be considered will make it possible to obtain directly the system reliability for the individual paths. Assuming these paths to be parallel, the overall system reliability will be easily calculated. An example of application is given. (Author in part)

REVIEW: This brief note serves in effect as an addition to the paper covered by RATR 2063. It presents a systematic method of finding all possible paths through the system. Thus it is addressed to one of the difficulties mentioned in connection with the original paper. However, as the author of that paper has pointed out in a comment published with the present note, a computer program has since been developed for solving this problem. ##

Serial Number 2686
ASQC Codes 715;782

TITLE: Combined environments versus consecutive exposures for insulation life studies

AUTHOR: F. J. Campbell (U. S. Naval Research Laboratory, Washington, D. C.)

SOURCE: IEEE Transactions on Nuclear Science, vol. NS-11, Nov 64, p. 123-129

PURPOSE: To describe an insulation life study.

ABSTRACT: The service life of an insulating material which will be used in a nuclear radiation environment cannot be predicted by the usual thermal-aging methods; neither can it be predicted from experiments in which thermal aging follows a pre-exposure to radiation at room temperature. To have any reliable significance, the experiment must be conducted in a combined environment of both thermal and nuclear radiation.

At the Naval Research Laboratory an apparatus has been designed and used to achieve this exposure condition. In this study, magnet wires insulated with various enamels and enamel-varnish combinations were selected to represent a variety of polymer classes. The insulation life of each was obtained using each of the following methods: (1) thermal aging of unirradiated specimens, (2) thermal aging following Gamma radiation, and (3) combined environment of Gamma radiation and heat. Comparison of the wire aging lives thus obtained shows that by combining radiation with heat the normal thermal life of several materials is increased by as much as 800 percent in some temperature/dose-rate combinations (polypyromellitimide @ 300°C/0.37 MR per hr., polyvinyl formal @ 160°C/0.4 MR per hr., and modified polyester-oil modified phenolic @ 200°C/0.2 MR per hr.). For one of these materials the increase was over 3500 percent in one combination of radiation and heat (polyvinyl formal @ 180° C/0.09 MR per hr.). This is probably due to a balancing of the chain-scission and cross-linking mechanisms which occur in polymer reactions. Increased life is not universal for all materials or for all exposure combinations of the above material, for in some of these experiments less than normal thermal life was observed. (Author in part)

REVIEW: The results presented in this paper will be of use to those concerned with the service life of insulation materials in thermal-radiation environments. The paper points up the need for testing in the combined environments of anticipated service in order to obtain realistic data. Also of interest is the attention given to the basic mechanisms responsible for the deviations from expected life. For other papers concerned with the life characteristics of insulated wires see RATR 1752 and 2065. ##

Serial Number 2687
ASQC Code 800

TITLE: Reliability Engineering--a sophisticated gamble with time

AUTHOR: Harold B. Olsen, Jr. (Editor, Oil Power)

SOURCE: Oil Power (publication of Mobil Oil Company, a division of Socony Mobil Oil Company, Inc., 150 East 42nd St., New York 17, N. Y.), vol. 64, no. 2, 25p

PURPOSE: To present the fundamental mechanics and some specific applications of Reliability Engineering.

ABSTRACT: Various facets of Reliability Engineering are examined under the following headings:

I. Probabilities: The Art of the Educated Guess--the mechanics of probability.

II. Success Through Failure--reliability measurement through the study of "failures" (Failure Rate, MTBF, Probability of Success, the bathtub curve).

III. Reliability: The Secret Ingredient--contributions to quality and economy during the entire life cycle of products ("Total Quality Control").

IV. Reliability: F.O.B. Detroit--"engineering-in" optimum reliability as standard equipment on new automobiles.

V. Reliability is no Luxury--the reliability program of the International Harvester Company.

VI. Maintenance: The Customer's Contribution to Reliability--MI/DAC, a maintenance system using data processing techniques.

Also included are short essays on: Redundancy; Quality Control vs. Reliability Engineering; To err is human (the reliability program of the Boeing Co.); and the Archives of Automotive Reliability (Mobil's automotive reliability data center).

REVIEW: This is a well-written expository article on reliability, which will be of most value to the newcomer to the field. It covers a wide spectrum of topics, ranging from elementary probability to the management of reliability. Consequently no topic is treated in depth. No references are cited, but quotes appearing throughout the paper indicate an awareness of the general reliability literature. ##

Serial Number 2688
ASQC Codes 838;873

TITLE: Unreliability reduction for a digital computer system using redundancy

AUTHORS: S. Claypoole and P. E. Watts (Sperry Gyroscope Company, Division of Sperry Rand Corporation, Great Neck, N. Y.)

SOURCE: Presented at the Systems Engineering Conference, Coliseum, New York City, 8-11 Jun 64, 14p

PURPOSE: To examine techniques utilized in unreliability reduction of a repairable redundant computer system.

ABSTRACT: Completely redundant computer systems that are repairable provide the potential for achieving high reliability but do not necessarily insure that it will be realized because of the ever-present probability that both computers will be down at the same time. Efforts made to minimize the down time or repairable time of a redundant computer system will, in turn, reduce the probability that both computers will be inoperative at the same time. In this report, computer subroutines and logic techniques are examined in an attempt to reduce "repair time"--consisting of the time to detect, the time to diagnose and the time to repair. Self-test, system test and memory tests were employed to achieve malfunction detection in different parts of the computer where different failure rates were anticipated and aided in diagnosis by indicating the probable area of failure. In addition, parity checks on all data and program words were conducted continuously. The malfunction was further isolated by returning to the test subroutines where the failure occurred and proceeding manually one step at a time until the malfunction was observed on the displays whose pattern of information then directed the operator to a small functional group of components. The time to repair the malfunction once it had been narrowed down depended upon the packaging and sparing philosophies employed. In this computer the components were packaged in functional clusters on printed circuit boards. Spares were maintained for each type of board so that if the malfunction was isolated to a particular board, it was replaced and the system retested to insure proper operation. A simple flow diagram of the self-test routine is included along with tables comparing the effectiveness of the three test routines with and without data handling requirements. (Authors in part)

REVIEW: This paper is based on a comparison of the reliability of a single computer with that of a redundant computer system and with that of a repairable redundant computer system. The equations on which the comparison is based are stated without proof, and no reference to a proof is provided. This lack will prove to be an inconvenience for the reader who wishes to follow the technical aspects closely. However, for those who are interested in a qualitative discussion of the techniques used to minimize down time, the paper is satisfactory, though brief. ##

Serial Number 2689
ASQC Codes 814;816;833

TITLE: Practical statistical techniques for gathering information on failure

AUTHOR: George H. Ebel (DuMont Laboratories Divisions of Fairchild Camera and Instrument Corporation, Clifton, N. J.)

SOURCE: Presented at the ASME Design Engineering Conference, New York, N. Y., 17-20 May 65, Paper 65-MD-1, 7p (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017)

PURPOSE: To present a systematic, statistical approach to improving reliability while reducing overall costs.

ABSTRACT: Generally failures occur when standard deviations become large and individual parts do not fit the general distribution. Making use of the fact that parts should come from a homogeneous population, an approach found effective in economical part selection requires the use of simple (nondestructive) tests to determine the distributions of various parameters. Distributions are then compared for continuity, dispersion, specification margins, etc., and part selection made on the basis of the smoothest and tightest distribution.

A successful method for determining where a given amount of effort will result in the greatest economic gain is to conduct thorough failure analyses on parts removed during manufacturing test. The large number of equipments tested and the relatively accurate failure information obtainable at this point allow meaningful application of statistical techniques. In addition, the early feed-back to designers at this stage minimizes continuous "in-plant" repairs and reduces warranty costs--costs which usually represent a major portion of the difference between a profitable operation and a losing effort. The step-by-step procedure for handling part removals is described with specific examples illustrating the determination of "top priority" items, vendor selection, parts removed that no longer pass incoming inspection and parts removed that still pass incoming inspection.

REVIEW: This paper is concerned with economical part selection, and, in spite of the title, does not treat statistical techniques in any depth. However, it contains some ideas which should be helpful to those involved in selecting components in such a way as to minimize manufacturing and warranty costs. ##

Serial Number 2690
ASQC Code 800

TITLE: Systems reliability and engineering statistical aspects

AUTHOR: G. J. Levenbach (Bell Telephone Laboratories)

SOURCE: American Scientist, vol. 53, Sep 65, p. 375-384, 7 refs.

PURPOSE: To convey some of the flavor of reliability engineering to the nonstatistician.

ABSTRACT: A brief look at some "reliability history" reveals that one of the basic causes of unreliability, the lack of high quality components, became readily apparent when a few simple statistical models applicable to electronic equipment were developed. However, it turned out that more than good components was involved, for even the best parts, when misapplied in circuits or subjected to unanticipated environmental conditions, will fail. In other words, there is more to reliability than putting numbers into a statistical model and writing numerical reliability requirements into a specification. Reliability is, as it always has been, an engineering function. Exemplifying active systems, the lighted news sign at Times Square, New York, and the transatlantic telephone cable illustrate systems reliability concepts such as constant failure rate, redundancy, availability, and a series chain of elements but also indicate years of engineering experience under all kinds of environmental and service conditions. Statistics has had a great impact on reliability and provides a powerful tool, but for a complex system it is unlikely that one can produce a single number adequately and completely describing the reliability of a system. The user is interested in a system that functions for a minimum total cost, including maintenance and operation, for the time period for which it was designed. A brief discussion of the general flow of events from inception to completion of a system as seen from the reliability viewpoint indicates the statistical aspects involved in each phase while showing that the important and difficult task in creating a reliable system is maintaining the systems outlook during the entire process. Otherwise, as experience has shown, the components might be fine, but the system will not work.

REVIEW: This paper is concerned with the impact of statistics on reliability. The point of view is expository rather than tutorial, and the presentation is that of a well-written, rather general review. It will consequently be of more interest to the general scientist than to the reliability engineer. It may be worth pointing out that many users of systems are interested in considerations other than low over-all cost. ##

Serial Number 2691
ASQC Codes 821;838

TITLE: Statistical independence in calculating the reliability of redundant systems

AUTHOR: Ralph A. Evans (Research Triangle Institute, Durham, N. C.)

SOURCE: Journal of the Electronics Division; American Society for Quality Control, vol. 4, Jan 66, p. 14-19

PURPOSE: To show that conditional independence does not necessarily imply independence.

ABSTRACT: In many reliability studies it is assumed that certain events are statistically independent. Unfortunately this assumption is too often implied rather than stated explicitly. However in some situations it is more reasonable to assume that the events are independent only conditionally on a given environment. That is suppose X, Y, E_i $(i = 1,\ldots,N)$ are events and the E_i (environments) are mutually exclusive and exhaustive. Then we may be able to reasonably assume that $P(XY|E_i) = P(X|E_i)\,P(Y|E_i)$ for each i. This we will call physical independence. The question is whether or not this implies that X and Y are statistically independent, i.e. $P(XY) = P(X)P(Y)$. It is shown in this paper that physical independence does not necessarily imply statistical independence and that under certain additional assumptions we have $P(XY) \geq P(X)P(Y)$.

REVIEW: It is well-known that conditional independence, $P(XY|E_i) = P(X|E_i)\,P(Y|E$ does not necessarily imply independence, $P(XY) = P(X)P(Y)$. This paper is an attempt to discuss the engineering implications of this fact. ##

Serial Number 2692
ASQC Code 830

TITLE: Safety and reliability through design

AUTHOR: Obed T. Wells (Cessna Aircraft Co.)

SOURCE: Presented at the National Aeronautic Meeting, Washington, D. C., 12-15 Apr 65, SAE paper 650228, 6p (*Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N. Y. 10017)

PURPOSE: To review some innovations and design concepts incorporated into aircraft in the interest of safety and design.

ABSTRACT: Statistics indicate that the safety record of general aviation is steadily improving. Innovations and design concepts incorporated into Cessna aircraft, such as improved landing gear, wider visibility, centerline thrust, and safer cabin interiors, are discussed.

Since the primary aim of aircraft manufacturers is the development of a safer, more economical aircraft, service and reliability are of prime importance. In order to maintain above average reliability, a strong service organization is employed to keep Cessna operators informed of corrective action required for their aircraft. A great number of design improvements are continuously under fatigue and service tests before being incorporated in prototype models where they will be given actual service experience.

Trends in general aviation indicate steps toward: (1) reduction in the number of parts in order to simplify an assembly and thereby increase reliability, (2) redesign of the cockpit and instruments in order to simplify flying, (3) recodification of the Civil Air Regulations into a more understandable and usable set of requirements. (Author in part)

REVIEW: The ideas on design for safety and reliability of general aviation aircraft which are presented in this paper should be of interest to manufacturers of this type of equipment. The presentation is brief, clear, and well illustrated. ##

Serial Number 2693
ASQC Code 800

TITLE: Safety and reliability in commercial transport aircraft

AUTHOR: W. J. Overend (Delta Air Lines, Inc.)

SOURCE: Presented at the National Aeronautic Meeting, Washington, D. C., 12-15 Apr 65, SAE paper 650229, 6p (*see RATR 2692)

PURPOSE: To point out the importance of communication and coordination between the manufacturer and the operator to achieve safety and reliability in the operation of commercial transport aircraft.

ABSTRACT: Without question, safety and reliability can be linked to the success and economic advancement of the airlines. Just as the question of a potentially safe operation affects the number of passengers willing to fly, so will the passengers be driven away if the operating schedules become unreliable. Therefore, in the coordination of people directly involved in airline operation and in all phases of design, development and production by the manufacturer, these factors must be maintained to the highest degree. This paper examines the past history, gives an assessment of present operation, and also a projection of future requirements for safety and reliability in commercial aircraft operation.

Graphs illustrate the increased safety in airline operation and also that the airlines on the whole are achieving a remarkable reliability in their mechanical operation. The economic value of the highly reliable operation of equipment is stressed. A future with a 100% mechanical reliability for airline aircraft is quite possible but the attainment of this maximum reliability is dependent upon the development of an adequate system of user-producer communication in all phases of operation. The existence of competition is also essential to this continued development.

REVIEW: This is a rather brief and general paper. However, it has a message which should be of interest to those concerned with the design and production of components and systems for commercial aircraft. ##

Serial Number 2694
ASQC Code 800

TITLE: Reliability: camp or reality?

AUTHOR: Frank H. Squires (4700 Crenshaw Blvd., Los Angeles, Calif. 90043)

SOURCE: Quality Assurance, vol. 5, Jan 66, p. 16, 45

PURPOSE: To express concern about very high MTBF requirements.

ABSTRACT: Very high MTBF's such as 100 years and more are not readily comprehended. It is also not terribly obvious to everyone that testing 100 components for one year is equivalent to testing ten components for ten years. Common sense tends to rebel at the astronomical requirements of reliability specialists. Does everyone else think it's just a big game? The lay people need to be instructed and persuaded that these numbers do make sense.

REVIEW: The point of the paper is not immediately obvious, even at the end. Certainly, in the first part it is possible to get the opposite of the point apparently intended by the author. It would have been better perhaps if he had shown that most of the problems are associated with the exponential distribution wherein the MTBF is a parameter which cannot stand much of a physical interpretation. The lay person tends to think of the life of a part as having a rather narrow dispersion and thus the idiosyncrasies of the exponential distribution (wherein over half the failures occur before 70% of the average life) are completely foreign to him. It may in fact be completely foreign to the way many parts behave.

In a private communication the author has indicated that he intended to provoke a dialogue between the reliability staff and management, where it is sorely needed, to assure that program support is based solidly on knowledge and conviction. ##

Serial Number 2695
ASQC Code 815

TITLE: Defogging reliability specs

AUTHOR: Lee G. Reynolds (Martin Co., Orlando, Fla.)

SOURCE: Quality Assurance, vol. 5, Jan 66, p. 33-36

PURPOSE: To point out some deficiencies hampering the profitable use of specifications from a reliability viewpoint.

ABSTRACT: Unclear and disorganized specifications may be the cause of a prime or subcontractor's failure to meet reliability needs. The guidelines for incorporating reliability and quality requirements into specifications are scattered, incomplete, and, to some extent, obsolete. The engineer who is assigned the task of writing specifications is scarcely aware of the partial guidelines that exist and hardly has time to collect them to filter out the applicable requirements hidden in the multitude of referenced specifications. Direction is particularly lacking in the quality/reliability interface, the safety margins concept, and success-failure-defect criteria.

Concerning "where to look," Defense Standardization Manual M200A provides valuable guidelines for locating reliability requirements in a specification and indicates a method of identifying reliability levels. In Military Specifications, paragraph 2 "Applicable Documents" lists the reliability and quality specifications which support the document. It is required that each of them also be mentioned under the "Requirement" portion of the specification (paragraph 3), together with the extent of their applicability. The "Requirements" section should contain explicit and complete requirements--but these are sometimes misleading. Selecting the right requirements by reference to these specifications can be a real timesaver, but should be done with caution. A stratified list of government documents establishing and supporting reliability requirements is included. (Author in part)

REVIEW: The specification problems which are identified in this paper seem to be perennial. The chart on reliability specifications and supporting documents which is presented is an updated version of the one which has appeared in several reliability publications. There is little here except the admonition to do better for someone experienced in government hardware contracting, but others can get a capsule view of reliability document identification and of perpetual specification problems. Apparently part of the problem is that specifications are too often prepared by inexperienced personnel.

Phrasing used in the left column on page 36 can easily be taken to yield an unreasonable meaning. For example: "Sometimes, for example, specifications indicate that an item in section 3 shall be designed to meet the qualification tests of section 4. This is poor practice." It is the intent of specifications that an item be designed to meet the qualification tests, and the customer who prepares specifications would indeed consider it poor practice for the item not to be so designed. Apparently the author has some thoughts here which are not clearly expressed. (RATR 2437 covers a related paper by the same author.) ##

Serial Number 2696
ASQC Code 864

TITLE: The application of reliability techniques to domestic appliances

AUTHOR: Robert A. Yereance (Battelle Memorial Institute)

SOURCE: Presented at the IEEE 16th Annual Appliance Technical Conference, Columbus, O., 18-20 May 65, 6p (Conference Paper 34CP-65-283)

PURPOSE: To discuss the application of reliability techniques to domestic appliances.

ABSTRACT: There are many reliability techniques which have been developed on military or government-financed contracts which could be applicable to the domestic appliance field. One of these, field failure reporting and analysis, is discussed in relation to domestic appliances, washing machines in particular.

According to a poll conducted by the author, a wide discrepancy exists between user reports based on actual application in the home and laboratory tests. It seems probable that few, if any, domestic appliance manufacturers have accurate information concerning the first failure of their product in the home. It is observed that, in general, (1) appliance manufacturers provide no means for the customer to convey his complaints or desires to the manufacturer; (2) manufacturers have no means of obtaining failure reports that can be sorted or categorized into first failures, expensive repairs, minor annoyance, etc.; (3) failure data from the customers does not reach the production department, or if it does, it does not result in action. Steps the manufacturer could take to improve communication with the consumer include the use of name plates which give the manufacturer's address, cards for reporting first failure, and a salesman approach to obtain data on machine performance and customer's desires. A system should then be established to categorize and analyze failure reports, with the output used to suggest areas where redesign or improvement is needed.

The information resulting from such a program might provide a beginning of a basis of correlation of laboratory test data and data under consumer-service conditions. A current trend toward replacement rather than repair of items indicates that improvement of product maintainability and customer-manufacturer communications is economically feasible.

REVIEW: It has often been pointed out that a fall-out of know-how from military reliability programs can be useful in the design and manufacture of commercial products, and also that a good reliability program does not cost--it pays. Both of these thoughts are worthy of attention by manufacturers of commercial products. This paper is concerned with the need for effective communication between customer and manufacturer in the collection of warranty data. The author presents his case well and makes some good suggestions. The implementation of these suggestions will involve some initial costs, but hopefully it should pay in the long run. ##

Serial Number 2697
ASQC Code 813

TITLE: Reliability facts and factors--features of successful system reliability programs

AUTHOR: Robert A. Yereance (Battelle Memorial Institute, Columbus, O.)

SOURCE: Systems Design, vol. 9, Aug 65, p. 3

PURPOSE: To point out the fundamental features of successful system reliability programs.

ABSTRACT: To achieve adequate system reliability at the lowest cost, its development must incorporate the following features.

1. Management understanding and support:
To be effective the reliability engineering group must analyze the data available and present an over-all picture, in gross terms, of the reliability situation and its effects in order to provide management with an understandable basis for decisions concerning reliability.

2. Use of every available tool:
Mathematical analysis, testing and other reliability techniques are tools that should be realistically considered and their potential evaluated, even in the development of the cheapest product.

3. Action based on feedback:
Flexibility is a major consideration in the use of feedback data. If information is available on which to base improvements, mechanisms must be provided to incorporate these into the product. A satisfactory balance must be achieved between complete redesign and maintenance of the status quo.

REVIEW: This paper will be worthwhile reading for those concerned with the setting up and managing of a reliability program. The author's points are made clearly and concisely, and are based on a breadth of experience with reliability programs. This is a subject on which much has been written but, regrettably, repetition of the essential points does seem to be necessary. ##

Serial Number 2698
ASQC Code 832

TITLE: Human factors and system effectiveness

AUTHOR: Harald R. Leuba (ARINC Research Corp.)

SOURCE: ARINC Research Newsletter, vol. 11, Dec 64, 4p, 8 refs.

PURPOSE: To discuss the contributions of human factors to system effectiveness.

ABSTRACT: Unlike other design disciplines, Human Factors has a reservoir of "sympathy" with respect to the nature of man as a system component. Thus, one of the most valuable services this discipline can perform is in the area of model building. If it could incorporate its understanding of the nature of man into the design of system concepts, system effectiveness goals would be more readily attained. This paper briefly highlights published work, emphasizing the contributions of human factors to reliability, operational readiness, maintainability and design adequacy, all important portions of system effectiveness.

In evaluating system effectiveness, there is an equal need to study equipment and human reliability. Within the past two or three years there have been several techniques developed for quantifying human reliability for specific types of tasks. The basis of these predictions is analogous to the basis of equipment reliability predictions: the part failure rate. In predicting human reliability, types of errors have been analyzed and classified and "failure rates" have been collected. The resulting "data store" is currently quite small and predictions based upon it are appropriately hazy. However, the data store can be enlarged by using manufacturing production data which could be of significant value. Human factors can contribute to the reliability of systems by (1) developing task descriptions which identify the areas of error likelihood, (2) developing training programs which emphasize techniques for avoiding errors, and (3) developing criteria for evaluating the potential for human error in system designs. (Author in part)

REVIEW: For those who are concerned with the effectiveness of man-machine systems and the contributions which human factors can make to it, this paper serves a useful purpose. In itself it is a concise and competent discussion, but, perhaps more importantly, it cites some eight references and places their contributions in focus. In addition, four items of "Related Reading" are briefly described. ##

Serial Number 2699
ASQC Codes 813;815

TITLE: A reliability assurance program provides failure rate sampling plans

AUTHOR: Don Kear (Defense Electronics Supply Center, Dayton, O.)

SOURCE: Electromechanical Design, vol. 9, Sep 65, p. 64-65

PURPOSE: To summarize the background and reasoning involved in the development of MIL-STD-790, a reliability assurance program operating in the electronic parts industry.

ABSTRACT: The need for improvement in the reliability of military electronic equipment led to an exhaustive study by DoD and to the development of MIL-STD-790 "Reliability Assurance Program for Electronic Parts Specifications." This article summarizes the background and essential elements of this reliability assurance program.

A preceding study yielded failure rate sampling plans which provided the basis for failure rate levels. This study indicated that testing at high levels of confidence was not always economically feasible. On these conclusions is based the underlying principle of MIL-STD-790 that maintenance of qualification at a low confidence level (10%) is justified if the production processes are controlled to such a degree that uniformity of production can be assured and if reliability testing is performed on each inspection lot. MIL-STD-790 provides the basis for assuring uniformity of production by establishing minimum requirements a manufacturer must meet in order to qualify to an established reliability specification. It requires the documentation of manufacturing operations, inspection procedures and materials control. When the manufacturer has documented the details of the operation, and provides assurance that the details are adhered to during all operations, the parts selected for qualification testing and for maintenance of qualification can be considered representative of the production line. Accordingly, the necessity for extensive failure rate testing is reduced. MIL-STD-790 establishes one level of management control which is applicable to all manufacturers regardless of size. The standard prescribes the elements that must be included in a reliability assurance program, and the manufacturer defines the degree of application of a particular element. (Author in part)

REVIEW: This is a very brief paper which presents the philosophy behind MIL-STD-790. As such, it will be of interest to those not familiar with this standard, but wishing to have a general acquaintance with its objectives and requirements. The low confidence levels are an example of the failure of conventional statistics to take into account prior knowledge. In this case, apparently they decided how much testing they could afford and/or thought necessary, decided what failure rate level applied to the product, and calculated the confidence level needed to make it come out right.

The author, in a private communication has commented as follows. "I suggest that it be made known that the title assigned by the magazine is in error. MIL-STD-790 does not provide failure rate sampling plans. The title should have been: A Reliability Assurance Program for Electronic Parts." ##

Serial Number 2700
ASQC Code 832

TITLE: Operability

AUTHOR: R. C. Winton (Mullard Ltd.)

SOURCE: Industrial Electronics, vol. 2, Jul 64, p. 323-325

PURPOSE: To discuss some of the ways in which apparatus can be improved to minimize the chance of the operator making a mistake.

ABSTRACT: "Operability," the characteristic which matches an equipment to its human operator, is assuming increasing importance in the design of equipment because, as equipment becomes more reliable, the proportion of errors due to the human operator is increasing. The human operator presents peculiar problems to the designer because almost all one can predict about him is that he will make a mistake sooner or later. This article discusses some of the ways in which apparatus can be made more operable, using facts from research in the field of ergonomics, the study of man in relation to work.

Illustrations show that good design and layout of control knobs and panels can greatly minimize the chance of the operator's making a mistake. For example, keeping a check on an equipment is simplified if every meter pointer lies in the same, rather than different, directions to indicate normal working. In a control layout, for instance, where the operation must always follow the same sequence, the controls and displays should be laid out in that order; otherwise the best grouping is according to function.

Good operability facilitates accuracy and speed in normal operation and is especially valuable in an emergency. Unfortunately, however well an equipment is suited to its human operator, he will sooner or later make a mistake. Operation by a cross-checking team is the only way in which the human error can be drastically reduced.

REVIEW: Human factors are something which a design engineer cannot ignore when the over-all reliability of equipment and operator is a prime objective. This paper provides a few simple examples of how the human operator can be considered when designing equipment. The idea of using a cross-checking team instead of a single operator is particularly worthy of note where the situation demands it. However, the ingenuity of the designer in visualizing ways in which errors can be made, and then designing around them, is an indispensable asset. ##

Serial Number 2701
ASQC Code 871

TITLE: New trends in air transport maintenance

AUTHOR: J. W. Stillwell (Douglas Aircraft Co., Inc., Aircraft Div.)

SOURCE: Presented at the National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., 5-9 Oct 64, SAE paper 922D, 4p, summarized in SAE Journal, vol. 73, Aug 65, p. 84-85 (*see RATR 2692)

PURPOSE: To describe the present trends in air transport maintenance.

ABSTRACT: New trends in aircraft maintenance that are expected to result in improved safety and reliability at reduced cost indicate:

1. Reduced reliance on scheduled component overhaul as a "preventive" maintenance technique.

2. Increased emphasis on system and subsystem integrity and decreased preoccupation with the condition of individual components.

3. Increased awareness on the part of aircraft manufacturers that maintainability must be designed into their products and that self-test and self-check features are desirable in most functional systems.

These evolving trends indicate an increasing awareness that the detective and corrective functions are fundamental to safety. They also indicate the possibility that the detective process more readily lends itself to time limits and controls than the preventive process. The corrective process, which is probably the most vital to jet transport safety, has been and will continue to be an inherently unscheduled function.

REVIEW: This paper presents some ideas on maintenance strategy for jet transport aircraft. The author advocates a Test and Repair as Necessary (TARAN) philosophy, instead of the more conventional scheduled overhaul maintenance technique. The implementation of this philosophy will have implications of importance to designers. See also RATR 2702. ##

Serial Number 2702
ASQC Code 871

TITLE: Are scheduled component overhauls necessary?

AUTHORS: P. A. Hussey and S. G. Thomas (United Air Lines, Inc., San Francisco International Airport, San Francisco 28, Calif.)

SOURCE: Presented at the National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., 5-9 Oct 64, SAE paper 922C, 7p, 7 refs.; summarized in SAE Journal, Apr 65, p. 54-58 (*see RATR 2692)

PURPOSE: To advocate the adoption of new approaches to aircraft component maintenance.

ABSTRACT: United Air Lines studies show that, rather than improving reliability, rigid adherence to the policy of setting arbitrary component TBO's (Times Between Overhaul) usually will: (1) increase exposure to infant mortality, (2) not prevent a complex or dynamic unit from failing at a low TSO (Time Since Overhaul), (3) inhibit or even prevent units with the capability of achieving high TBO's from realizing their full potential, and (4) impede exploration of high total time reliability characteristics of component parts.

As steps toward a more rational and economical component maintenance program, four special programs are currently exploring the age versus reliability characteristics of certain complex or dynamic components. These programs cover: (1) accessories (Component Reliability Program)--repair, rather than overhaul, of six accessories with stable failure rates; (2) electronics (Reliability Controlled Overhaul)--permits five units lacking the wear-out characteristic to operate on jet airplanes until failure; (3) hydraulics (Test and Replace as Necessary--the TARAN program)--measures the installed units' predisposition toward failure; and (4) air conditioning (Component Reliability Engineering Evaluation Program--the CREEP program)--stresses functional tests and panel reviews of each sampled component.

Fixed limits on overhaul times should be gradually abandoned in favor of realistic functional tests on the airplane as criteria for removal data and overhaul. Implementation of the TARAN maintenance concept on a new airplane type would help realize the potential inherent in most airplane components and would prove that scheduled component overhauls are hardly ever justified.

REVIEW: This is a good concise paper which makes a strong case against the conventional aircraft maintenance policy of scheduled component overhauls. However, as the authors have said, the policy cannot be abandoned without replacing it with a more worthy method--breaks with "tradition" are never easy. This is particularly true when so many human lives are at stake. Evidence such as that presented in this paper will help to promote the establishment of more effective maintenance programs. See also RATR 2701. ##

Serial Number 2703
ASQC Code 841

TITLE: Improving reliability through performance recording

AUTHORS: B. M. Meador and J. F. Nemecek (Trans World Airlines, Inc.)

SOURCE: Presented at the National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., 5-9 Oct 64, SAE paper 922B, 4p (*see RATR 2692)

PURPOSE: To describe an aircraft performance recording system and evaluation program.

ABSTRACT: Attempting to achieve greater aircraft reliability, Trans World Airlines has adopted an airborne multi-parameter recording system to record in-flight responses of the various airborne systems. Data are obtained by airborne sensors detecting and measuring changes in electrical, structure, mechanical, and engine parameters; the various signals are translated into digital or analog form, then multiplexed and recorded on magnetic tape for subsequent reproduction on the ground. They are then analyzed to determine equipment and aircraft performance. Data can be used for trouble detection, trouble diagnosis, and/or "long range analysis" of performance trends to predict when performance will deteriorate below accepted limits. Application of performance recording to a maintenance problem concerning the fire warning system and a water injection valve problem resulted in fairly clear assessments of the malfunctions and their nature. While such systems add to the ever-increasing complexity of the aircraft and its systems, the end use of recreated data appears to offer sufficient increase in the state-of-the-art of aircraft maintenance to more than offset the increase in complexity. Further program refinements may come through the addition of a small airborne computer.

REVIEW: This paper is concerned with a method of data-collection which enables more penetrating reliability analyses than would be possible otherwise. The key consideration prior to its implementation is whether the results are worth the additional cost--measured in terms of dollars, added weight, increased complexity, etc. In some cases this consideration will be difficult to evaluate. The examples cited illustrate the potential of this tool for the improvement of aircraft reliability.

The author in a private communication has indicated that the system described is being implemented on one fleet of jet aircraft in 1966.
##

Serial Number 2704
ASQC Codes 612;844

TITLE: Pinpointing system malfunctions

AUTHORS: H. Pallulat and R. F. Klawa (General Dynamics/Astronautics)

SOURCE: Presented at the National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., 5-9 Oct 64, SAE paper 914C, 5p (*see RATR 2692)

PURPOSE: To describe FASTI, a methodology for rapidly pinpointing system malfunctions.

ABSTRACT: The FASTI technique (Fast Access to System Technical Information) is a computer-oriented analytical methodology. As a tool for rapid malfunction isolation it consists of three major processes: (1) structuring a model of the system under consideration, (2) simulating operation of the system with and without inserted component malfunctions, and (3) documenting the resultant computer analyzed output.

A system, to the FASTI technique, may be comprised of hardware components, tasks, events, or any combination of man-machine activities wherein the logical relationships can be defined and are governed by time parameters. Modeling is accomplished by preparing, for each component, a Boolean logic equation which defines the relationships and interdependencies of the component to all others in a given network. Timing parameters are the time increments during which a component physically activates or deactivates.

Simulation is accomplished by the Discrete Network Simulator, a uniquely constructed, universal type, computer program. From the logic and timing equations, it produces the chronological sequence of component action and the activity state of each action, i.e., on-off, etc. Malfunctions are introduced into system operation by changing the component's normal state or by changing the time parameters attributed to its activity periods. The computer will print out the subsequent system activity. It can also compare this activity with normal system activity and print, in sequence, only those components whose state changed. In addition, the print-out can be limited to indicators whose state changed, yielding a distinct indicator pattern for a specific malfunction.

Each indicator pattern and its cause is appropriately documented to the requirements of the system involved. The data are cross-referenced by a numerical index to the system indicators and stored in any suitable device which permits an operator immediate access at point of use. The philosophy and concept of the FASTI technique is vital where trouble-shooting is critical with respect to time, possible mission failure, or imminent danger. It can also be used in solving design problems, testing design changes, developing and checking out system test programs, monitoring, evaluating and re-establishing complex programs and schedules.

REVIEW: This paper describes an important concept, the implementation of which could be extremely valuable. However, the paper is very brief, and presents only the underlying philosophy of the process, rather than details on its application. No references are cited. ##

Serial Number 2705
ASQC Codes 817;831;844

TITLE: Reliability analysis of life-support systems

AUTHORS: R. A. Bambenek and T. R. Charanian (General American Transportation Corporation, MRD Div.)

SOURCE: Presented at the National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., 5-9 Oct 64, SAE paper 912G, 6p (*see RATR 2692)

PURPOSE: To describe a procedure for determining the effective weight penalty for equally reliable life-support systems so that more meaningful comparisons may be made.

ABSTRACT: To eliminate unfair bias, weight penalty trade-off studies to determine the most effective life-support systems for manned spacecraft should compare systems having the same inherent reliability. In the following reliability analysis, operational reliability data was not available for any of these systems; therefore it was necessary to utilize estimated or generic data to synthesize systems of equal inherent reliability and determine the true weight penalties for each type of system. Generic failure rate data may be in error by one order of magnitude, but the method allows reasonably accurate comparisons.

Schematic flow diagrams, design calculations and a failure-mode-and-effect analysis are steps performed before the failure rate is estimated for each component and part. After calculating the reliability of each component, the system reliability is obtained. Since spare parts increase both reliability and system weight, the process of adding spares to the weakest components is repeated and the spare part weight estimated each time until a relationship between system weight and reliability is established. The analysis is concluded by comparing weight-reliability curves for each system and selecting the optimum system on the basis of minimum weight necessary to achieve a required reliability. To illustrate the significance of the procedure, three types of CO_2 removal systems are analyzed and compared.

REVIEW: This is a good case-history type of paper. The analysis is described in reasonable detail, and actual data are given. The paper serves in part as a good brief example of a failure-mode-and-effects analysis. While the specific reference is to life support equipment, the principles are clearly applicable to a wider class of systems. ##

Serial Number 2706
ASQC Codes 814;815;871

TITLE: The project definition phase and maintainability

AUTHOR: Robert J. Massey (Department of the Navy)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 296-301, 312, 8 refs. (*see RATR 2646)

PURPOSE: To review the current project definition phase (PDP) doctrine of the government with attention to reliability and maintainability.

ABSTRACT: PDP is a formal step preceding full-scale development during which preliminary engineering, contract and management planning are accomplished in an environment that encourages realism and objectivity. It is a funded effort by two or more contractors. PDP was devised in an attempt to deal with the underlying causes of the massive cost overruns and schedule slippages. In PDP analysis trade-offs between cost, time and all elements of performance--specifically including maintainability and reliability--are to be made. The resulting elements are to be expressed quantitatively in a firm-fixed-price or incentive contract. However, the techniques and management tools required to implement this policy are not, at this time, developed to the level required to support this policy. We will not only develop the capabilities to match our aspirations in the fields of maintainability and reliability, but will also see a spectacular improvement in the "systems effectiveness" of overall government military capability acquisition machinery. Government policy calls for maximum exploitation of the "profit swing" permitted under the Armed Services Procurement Regulation. In the meantime, Contractor Performance Evaluation is helping fill the gap. This program provides a long-term incentive to contractors by creating a government "memory" of their performance. A contractor who optimizes profit under one contract by ignoring one or more of the government's stated objectives may find that his action has adversely affected his selection for future contracts. The wise anticipate the future and prepare for it. The government will soon be able to determine what it wants, define what it wants, and be a knowledgeable customer in getting it. (Author in part)

REVIEW: Although this paper does not dwell much on reliability and maintainability, it says what those in the field have long been awaiting. That is that the policy of the government is to determine the level of support of efforts for reliability and maintainability on a cost-effective basis. Of course other government spokesmen in addition to the author have also recently said this, and hopefully this is a sign of forthcoming widespread application of this policy by the many government agencies. This paper also indicates how incentive contracting and a contractor's performance record are related to the implementation of the cost-effectiveness approaches. ##

Serial Number 2707
ASQC Codes 872;875

I. TITLE: Total system verification and demonstration of maintainability

AUTHORS: H. L. Dimmig (Air Force Systems Command, U. S. Air Force) and Waino Suojanen (University of Miami)

II. TITLE: Maintainability measurement and prediction

AUTHORS: L. R. Anderson and H. G. Maddera (Denver Div., Martin Co.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 308-312; 313-317, 359 (*see RATR 2646)

PURPOSE: To describe advancements in maintainability measurement and prediction; to examine means of demonstrating total system maintainability

ABSTRACT: I. Characteristics and criteria which are important in the determination and verification of total system maintainability are identified. Three methods which may be utilized to measure them are: (1) actual use, (2) a specially conducted test, (3) a computer simulation. The optimum solution for verification and demonstration of total system maintainability is an aggressive special test program. This function is an integral part of the basic system testing program and must be conducted by well-qualified maintenance and engineering personnel.

II. The RADC maintainability prediction technique which was developed by RCA involves the use of an analytical model relating numerically scored qualitative characteristics to system maintenance downtime. The BUSHIPS technique which was developed by Federal Electric Corporation involves the use of a matrix of standard times to accomplish hardware maintenance at specific functional levels. A research program was accomplished by Martin Company to adapt, enlarge, and verify these techniques for use on aerospace ground and airborne electronic and mechanical systems. A data collection program was initiated to gather data on the Titan II system. The RADC technique was selected as the main pattern because it is applicable in the conceptual stage during which alternate designs and maintenance concepts are being established. The RADC technique was verified as applicable to the Titan II where its scope was enlarged to cover IGBM electrical and mechanical equipment.

REVIEW: I. The actual list of maintainability characteristics to be considered and the criteria to evaluate them would serve as a useful check-off list for those concerned with maintainability demonstration. Otherwise the paper dwells at a general level and, aggravated by a mythical example, contains little that is of interest.

II. The techniques available for the prediction of maintainability indices are broadened by this study which brings in a cross section of missile electrical and mechanical equipment. Those concerned with maintainability analysis will profit from reading this paper, but they will also need to obtain the referenced report in order to see the details fully. ##

Serial Number 2708
ASQC Codes 612;863;881

TITLE: The support-availability multi-system operations model

AUTHOR: T. C. Smith (The RAND Corporation)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 334-339 (*see RATR 2646)

PURPOSE: To describe a large-scale computer simulation which takes into account complex interrelations among operations events and logistics support requirements triggered by the reliability and maintainability characteristics of weapon systems.

ABSTRACT: The Support-Availability Multi-System Operations Model (SAMSOM) is a Monte Carlo simulation model programmed for the IBM 7090/94 computer. It is a third-generation version of models begun during the early 1950's. Model inputs include system and subsystem reliability and maintainability parameters and desired quantities of support resources (people, parts, equipment, and facilities). Activated by flying schedules, sortie requirements, alert commitments, and operations policies, it simulates weapon system operations and logistics support requirements at one or more bases. It also provides outputs reflecting the capability of an aircraft organization to maintain selected readiness and alert postures and generate sorties to support interdiction, air-defense, close-support, or other operations requirements. Time is the common denominator of the simulator and thus becomes the prime measure used to evaluate costs and effectiveness. Dollar-costs are not included in the model, but where time (weapon time, man-hours, equipment life, weapon status, and time-related events) may be readily translated into costs per hour or other unit of effectiveness, they may be computed for cost-effectiveness analyses. Simulation tools such as SAMSOM can fill an essential role in quantifying costs, gains, and degradations in a systematic analysis of a weapon system's capabilities. (Author in part)

REVIEW: The system effectiveness model which is described in this paper is an extremely flexible version of the type of model currently used by most systems-oriented activities. The paper is readable and serves to: (1) give those not already familiar with such models an introduction to them, and (2) identify the flexible features which can be incorporated. No mathematical developments are presented; the description is all verbal. ##

Serial Number 2709
ASQC Code 871

TITLE: Control for maintainability in aerospace fluid power systems

AUTHOR: A. B. Billet (Vickers, Inc., Aerospace Div.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 340-349 (*see RATR 2646)

PURPOSE: To show that maintenance expense can be reduced by good engineering.

ABSTRACT: The cost to DoD and industry for maintenance is very high. By reviewing the design at many stages and from the points of view of all departments in the plant, the need for maintenance and repair can be reduced and the ease of making a repair can be improved. Both of these techniques are illustrated by an example of a main system hydraulic pump. Time between overhauls has been improved from 1200 hours in 1958 to over 5000 hours in some cases. TWA has installed an inflight recording system which monitors and records 40 parameters on each of the four engines. Field reporting of failures is important and continuing attention needs to be devoted to efficient design of reporting forms and how to get them used properly.

REVIEW: Most of the explicit examples in this paper are concerned with reducing the need for a maintenance action rather than with making such maintenance easier to perform. The emphasis on reviews during design is very good. They cover all phases of the product from purchasing parts and materials through manufacturing. An interesting point the author chooses to emphasize is that better performance does not necessarily mean more complexity, at least from the user's viewpoint; modern packaging methods can often be used to simplify and improve a product. Nondestructive testing and inflight recording of results is becoming more widely recognized for the valuable tool it is. Even post-flight tests such as spectrographic analysis of engine oil can be used to monitor behavior. Again, most of these techniques have little effect on maintainability, the title of the paper, but they do of course drastically improve reliability and availability. ##

Serial Number 2710
ASQC Code 873

I. TITLE: Maintainability control in design

AUTHOR: Thomas R. Griffith (United Aircraft Corp., Sikorsky Aircraft Div.)

II. TITLE: Engine maintainability by design

AUTHORS: Donald B. Clark and Michael Davis* (Wright Aeronautical Div., Curtiss-Wright Corp. *now with Aerospace Systems Div., General Precision, Inc.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 350-351, 352-359 (*see RATR 2646)

PURPOSE: To show how new disciplines have been applied to design for maintainability.

ABSTRACT: I. Maintainability control in design can be achieved by means of a formal procedure which utilizes all relevant talents available within a corporation. The procedure must have management support and proper funding. Effective maintenance engineering analysis is a primary element in maintainability control. The plan for use and the plan to maintain are key factors for consideration as is the maintenance capability of the customer. Examples of effective results are used to demonstrate maintainability control in action. (Author)

II. A procedure is outlined by which an engine can be designed and developed to meet specific objectives for service life and maintainability. While the specific system illustrated is the engine for the Supersonic Transport, the method is applicable to any engine development where maintainability is a significant factor. Topics covered include design objective, overall program, apportionment of reliability goals, apportionment of failure rates, design for reliability, design reviews, development reviews, cyclic endurance test, and reliability demonstration. (Authors in part)

REVIEW: The first of these papers is a very brief qualitative discussion, concerned mainly with the support which the design engineer must have if maintainability control in design is to be achieved. As such it will be only indirectly helpful to the designer, through indicating some things to expect or for which to watch out.

The second paper is essentially a case history on design for maintainability of a particular aircraft engine. As the authors have indicated, the method can be applied to other engine development programs. It is possible, too, that the principles, suitably modified, can be applied to the development of other types of equipment in which maintainability is a significant factor. For example, the authors refer to the use of high-speed computers to study design alternates before freezing the design. ##

Serial Number 2711
ASQC Codes 815;832

I. TITLE: Safety engineering for piloted aircraft

AUTHOR: William F. Funk (General Dynamics/Fort Worth)

II. TITLE: Engineering safety into missile-space systems

AUTHOR: Rex B. Gordon (Rocketdyne, Div. of North American Aviation, Inc.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 370-379, 386, 6 refs., p. 380-386, 11 refs. (*see RATR 2646)

PURPOSE: To describe the concepts and accomplishments of safety engineering and human-error prevention in the man-machine-environment complex.

ABSTRACT: I. Safety engineering is a management tool for the prevention of aircraft accidents and is based upon the need to conserve life, material, and financial resources. Established safety design requirements, including consideration of the man-machine relationship and the true operational environment, must be followed from concept to obsolescence. Flying can be made safer and military success more likely through better safety education, thorough design analysis for hazard elimination, realistic environmental testing, and management's accepting responsibility for safe design. (Author in part)

II. A new methodology, applied to complex missile and space systems, is "System Safety Engineering." A comprehensive approach to safety is included as a contractually covered adjunct to the design, development and operational phases of a system's life cycle. The need for it has become apparent from costly missile mishaps. The general concepts and accomplishments of this new engineering discipline are described along with possible beneficial relationships with Reliability and other elements engaged in safety-related activities. (Author in part)

REVIEW: The first of these papers deals with safety engineering in the aerospace industry with emphasis on the fallible-man factor. The importance of attention to detail comes through clearly, the principal role being played by the design engineer supported by the design safety engineer. The paper makes a number of very good points which are effectively illustrated with examples.

The second paper is concerned with safety in missile-space systems, Air Force safety requirements and means for compliance therewith. It is not a detailed description of requirements per se, but is rather a discussion of the overall problem. Some space is devoted to a discussion of the relationship between reliability and safety. While these two functions are closely related and use some of the same concepts, it must not be assumed that adequate achievement in either one automatically ensures the same in the other. This point is worthy of consideration by management in the aerospace and missile industries. ##

Serial Number 2712
ASQC Code 813

TITLE: Manufacturing controls for reliability of products

AUTHOR: Paul H. Ockerman (Westinghouse Electric Corp.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 428-431 (*see RATR 2646)

PURPOSE: To discuss the needs for manufacturing-control programs in making a reliable product.

ABSTRACT: The role of the manufacturing department is either taken for granted or assumed to do nothing but degrade a product. Little attention is paid to this essential step; reliability programs sometimes operate as if there were no needs to be met in this area. Even during design and development, the manufacturing department should be involved so that compatible processes can be worked out and used. The capability of each process must be known so that the design is compatible with it. In the plant itself, operators must be trained in formal programs whenever a process is changed. Operators must be kept informed of all changes and needs. Quality control activities need to be integrated into the entire product cycle.

REVIEW: The points made here are excellent; if any criticism is in order, it is with regard to the nominal acceptance of clichés such as "manufacturing cannot do anything but degrade the reliability of the product." Actually, by his discussion, the author implicitly shows the lack of insight of this misleading idea. By showing how Manufacturing actually shares in the design and development process and how Design shares in the manufacturing process, the author graphically portrays the interdependence of the groups.

One reason why much of the organized Reliability effort has overlooked the manufacturing controls is that they were doing the job well compared to the design groups. Today in high reliability efforts, each phase of the product cycle must be carefully studied, controlled and improved; each phase must be recognized as being necessary, but not sufficient to the product; each phase must be accorded its own positive and negative contributions to product integrity. ##

Serial Number 2713
ASQC Codes 770;860

TITLE: Indispensable role of the field testing program in the realization of manned aerospace system reliability

AUTHOR: Otto H. Fedor (Martin Co., Canaveral Div.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 442-454, 14 refs. (*see RATR 2646)

PURPOSE: To point out the importance of the field test program in the realization of manned aerospace system reliability.

ABSTRACT: No aerospace system ever leaves the factory in flight-ready condition; hence a large number of program objectives remain to be achieved in the field test program. Field testing consequently contributes a significant portion of the effort to establish engineering confidence prior to launch. The inherent reliability of a system can be conserved at the launch site by enforcement of established reliability practices. Proof that reliability can be achieved through correct field testing and that this is particularly applicable to man-rated programs is verified by: (a) examination of the problem of reliability in the design, construction and testing of aerospace vehicles; (b) examination of field failures due to unreliable systems and procedures which have not been field tested; and (c) development of the relationship between the field test program and achieved reliability. Flight failure histories (Pershing, Titan, Atlas, Mercury experience) indicate that a significant percentage of failures could have been avoided by proper field test programs. Attempting to develop a fully reliable man-rated launch vehicle, the field reliability system in use on the Gemini program encompasses failure data collection, analysis and evaluation, dissemination of information and direction for corrective action. Since launch operations for a manned vehicle differ so much in exigency from missile operations, reliability and pilot safety play a dominant role in test operations. Flight success depends upon a testing philosophy which states that no defective vehicle will ever reach the lift-off stage if all the correct tests have been properly performed, the data properly evaluated and the necessary corrective measures properly incorporated. Restrained firings are useful early in a new program to assure the quality of the assembled subsystems and to reveal any possible design deficiencies. The Gemini component test program revealed vibration and EEI environments as the principal sources of design problems. (Author in part)

REVIEW: The paper provides many useful experiences in testing aerospace systems. These results can point the way for improved reliability analysis and testing approaches which will result in the largest potential increase in system reliability and crew safety. The author's emphasis on the importance of field testing is reasonable. However, a greater potential for achieving high reliability would seem to be with the influence of these testing results on the initial design stage analyses. Knowing something about the nature of the failures will aid in the formulation of more appropriate design reliability analysis procedures. ##

Serial Number 2714
ASQC Codes 770;850;875

I. TITLE: Manufacturer's flight testing for reliability and maintainability

AUTHOR: Bryan E. Mahon (The Boeing Co., Airplane Div.)

II. TITLE: Airline flight testing for reliability and maintainability

AUTHOR: R. C. Collins (United Air Lines)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 455-457, 458-459 (*see RATR 2646)

PURPOSE: To discuss the role of flight testing in attaining reliability and maintainability of airliners.

ABSTRACT: I. Initial developmental and certification test-flying verifies the design, reveals unexpected defects, and suggests improvements. Production testing verifies quality control in manufacturing. Close attention to test results by the designers is necessary to insure early recognition of problems which would become chronic in service if not corrected. Because of developmental changes, the flight time in a final configuration by the manufacturer is often too short for accurate quantitative determination of reliability and maintainability during certification, but good qualitative judgments can be made from experience. (Author)

II. A major portion of airline flight test activities is devoted to the testing of airplanes after they have received a periodic overhaul. These tests are essential to confirm that there are no reliability deficiencies which would affect safety. Flight tests can assist in maintaining the general level of reliability insofar as non-safety aspects are concerned but this is a very expensive method of assuring reliability. The cost and the effectiveness of flight test as a method of controlling the general level of reliability are exemplified. (Author)

REVIEW: The first of these papers is concerned with the manufacturer's flight testing and deals mainly with the flight test program for the Boeing Model 727 airplane. Such a program contributes to reliability and maintainability primarily through engineering evaluation of new designs using comprehensive instrumentation. The paper is brief and general, conveying no real detail.

The second paper is concerned with flight tests conducted by airlines, with emphasis on post-overhaul test flights. A major concern is the cost of these flights in relation to their effectiveness as a means of reliability assurance. Perhaps a reasonable question for consideration is whether, in the context of airliner operation, reliability as such is important as compared to airworthiness and safety. Reliability and safety are generally not considered synonymous; i.e., the achievement of one does not automatically ensure the achievement of the other. ##

Serial Number 2715
ASQC Code 832

I. TITLE: Man's reliability in the X-15 aerospace system

AUTHORS: R. B. Wilson and J. L. Gaffney (North American Aviation, Inc., Space and Information Systems Div.)

II. TITLE: Spacecraft reliability + man = mission success

AUTHORS: B. G. Peters, D. Amorelli, and J. T. Celentano (North American Aviation, Inc., Space and Information Systems Div.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 460-480, 481-489 (*see RATR 2646)

PURPOSE: To discuss the relationship of man to the reliability of aerospace systems.

ABSTRACT: I. History of X-15 performance reveals that the pilot, by unscheduled or unplanned inputs, enabled completion of almost twice as many flights as would otherwise have been completed on a routine basis. The prelaunch team (including the pilot) supported 92 successful routine launchings and overcame malfunctions to enable 10 additional launchings; 13 missions were unsuccessful because of team error. The maintenance crew was responsible for 6 failures out of 164 mission attempts. A reliability point estimate of 0.84 for the X-15 personnel subsystem is derived from these comparisons. (Authors)

II. This paper discusses the relationship of man to total system reliability, and the techniques and controls used to insure spacecraft mission success through reliability. Former maintainability concepts for weapon systems are reviewed briefly, pointing out their inadequacies for manned spacecraft. The reliability concepts for manned spacecraft are examined. Examples of man's contribution to the reliability of aircraft and spacecraft systems are discussed. The method for integrating reliability concepts into design analysis and review is discussed in detail, as is the subsequent extension into test and redesign activities. The method for integrating man into the space system reveals his capability to manually override, maintain, and repair, thus upgrading reliability. (Authors in part)

REVIEW: The first of these papers is a reasonably detailed report which does a good job of presenting the importance of man in the man-machine system, with specific reference to the X-15 aerospace system. Considerable data are given in support of the conclusions drawn. Such data will be useful in planning for man's role in the operation of future aerospace systems.

The second paper is concerned with man's contribution to the space mission from the standpoint of implications for system design and mission planning. As the authors have pointed out, it is not a question of which performs more efficiently--man or machine, but rather one of planning for their effective operation as a team. To do this properly requires knowledge of man-machine relationships, which will come with the accumulation of empirical data. ##

Serial Number 2716
ASQC Code 832

TITLE: Transients in reliability associated with human learning

AUTHOR: James N. Anderson (Curtiss-Wright Corp., Curtiss Div.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 490-497 (*see RATR 2646)

PURPOSE: To review the effects of human learning on reliability growth.

ABSTRACT: Analysis of performance data for complex mechanical energy conversion and control equipment has shown that human learning is a contributing factor to reliability growth. Resolution of technical problems is delayed until the personnel involved have developed the skills enabling them to do their jobs effectively. The problem is compounded when the manufacturer of the system is a sub-contractor, which usually results in his loss of direct contact with the ultimate user. Experience has shown that there is a finite time period in the order of six months to two years for a person to learn a reasonable amount about a new field. This is extended when the learner refuses to admit his ignorance and when the teacher withholds information for personal security. Premature removal rate curves from several development programs are presented. Set-backs to the downward trend of the curves occur at the start of a program, during transition to more severe testing conditions, during changeover to a new organization involving change in personnel, and during transient situations when in full service. The contribution of human learning to these set-backs is shown. Suggestions are presented for improving these conditions through: (1) better coordination between organizations during transition, (2) indoctrination programs, (3) tighter data feedback loops, and (4) better access to failed equipment at least during early stages of service.

REVIEW: Attention is directed by this paper to the lowering of reliability growth by a cause which has not received much attention, namely the adverse effects of the time required for typical people to learn a subject. The validity of this as a cause rests as much in its being reasonable as it does in the arguments which are advanced in this paper. Five different sets of data are presented, each illustrated with a figure, and each showing in some sense that a reliability index improves with system maturity. Figures 2 and 4 contain information which can be related to personnel changes, but the question arises as to whether this is the only change. The paper tends to associate all reliability improvement as illustrated by the figures with human learning. It is not clear who these humans are--they seem to be mainly the operating and maintenance personnel but this is not explicitly stated. Neither is it clear how other possible causes of reliability growth fit into this analysis, i.e., elimination of parts with incipient failure mechanisms, changes in design, or changes in manufacturing techniques with later models. There is no doubt that the human factors area has not received adequate attention in reliability efforts, and even with the looseness in its arguments, this paper does serve to call attention to a particular facet of the problems of human reliability. ##

Serial Number 2717 -1
ASQC Code 863

I. TITLE: Spares management in the USAF

AUTHOR: James A. Bailey (Lt. Col., U. S. Air Force, Directorate of Supply & Services)

II. TITLE: Spares management in the Navy

AUTHOR: John V. Koch (Capt., U. S. Navy, Aviation Supply Office)

III. TITLE: A review of progress in the areas of aeronautical and aerospace spares management

AUTHOR: Otto F. Janssen, Jr. (The Garrett Corp.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 512-517; p. 518-535, 545; p. 536-545 (*see RATR 2646)

PURPOSE: To review the management of aeronautical, naval, and aerospace spares.

ABSTRACT: I. Spares management has provided the largest single contribution to the Air Force cost reduction program. Concentrated efforts have occurred at three major segments of the spares management function. First, the most modern automatic data processing equipment has been used to handle the millions of transactions. Second, the capability and skill of personnel at every level of the decision-making process have been improved. Finally, successively higher levels of review of those actions involving the expenditure of significant dollars and assets have been emphasized. Another factor in reducing spares requirements over the past several years has been a critical examination of maintenance practices. The objectives have been to increase the amount of repair done at the base or using level and to decrease the mandatory inspection and removal intervals on items installed on aircraft. In some instances levels of stock may have been reduced to a point affecting combat capability. Risks are being taken, but they are considered basically sound. The emphasis is on tough management that is willing to take a well-calculated risk.

II. This paper is addressed to the fundamentals of aeronautical spares management as exercised by the principal Inventory Control Point (Aviation Supply Office, Philadelphia, Pa.) under the management control of the Bureau of Supplies and Accounts and the technical control of the Bureau of Naval Weapons. Spares management in the Navy is a two-fold responsibility: (1) procurement, distribution, retrieval, disposal; and (2) withdrawal, use, maintenance, repair and exchange; the former is supply management, and the latter operational management. Consequently, control of spares actually

passes from "supplier" to "user" and back to "supplier" in a revolving manner with new items introduced into the "wheel" while obsolete items are withdrawn and disposed of. Spares are of two types: (1) repairables and (2) consumables. The repairables are managed in a regenerative system and the consumables in a consumption system. A detailed description is presented of the actual practices used in the Navy's aeronautical spares inventory management. It is intentionally factual so as to remain unbiased and of practical value to those interested in studying the art.

III. The progress which has been made in aeronautical and aerospace spares management is reviewed by looking back at the history of spares management in the last 20 years. The aspects which are covered include provisioning, ordering, inventory control and distribution of spares in three major areas: commercial airlines, the Department of Defense, and the National Aeronautics and Space Administration. Progress has been considerable over the past 20 years, and it is anticipated that more efficient spares management is imminent as refinements and improvements are continued.

REVIEW: These three papers have in common the facts that each gives an overview of a particular spares area and that each contains little or no tie-in with reliability or maintainability. These papers are for someone who is curious about the logistics discipline from an introductory management viewpoint. There is a hint of some useful reliability and maintainability data in the computerized record systems, particularly in the high cost items which are individually recorded by serial number. The efforts for improving the USAF spares management which are presented in I leave a favorable impression. II amounts to little more than a formal procedural document and no attempt is made by the author to interpret these procedures. Also, the title of II implies a Navy-wide coverage, whereas the paper is restricted to aeronautical spares. The review in III treats each of the principal spares customers, brings in some problems and limitations, and points out some major differences in the spares approaches of the commercial airlines and various government agencies. ##

Serial Number 2718 -1
ASQC Codes 822;837

TITLE: Designing a specified reliability directly into a component

AUTHORS: Dimitri Kececioglu and David Cormier (The University of Arizona)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 546-565, 43 refs. (*see RATR 2646)

PURPOSE: To develop and illustrate probabilistic methods of calculating the reliability of components from their stress and strength distributions.

ABSTRACT: Safety factors and safety margins have gross inadequacies as design tools, not to mention having several definitions each. The proper design method is to calculate the nominal stresses, then correct them to actual stresses by the conventional techniques. The same is true for strength. Then the variability is known for both stress and strength. The probability of failure can then be calculated by standard methods of combining probability distributions.

REVIEW: This paper is much too long and some of the derivations are trivial. The comments on calculating stresses and determining the criteria for failure are good, but certainly not novel. The discussion on strength is less adequate, but serves to summarize the situation for someone already familiar with the basic ideas. Sometimes the ideas or words are confused such as in the following: "The strength distribution has to be of that strength which if exceeded by the failure governing stress would result in a failure probability."

The mathematics is fair, except for such errors as in Equations 22 and 23 which are plainly wrong. (When a double integral contains two variables of integration, differentiation of the result with respect to either gives zero always!) The combined distribution for "reliability" as shown on the graphs is not clear at best (especially as regards the labeling of the abscissa).

The big problem, however, was not even broached in the text. It is that it is virtually impossible to know the distributions of stress and strength in the adjacent tail regions sufficiently closely for this method to be a significantly better design tool than Lusser's safety margin concept. It is usually easy to know where the 10% point in a tail region is, difficult to know the 1% point and virtually impossible to know the 0.1% point. Of course, in a tractable distribution, these points are all easily calculated; the problem arises in that Mother Nature is far from being as tractable as the distribution. Safety factors are an adequate design tool (and have been for many years) where design changes are slow and there is much experience. They also serve to account for failure modes other than the nominal one. For example, the large safety factor applied to the tensile strength of steels encompasses the lower fatigue strength of the material. It also compensates for the fact that the designer is generally woefully ignorant of the exact distribution of stresses to be encountered in service.

The safety margin of Lusser goes further into more exact design than the safety factor, but requires much more knowledge of failure modes, materials properties and service loads. It is not usually possible to calculate failure probabilities if they are small; but calculating a failure probability is not the sine qua non of design.

The probability of failure concept, as applied to the simple stress-strength model for failure, is helpful but suffers severely from its overdependence on extrapolation into the tail region of a distribution where the exact shape is unknown and where guesses may be off by a factor of 10 or more. Another less obvious disadvantage is the inadequacy, for some failure modes, of the simple stress-strength model for failure. Fatigue is an example of the inadequacy of that simple model.

In the derivation of the reliability for the stress-strength model, the authors might have done as well to use the convolution integral method for combining probability distributions such as found in statistics textbooks. They would have avoided the errors, shortened the paper, and been consistent with the derivation in the numerical example. The assumption of statistical independence between stress and strength is implicit; even when it is likely to be true, it is wise to make such an assumption explicit.

In a private communication the first author has shown how he apparently meant to derive Equations 22 and 23 so that the derivation and definition would be correct. He feels that the review should devote more attention to ways of finding the exact distribution in the tail region rather than vilify the entire methodology, and that Lusser's safety margin is inadequate because it fails to give a probability number. ##

Serial Number 2719
ASQC Codes 822;844

TITLE: A model for time varying and interfering stress-strength probability density distributions with consideration for failure incidence and property degradation

AUTHORS: M. J. Bratt, G. Reethof, and G. W. Weber (General Electric Co., Large Jet Engine Dept.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 566-575, 592, 8 refs. (*see RATR 2646)

PURPOSE: To present a complex stress-strength model for failure.

ABSTRACT: There are many ways in which mechanical parts can fail. The stress-strength model, wherein failure occurs when stress exceeds strength, is a useful concept. In this case, anything that causes a reversible change in the stress-strength difference is considered as a stress. If it causes damage (an irreversible change) it is presumed to modify the strength of the non-failed parts. As time goes by, the weaker parts will fail, thus modifying the strength distribution of the remainder. A model for degradation and for part failure was set up, and then analyzed on a digital computer. Various assumptions were made and the results are shown.

REVIEW: This is an interesting paper and presents worthwhile thoughts on the nature of failure. The exact details of the failure model were not checked in detail, but the appearance is reasonable. As the authors have pointed out, the work is preliminary and further work is being done. There are difficulties with this method of assessing failure probability if the probability is less than a few percent--just due to lack of knowledge of actual stresses and strengths. ##

Serial Number 2720
ASQC Code 433

TITLE: Research toward a Bayesian procedure for calculating system reliability

AUTHORS: C. W. Hamilton and J. E. Drennan (Battelle Memorial Institute)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 614-620 (*see RATR 2646)

PURPOSE: *To describe research toward the application of Bayesian statistical methods to the calculation of system reliability.*

ABSTRACT: The motivation for the suggested procedures stems from (1) the fact that Bayesian methods provide for the formal inclusion of all relevant information in reliability calculations, and (2) the suitability of Bayesian methods to problems in which the probability distributions of interest change over time. In this report, suggested procedures are given for obtaining component reliability estimates based on system test outcomes. System reliability is initially calculated from prior component reliabilities using the product rule. This prior system reliability estimate is then modified as each successive test outcome is observed. The approach is to specify the prior component reliabilities in the form of a ratio, and modify the ratio by Bayes' rule based on the outcome of a system test. Three possible test outcomes are considered: (1) success, (2) failure caused by known components, and (3) failure caused by unknown components. Using this procedure, substitution of new components or modification of the configuration of the system does not invalidate the test data accumulated up to the time of the changes.

A partial set of test firings of an ARGMA surface-to-surface missile is analyzed to illustrate the procedure for a simple application--binomial test data and a series system. Difficulties in applying the procedure and recommendations for further application are included. (Authors in part)

REVIEW: This paper contains a good discussion of the application of a Bayesian procedure to calculating system reliability. The fact that several papers have appeared recently in this subject area indicates the interest in using this approach in an objective system reliability calculation. (See, for example, RATR 2072, 2268, 2381, 2430, 2477, 2564, 2611, and 2663.) The inclusion of a real example is a special treat for papers on Bayesian techniques. The critique given by the authors concerning the Bayesian approach is very interesting. ##

Serial Number 2721
ASQC Codes 824;844

TITLE: Engineering applications of extreme value theory

AUTHOR: R. P. Haviland (Missile & Space Div., General Electric Co.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 621-627, 14 refs. (*see RATR 2646)

PURPOSE: To illustrate the application of extreme value theory to certain reliability problems.

ABSTRACT: This paper illustrates the applications of extreme value theory to a group of engineering reliability problems. The importance of the largest load, the weakest link, the largest flaw and the shortest life are shown. The exact and asymptotic forms of the extreme value distributions are developed, using the relations of Gumbel. Examples from the literature are given. The results are combined with the functional theory of reliability to show the technique of life prediction needed for reliable design. (Author)

REVIEW: This paper is quite good in showing the types of reliability problems which can be approached through statistical extreme value theory. However, the explanation of the theory and practical use of the theory is rather inadequate. It is recommended that the book Statistics of Extremes, Columbia University Press, by E. J. Gumbel be consulted with regard to the use of the theory.

An application of statistical extreme value theory was also given in the reports covered by RATR 2293. ##

Serial Number 2722
ASQC Code 824

TITLE: Weibull renewal analysis

AUTHOR: John S. White (General Motors Corp., Research Laboratories, Mathematics Department, Warren, Mich.)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 639-657, 9 refs. (*see RATR 2646)

PURPOSE: To review the results and applications of renewal analysis for the Weibull distribution.

ABSTRACT: Renewal theory concerns itself with the replacement of randomly failing parts. In the simplest case we have a one component system which is kept running continuously by replacing a failed component at the instant of failure with an identical "new" component. The random variable N(t) = the number of failures (or replacements) to time t is then of interest in many types of reliability analysis. In this paper the distribution of N(t) is considered when the underlying failure law is a Weibull distribution. Tables of the mean and standard deviation of N(t) for various values of the Weibull slope parameter are presented. Applications to warranty and spare parts analyses are also noted.

REVIEW: This paper gives a very good review of the applications and results of renewal theory--in particular when the underlying failure distribution is of Weibull type. None of the results are new but they are presented in a convenient form. Several graphs and tables are included. ##

Serial Number 2723
ASQC Codes 425;822

TITLE: A simple technique to determine the exponentiality of field failure data

AUTHOR: Irwin Nathan (Aerospace Systems Div., General Precision, Inc.; present affiliation: Anathon, Inc., 11 East 36th St., New York, N. Y. 10016)

SOURCE: Proceedings Third Annual Aerospace Reliability and Maintainability Conference, Washington, D. C., 29 Jun - 1 Jul 64, p. 226-232, 6 refs. (*see RATR 2646)

PURPOSE: To describe a simple test for exponentiality.

ABSTRACT: The object of this paper is to present a technique and a procedure for the analysis of small sample size field failure data to determine if the distribution of failure times is exponential. If the distribution is found to be exponential, then a brief discussion of a technique useful in setting maintenance policy is presented. If the distribution is not exponential then a few useful analysis techniques are presented to locate the non-random times-to-failure.

The main point of the paper is to demonstrate the applicability of the powerful Kolmogorov-Smirnov One Sample Test to field failure data. The simplicity of this test procedure should be sufficient to insure its widespread use in such analysis, but it is also shown how flexible it is by easily locating non-random failures. Presently, such analyses are conducted using the χ^2 test. This test is both tedious to apply and relatively inefficient. Furthermore, it is one of the most subjective tests known for application to the analysis of small sample size data. (Author)

REVIEW: This paper attempts to present a useful statistical method for testing whether or not observed failure data come from an exponentially distributed population. However almost all of the statistics in the paper is wrong or at best misleading. To begin with, the null hypothesis is <u>not</u> that the empirical or sample c.d.f. of the data is exponential--this hypothesis could <u>never</u> be true! Second, the important theorem which serves as a basis for the method is stated incorrectly and one may infer from later statements that the author does not understand it correctly. Many more examples could be given.

The idea of using the Kolmogorov-Smirnov test (or Cramér-Von Mises test) is useful and has been suggested on page 141 of the book <u>Stochastic Processes</u> (Holden-Day, San Francisco) by Emanuel Parzen. The correct basis for the test is given as Theorem 4A on page 140 of Parzen's book. (It should be noted that the test is independent of the mean-time-to-failure.)

In applying the Kolmogorov-Smirnov test, one should perhaps heed the author's suggestion and consult any text with chapters on non-parametric statistics. ##

Serial Number 2724 -1
ASQC Codes 513;712;716;
773;782

TITLE: Cyclic strength of metals (selected articles)

AUTHORS: M. A. Yel'yasheva; T. V. Karpenko; V. A. Bykov, G. N. Vsevolodov; M. I. Chayevskiy; S. A. Gladyrevskaya, L. V. Ignatyuk, V. A. Svetlitskiy; and B. I. Aleksandrov

SOURCE: Russian Book, Tsiklicheskaya Prochnost' Metallov, Akademiya Nauk SSSR, Institut Metallurgii im. A. A. Baykova, Moskva, 1962, pp. 123-133, 233-266, Translation prepared by Translation Div., Foreign Technology Div., WP-AFB, O., FTD-TT-62-1872/1+2, 10 Jun 63, 70p, 38 refs.

PURPOSE: To present a group of selected articles concerned with the cyclic strength (fatigue) of metals.

ABSTRACT: This publication is composed of six selected articles from the Russian literature. The articles, briefly summarized, are as follows.

1. "Investigation of the possibility of applying the accelerated method of determining fatigue strength under conditions of an asymmetric loading cycle and with various production treatments"--The use of the accelerated method (based on the energy similarity between fatigue failure and melting of metals) to determine fatigue resistance offers promise. The data presented are regarded as preliminary, and the studies should be continued.

2. "Fundamental factors on investigation of the effect of the external media on fatigue resistance"--Attention should be directed towards production processes that precede finish machining and influence fatigue resistance in active media. The processes of importance are those that suppress variations and nonhomogeneities, create uniform surface hardening, and eliminate surface defects.

3. "Corrosion-fatigue resistance of cast brass"--Two propeller brasses were studied. Neither of the materials demonstrated tendencies to brittle failure under rigid stressing conditions. The limits of corrosion endurance for the two materials closely approximate the calculated allowable strength for propellers.

4. "Influence of low-melting metallic melts on fatigue resistance of carbon and chromium-nickel steels"--The influence of low-melting metallic melts on mechanical properties of steels is associated with different types of physico-chemical effects. The fatigue resistance of a steel may increase when in contact with a low-melting metallic melt, where an intermetallic layer and residual compressive stresses form in the surface layer as a result of adsorption, diffusion, or chemical processes. A decrease in the fatigue resistance of steels occurs in cases of only adsorptive activity of the melt.

5. "Apparatus for study of metal corrosion fatigue"--An apparatus with the necessary control and sensitivity was designed, built, and tested. The signal, and magnitude of the period, can be measured with an accuracy to $\pm 10^{-4}$ seconds; this makes it possible to analyze the smallest change in the specimen.

6. "Influence of temperature and technological factors on the endurance of thermal-shock resisting steel and alloys"--The influences of temperature, heat treatment, casehardening, and plastic deformation on the endurance limit are presented.

REVIEW: The selected articles are presented as unedited rough draft translations. They appear to be better than average translations because unusual word orders and sentence structures are not prevalent. Two or three figures containing photographs did not reproduce, but they do not detract from the usefulness of the material.

In general, the papers cover a wide variety of metallic systems, production treatments, types of loading, and environmental conditions. The articles contain varying amounts of useful design data. The article designated as number 5 would be of least value to the design engineer; however, it may be valuable to the fatigue-test engineer.

The titles of the individual papers are not always descriptive of the subject matter. In order to completely understand some of the articles, the reader should have access to some of the referenced papers. ##

Serial Number 2725 -1
ASQC Codes 425;513;523;
712;773

I. TITLE: An investigation of the fatigue of aluminum alloy due to random loading

AUTHOR: S. R. Swanson (University of Toronto, Institute of Aerophysics, Toronto, Canada)

SOURCE: UTIA Report No. 84, Institute of Aerophysics, University of Toronto, Feb 63, 72p, 56 refs.

II. TITLE: Practical fatigue loadings for aeronautical structures

AUTHOR: S. Roy Swanson (The de Havilland Aircraft Co. of Canada, Limited, Malton, Ontario, Canada)

SOURCE: Proceedings of the Fourth International Congress of the Aeronautical Sciences, Aug 64, p. 793-814, 15 refs.

PURPOSE: To report the nature of fatigue for 2024-T4 aluminum when subjected to random and constant-amplitude axial loading (I); to discuss in more detail the bimodal nature of fatigue life distributions and the random loading fatigue machines (II).

ABSTRACT: I. A statistical study of the fatigue behavior of 1500 unnotched 2024-T4 aluminum specimens (extruded bar stock) subjected to axial random and constant amplitude loading was carried out. In order to apply the random-amplitude loads, a shaker-driven fatigue machine was designed and built. Special levers were incorporated into the machine in order to shape and magnify the load so that large Rayleigh peak distributions and complex wave loading could be applied to the specimens. Throughout the work, various cumulative damage rules have been examined in light of the various random load tests.

Analysis of the constant amplitude fatigue data indicate that the S-log N curves for these tests can be separated into two failure distributions. The knee of the constant-amplitude S-log N curve reflects the transition from predominantly one log-Normal distribution of endurance to predominantly the other. A study of the data from a series of two-level (single-jump) constant amplitude tests indicates that the linear rule of cumulative damage could be applied when the order of loading is low pre-stress to high test stress; but, when this order of loading is reversed, the Corten-Dolan theory applies. When results from the random-load tests were compared with various cumulative damage theories, the linear rule of damage was completely inadequate and unusable. Freudenthal's rule and a modified Fuller's rule gave the best representation of endurance for stationary Rayleigh tests. A new technique of endurance prediction, based on a linear summation of "cycle ratios" of RMS stress and the experimental Rayleigh endurance relation, gives fair correlation for programed RMS tests.

The random-load tests were characterized by the appearance of

secondary cracks which were not observed under conditions of constant amplitude loading. The number of secondary cracks is dependent upon the load configuration and the RMS stress level. (Author in part)

II. There is steadily mounting evidence that the distribution of fatigue lives, under similar conditions of excitation, is bimodal in nature and that the short life portion decreases in importance as the severity of excitation decreases. Constant amplitude loading is too artificial, random loading is much more realistic. Several kinds of machines with random loadings are described and their advantages discussed.

REVIEW: I. This report is a worthwhile contribution to the published literature. The test device will be of interest to fatigue test engineers concerned with simulated loading of aircraft, ships, and other vehicles. Much of the data which are presented would be useful to the design engineer. The analysis and interpretation of the data are valuable to the general study of endurance distributions.

The paper deals primarily with statistical analysis and distributions of endurances, rather than with mechanisms of failure. While the main statistical assumptions are apparently stated explicitly, an important implication of one is not, viz., (from p. 3) "Each endurance mean value has the same weight" implies that the variances of such means are equal. Some of the analyses use N (e.g., in $N = ae^{-bS} + ce^{-dS}$ on p. 6) and some use log N. For the same set of data, it is difficult if not impossible for the hypothesis to be true for N and log N at the same time. Furthermore, unless the number at each stress is properly adjusted, the variance in the mean will be different at low and high stresses.

The subject matter is thoroughly covered and the paper is well illustrated and referenced. The large number of tests, 1500 in all, indicate that the author attempted to use an adequate number of tests. The mathematical formulae were not checked in their entirety. See also RATR 2726.

II. While this article does not establish the hypothesis about bimodality by producing large amounts of data which uniquely support the hypothesis, it does provide an interesting discussion and shows some results which can be interpreted in terms of bimodality. The use of random loading has much to recommend it and several fine arguments for it are given. (Interestingly, the author's support for bimodality appears to come largely from constant amplitude tests.) The author's points appear well worth exploring; fatigue theory is not so far ahead in practical applications that it can afford to overlook ideas that appear promising. ##

Serial Number 2726
ASQC Codes 513;712

TITLE: An investigation of the statistical distribution of constant amplitude fatigue endurances for a maraging steel

AUTHOR: F. Cicci (University of Toronto, Institute for Aerospace Studies, Toronto, Canada)

SOURCE: UTIAS Technical Note No. 73, Institute for Aerospace Studies, University of Toronto, Jul 64, 16p, 20 refs.

PURPOSE: To report the statistical characteristics of endurances near the knee of the fatigue curve for a maraging steel.

ABSTRACT: Constant amplitude (167 cycles/second) rotating bending fatigue tests were conducted for an 18% Ni-Co-Mo maraging steel. Parallel specimens were machined from a 194-pound 1/2 × 20 × 63 inch plate produced from a vacuum-stream-degassed air melt. Material properties--chemical analysis, inclusion and cleanliness ratings, tensile strength, modulus of elasticity, and hardness--were measured. Specimen design, test machine calibration, material heat treatment, error calculations, test procedures, and statistical considerations are presented in detail. Data pertaining to uncontrolled variables were also evaluated. The statistical distributions considered were log-Normal, extreme value, and Maxwell-Boltzmann.

Computer analysis of the data indicated that the large scatter in the endurance resulted from the nature and condition of the material. Furthermore, the endurances at any stress level cannot be represented by a single log-Normal or extreme value distribution. The log-Normal distribution gives a better fit to the data than the extreme value distribution. A linear correlation analysis of the uncontrolled variables showed no significant effects for machines, grip eccentricity, specimen section eccentricity, hardness of the unstressed material, hardness of the stressed material, Young's modulus, heat treat batch, ultimate tensile strength, surface finish, crack location, ambient temperature, or date of test. The time of day that the test was begun had a slight effect on the endurances, as did relative humidity. The Maxwell-Boltzmann distribution fits the data well; but further investigation, in greater detail, is required before its usefulness can be established.

REVIEW: This paper is concerned with the distribution of endurances at or near the "knee" of the fatigue curve and not the mechanism of failure. The author delves into the subject in detail, but he does it in a manner that is easy for the reader to follow. The paper is well illustrated and referenced.

The author appears to have completed his experimentation and analysis with caution and thoroughness, which gives the reader a feeling of confidence in the data reported.

The paper contains fatigue data which should be useful to the design engineer. The various formulae were not checked in their entirety. See also RATR 2725. ##

Serial Number 2727
ASQC Codes 822;824

TITLE: Estimation of the parameters of the extreme value distribution by order statistics

AUTHOR: Khatab M. Hassanein (University of North Carolina at Chapel Hill; now at Institute of Statistics, Cairo, U. A. R.)

SOURCE: Technical Report prepared by University of North Carolina, Chapel Hill, N. C. under Grant No. DA-ARO-D-31-124-G432, DA Project No. 20014501B14C; AROD Report 2776.17, 9p + tables, 11 refs. (AD-622 257)

PURPOSE: To tabulate coefficients for best (nearly best) linear unbiased estimates of the scale and location parameters of the extreme value distribution.

ABSTRACT: The extreme value distribution arises in many practical problems concerning, for example, the study of floods and droughts, breaking strength, extreme temperatures, etc. The exact distribution depends upon the initial distribution from which the observations are drawn and upon the sample size. However, under rather general conditions, it is known that the distribution of the normalized extreme value $y = \alpha_2(x - \alpha_1)$ converges to the distribution exp(-exp(-y)). This report considers the estimation of α_1, the location parameter, and $1/\alpha_2$, the scale parameter. The coefficients of the best (nearly best) linear unbiased estimates, BLUE (NBLUE), are obtained and tabled for $n \leq 6$ (BLUE), n = 1(1)10(5)25 (NBLUE), with all possible cases of singly and doubly censored samples. The efficiencies of these estimates with respect to uncensored samples are also given as are coefficients required for estimating percentage points.

A discussion of the results and a numerical example end the body of the paper.

REVIEW: In situations where the extreme value distribution applies, this paper will be useful for obtaining tractable estimates of the parameters. A related paper which demonstrates the applicability of extreme value theory to error probability estimation in a spacecraft receiver was covered by RATR 2293. ##

Serial Number 2728
ASQC Code 873

TITLES: The maintenance engineer looks at machine design
Design for maintenance--the user challenges the machine tool builder

AUTHOR: Nelson M. Hoffmann (Ford Motor Co., Transmission and Chassis Div., P. O. Box 1939, Cincinnati, O.)

SOURCES: Presented at the ASME Design Engineering Conference and Show, Chicago, Ill., 11-14 May 64, Paper No. 64-MD-21, 10p (The American Society of Mechanical Engineers, 345 East 47th Street, New York, N. Y. 10017)
Lubrication Engineering, vol. 20, Jun 64, p. 231-238

PURPOSE: To discuss maintenance problems in the use of machine tools resulting from inadequate provisions by the machine tool builder.

ABSTRACT: Although machine tool builders have introduced faster machines with better controls and have incorporated clever systems in their equipment, in many cases little consideration has been given to the provisions for maintaining such equipment. Provisions for lubrication seem to provide the greatest problems in maintenance, e.g., lack of accessibility to grease fittings or oil reservoirs. These may be considerably above the floor or placed behind machine components making it necessary in some instances to stop the machine and remove parts before a lubricant can be applied. Servicing problems also arise from improper couplings, seals, electric panels, and improperly sized oil cups. Improper selection extends to filters, cylinders and drive belts. Some problems in maintenance stem from poor workmanship on elements unrelated to or not covered in the user's drawings, e.g., location of pipes, tubing or wires which obstruct access to parts requiring frequent attention. Many problems are caused by inadequate drawings furnished by the builder which make it difficult to trace pneumatic, electric, hydraulic, or lubrication lines. Improvement is slowed by the lack of personal communication and exchange of ideas between the builder and the user.

The second paper deals in greater detail with maintenance problems in hydraulic systems. These result from a lack of standards in the type, design, and location of reservoirs to fit given applications. Reservoirs should be adequately sized and enclosed to prevent heating and contamination. Provisions should be made for filtering and cleaning. Filters and strainers should be easily removable and large enough so as not to require frequent changing or cleaning.

REVIEW: The problems discussed in the paper are those which have been experienced by any user of machine tools. The illustrations are familiar and the paper does point out a serious need. It is interesting to note, however, that the author is associated with the automotive industry where there is a growing tendency to commit the same sins in locating components on vehicles. There is hearty agreement that something needs to be done about the design-for-maintenance problems and, as with charity, a good place to start may be at home. ##

Serial Number 2729
ASQC Codes 711;712;830

TITLE: Correlation of fatigue design data on springs of many types

AUTHORS: George W. Kurasz and William R. Johnson (Associated Spring Corp.)

SOURCE: Presented at the National Farm, Construction and Industrial Machinery Meeting, Milwaukee, Wisc., 14-17 Sep 64, SAE Paper 893D, 7p (Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N. Y. 10017)

PURPOSE: To show that spring design information for cyclic loading can be related to the material properties for practically any spring configuration.

ABSTRACT: Stresses at the outer fibers normally control spring strength and performance. Design formulas are generally based on elastic bending and twisting theory and may be subject to error when stresses at the outer fibers exceed the yield points. When yielding does occur, consideration must be given to the effect of the resulting residual stresses on the applied stress if the net maximum and minimum stresses are to be accurately determined; the residual stresses may be beneficial. Favorable residual stresses may generally be induced by cold working the spring surface by methods such as shot peening which also helps alleviate stress concentrations.

In rapidly or cyclically loaded springs, stresses are usually higher than calculated, due to shock waves or resonance. In such cases damping may be helpful. Factors, besides stress, which affect fatigue life include temperature and humidity. Fatigue tests run under conditions of high humidity gave lower fatigue life than those run under dry conditions. Hydrogen embrittlement and time-dependent failures occur at a higher rate under humid conditions. Unidirectional constant deflection tests showed higher life values at elevated temperatures which is explained by resultant increased setting. Low temperatures, however, had no effect on fatigue performance. Surface treatments which do not affect the residual stress pattern, for example, painting, plating, and phosphating will affect fatigue life depending on their ability to prevent stress corrosion. However, they may produce cracks or rough surface conditions which could lower fatigue life. An illustration is given for predicting the fatigue life of springs at various stress ratios by first using the Goodman diagram to determine the equivalent stress range at a stress ratio of 1. This stress range is then used in conjunction with S-N curves run at a stress ratio of 1 for predicting the fatigue life.

REVIEW: The paper offers little that is new to those engaged in design work. It re-emphasizes factors which are important from the standpoint of fatigue regardless of the area of design. ##

Serial Number 2730
ASQC Codes 774;775

TITLE: Certifying heavy machinery for tough jobs

AUTHOR: Franklin H. Pennell (De Laval Turbine Inc., Trenton, N. J.)

SOURCE: Metal Progress, vol. 87, Jan 65, p. 99-103

PURPOSE: To describe tests and methods that are used for inspecting heavy machinery in order to insure satisfactory performance and long serviceability.

ABSTRACT: Tests and inspection methods are described that are used on centrifugal compressors, pumps, and turbines before such equipment is placed in service. Tests may be either destructive or nondestructive. Nondestructive tests include inspection by magnetic particles, radiography, and ultrasonics to check for physical defects such as cracks and poor welds. Tests are also made to determine the chemical analysis, mechanical properties, and the behavior of a unit or component under simulated operating conditions. When applicable, test procedures call for the measurement of amplitude of vibration due to unbalance; fatigue and natural frequency of turbine blades; stability at various temperatures; ability of casing to withstand hydrostatic pressure; tensile properties and hardness; and concentricity. Composition and mechanical property tests are generally made using test ingots which are cast at the same time as the part itself.

REVIEW: This paper serves only to point out to the reader the various types of inspection methods and tests that are used in insuring long life specifically in compressors, turbines and pumps.

None of the methods are described in great detail so that the paper does little to educate the reader except to suggest that some of the methods might be useful in his particular field. ##

Serial Number 2731
ASQC Codes 822;823;844

I. TITLE: Application of the Eyring model to capacitor aging data

AUTHORS: H. S. Endicott, B. D. Hatch (General Electric Company, Missile and Space Div., Philadelphia, Pa.) and R. G. Sohmer (Burroughs Research Lab., Paoli, Pa.)

SOURCE: IEEE Transactions on Component Parts, vol. CP-12, Mar 65, p. 34-41, 16 refs.

II. TITLE: Comments on "Application of the Eyring model to capacitor aging data"

AUTHOR: Paul Gottfried (Booz-Allen Applied Research, Inc., Bethesda, Md.)

SOURCE: IEEE Transactions on Parts, Materials and Packaging, vol. PMP-1, Dec 65, p. 40 (correspondence)

PURPOSE: To develop and apply a conceptual model of capacitor failure.

ABSTRACT: I. A damage law for capacitors is proposed of the form $dD/dt = nGV^{n-1}$ where D is damage; G, n are constants. The equation can be integrated for constant V, increasing V (constant rate), and step increasing of V. These equations are developed and compared. The value of damage at failure is a fixed number, but there is presumed to be initial damage which is a random variable. Expressions are developed for evaluating some of the unknowns by assuming a Weibull distribution (with two parameters). Mica capacitor life tests, run according to the methods above, fit the developed models quite well.

II. The statement in I that "a sound theoretical foundation has been established" is questioned. Some other implications appear doubtful from both philosophical and empirical viewpoints. A reply to these comments by the first author of I is included. This reply contains corrections of a few typographical errors.

REVIEW: With the exception of the introductory references to the Eyring and Arhennius relations, the paper (I) is reasonable. The model was largely developed in the paper covered by RATR 577. The comparison with the experimental data is generally quite good (although this does not mean that large amounts of extrapolation would be justified). The criticism (II) about the "theoretical development" of the Eyring model and the exponential voltage law is well made. The first author tried to squirm out of his inferences by quoting "... an empirical relation appears to have a sound theoretical foundation." But in his conclusions he states: "Through the Eyring Model ... this relation, which has been considered as being empirical, is shown to have a theoretical foundation." What the authors did, was to pick someone's modification of the Eyring model which contained a completely arbitrary function and two arbitrary constants and show that, by suitably choosing the arbitrary function and constants, they could "derive" the voltage law for capacitors. They could also, of course, "derive" virtually any other law by suitable choice of the arbitrary function and constants. The assumption in Eq. 8 that $t_o = 0$ is tantamount to assumption of $d_o = 0$ which means all capacitors have the same life; two errors cancel out and Eq. 8 is correct. ##

TITLE: Nonelectronic parts reliability philosophy

AUTHOR: D. W. Fulton (Rome Air Development Center, Griffiss AFB, N. Y.)

SOURCES: IEEE Transactions on Aerospace and Electronic Systems, vol. AES-2, Mar 66, p. 169-174
Proceedings of Air Force Systems Command System Effectiveness Symposium, presented at L. G. Hanscom Field, Bedford, Mass., 12-14 Oct 65, Paper II 4, 15p
Proceedings of the 1966 Spring Seminar on Reliability Techniques--Today and Tomorrow! Reliability Chapter, Boston Section, IEEE, 14 Apr 66, p. 1-6

PURPOSE: To review the state-of-the-art in reliability of nonelectronic components and to present a technique to measure the relative overall effect of failure of nonelectronic components in so-called electronic systems.

ABSTRACT: Emphasis in the field of reliability has been placed almost exclusively on the electronic function. The degree to which the nonelectronic function has been overlooked is inconsistent with the magnitude of the problem. Even "pure" electronic functions, such as transistor amplifiers contain mechanical connections, potentiometers, and switches. The significance of nonelectric failures in so-called electronic systems can readily be seen if the percentage of such failures in a given time interval is compared to either the total failures or to the electronic failures in the same time interval. A more proper method of determining the impact considers not only the ratio of failures in a time interval, but also the downtime for component replacement and the cost of the component. A ratio for doing this is presented.

For the responsive prediction of the reliability of nonelectronic components, it is necessary to evaluate the response to stress of the component's subparts to determine the failure rate characteristic of the component. This must be done for each member of a functional family in view of differences in design, materials, manufacturing methods, inspection, and so on. The use of electronic part derating factors is a necessary function of the electronic designer and is essential in optimizing his final design considerations. The safety factors employed by the electromechanical and mechanical designer are not synonymous with the electronic designer's derating factors. The need for safety factors stems from the designer's uncertainties in defining the stress envelope and the variable response of the design materials. The design based on safety factors will frequently be over-designed and will rarely be optimum from the reliability viewpoint.

The lack of standardization associated with electromechanical and mechanical components is probably why the concept of application factors for these components has lagged.

Failure data from the 413L system are analyzed to reveal significant failure modes and mechanisms which are of value in designing for, or assessing the reliability of, a specific component. An

overall "Figure of Hazard" for failure mechanisms is presented. (Author in part)

REVIEW: This paper is a concise presentation of a reasonable approach to the reliability problem for nonelectronic components. The reader desiring more detail will wish to refer to the comprehensive treatment of the subject referenced in the paper. As the author has indicated, the reliability of mechanical and electromechanical parts and components has received less attention than that of electronic components. Consequently an approach such as that described in this paper is needed and should serve a worthwhile purpose for design engineers. (There appear to be minor typographical errors in the expression for R(t) on page 170; both the numerals and the t's should be lowered relative to the λ's.)
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Reliability Abstracts and Technical Reviews

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71 MEASUREMENT OF QUALITY CHARACTERISTICS

R66-12733 (ASQC 712; 774; 844; 851)
National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
FATIGUE UNDER RANDOM AND PROGRAMMED LOADS
Eugene C. Naumann Washington, NASA, Feb. 1965 27 p refs
(NASA-TN-D-2629; N65-16579) CFSTI: HC $1.00/MF $0.50

An investigation was conducted to determine which combination of methods of counting and type of load programing best retains the essential fatigue-inducing characteristics of a random time history of stress. The data obtained in an earlier investigation were used to conduct axial-load fatigue tests of 2024-T3 aluminum-alloy sheet specimens with notched edges. The fatigue life obtained from tests using the random peak history was used as a basis of comparison. The elimination of various sized fluctuations, due to the different counting methods, had little, if any, effect on fatigue life in tests using a random sequence of loads. Tests conducted by using ordered loading produced lives greater than the random fatigue life. The value of life in the ordered tests varied with the counting method, with statistical properties of the time history, and probably with the assumptions made in reducing the data to block form. Author

Review: This paper deals with physics of equivalent representation of random time histories. The central idea of the paper, in its present state, is not directly applicable to design problems. Investigators interested in variable-amplitude fatigue testing or simulated aircraft service life may find the paper useful. The paper is easy to read, and it contains some tabulated fatigue data which may be useful to design engineers.

R66-12764 ASQC 711; 712; 770
A COMPARISON OF ULTRASONIC AND CONVENTIONAL AXIAL FATIGUE TESTS ON ALUMINUM ALLOY ROD.
A. Fox (Bell Telephone Laboratories, Inc., Metallurgical Engineering Dept., New York, N.Y.).
Materials Research and Standards, vol. 5, Feb. 1965, p. 60–63. 6 refs.
(A65-16679)

Comparison between results obtained from conventional (60 cps) and ultrasonic (17.5 kc) axial load fatigue tests. The data obtained from both ultrasonic and conventional frequency axial load fatigue tests are in good agreement. A fatigue strength at 10^8 cycles and zero means stress of approximately ± 14 ksi was obtained when using both methods to test 2024-T4 aluminum rod. The limited strain range and power of the barium titanate transducer, however, make it necessary to use a rather small specimen cross section at the expense of accuracy in the stress determination. This accuracy is of the order of $\pm 12\%$ and is not satisfactory from an engineering standpoint. Thus, if ultrasonic methods are to be used in the determination of fatigue strength values, a more powerful transducer that is able to vibrate a larger mass at a greater amplitude should be used. A.B.K.

Review: No definite conclusions are reached with respect to correlation between the 60 hertz and the ultrasonic axial fatigue tests; however, the paper does illustrate techniques for ultrasonic testing, which is its greatest contribution. It is hard to conceive of ultrasonic testing except in relatively small specimens because of power requirements and heating problems associated with high frequency tests of large specimens. As a result, any extrapolation of results obtained by ultrasonic techniques on small specimens to larger specimens might be subject to size and temperature effects and could require correction factors. The paper is excellent from the standpoints of organization and clarity.

R66-12767 ASSC 711; 712; 782
EFFECTS OF ENVIRONMENT AND TEMPERATURE ON THE ENVIRONMENT STRESS-CRACKING OF HIGH-DENSITY POLYETHYLENE.
H. Hojo, T. Ikeda., Y. Okamura, and Y. Suezawa (Tokyo Institute of Technology, Tokyo, Japan).
Materials Research and Standards, vol. 5, Feb. 1965, p. 55–59. 5 refs.

Tests on high density polyethylene were carried out at a constant temperature of 25° C under biaxial stress, with stress ratios of 0.25 and 1.0 respectively. Environments used were carbon tetrachloride, castor oil, ethanol, motor oil, trichloroethylene, and Igepal. Results show that under a constant stress ratio of 1.0, specimens tested in carbon tetrachloride and in trichloroethylene failed by ductile fracture accompanied by swelling; several relatively small cracks appeared in specimens tested in castor oil, motor oil, and ethanol; a few large cracks appeared in Igepal. In every environment, higher stresses caused smaller cracks. Data analyses are based on adhesion, which is defined as the work required for separating an adherent liquid from a unit area of a solid surface. It was concluded that the crack time is a function of adhesion between the specimen surface and the environmental liquid, as well as a function of equivalent stress and of stress ratio. To determine temperature effect, tests were carried out in Igepal at 15°, 25°, 40°, and 50° C under constant equivalent stress. Results indicate that the crack time is shorter when the temperature is high. A generalized design curve for predicting the crack time of a material is also presented. M.G.J.

Review: This paper presents an interesting analytical approach to the differences found in the time to crack in various environments. It offers a method for predicting life of polyethylene under arbitrary conditions of stress, environment, and temperature that may very well be applied to other plastic materials as well. The results are well presented in a paper that is brief and to the point.

80 RELIABILITY

R66-12749 ASQC 800
THE FUTURE OF RELIABILITY.
Robert A. Yereance (Battelle Memorial Institute, Columbus, Ohio).
Battelle Technical Review, vol. 13, Nov. 1964, p. 18–23. 8 refs.
(A65-10299)

Consideration of the probable course of reliability developments with reference to defense, space, and consumer products. Comment is made on the emphasis currently placed on physics-of-aging studies, circuit analysis, reliability prediction, accelerated test techniques, parts screening, and Bayesian and conventional statistics developments as an index of the significance of reliability as an identifiable activity. The history of the subject is reviewed, and early developments and the current situation are compared. It is considered that the emphasis on statistics will decrease, with increasing effort being devoted to studies of the physics of aging and the physics of failure. Improvements will be achieved in writing reliability specifications, in analyzing the cost of reliability, and in solving problems involved in contracting for reliability. Consumer products can be expected to benefit. F.R.L.

Review: This is a well-written general article, which reflects the author's good grasp of the over-all reliability field. The predictions for the future seem reasonable in view of current developments. For the statistician the following statement is noteworthy: "The field of Bayesian statistics holds particular promise for meeting the challenge of obtaining the most information from the fewest possible tests on a limited number of parts." This point is attracting some attention by statisticians and engineers (see, for example, RATR 1287, 1291, 2072, 2268, 2381, and 2430). Interest in this area is a natural consequence of the dependence of classical statistical methods on large samples, which are seldom available in practical reliability-analysis situations.

81 MANAGEMENT OF RELIABILITY FUNCTIONS

R66-12736 ASQC 814; 863; 872; 882
THE ECONOMIC ANALYSIS OF MAINTAINABILITY.
L. Calden (Honeywell, Inc., Aero-Florida Div., St. Peterburg, Fla.).
IEEE Transactions on Aerospace and Electronic Systems, vol. AES-2, Mar. 1966, p 201–204. 8 refs.
(A66-25660)

This paper discusses the application of appropriate analytic techniques to the formulation of a cost-effective tactical doctrine. The economic analysis of maintainability is concerned with the selection of one of several feasible alternative maintenance resource allocations. The available resources are specified by the operational deployment of the prime mission equipment. Operational requirements such as reaction time, on-station time, dispersal time, and mission time will directly affect maintenance doctrine and hardware. The complexity of the cost-operations-maintenance interaction and the consequences of decision are such that the selection of an alternative cannot be done by chance or by the adoption of the first feasible solution. Author

Review: For those who are concerned with fiscal constraints upon hardware design, this paper will convey a concise picture of the major considerations and an approach to their analysis. The concepts discussed are important in the design of prime mission systems for overall effectiveness—a broader context than that of such single indices as reliability, maintainability, availability, etc. While no great amount of detail is given in this paper, references are cited for those who wish to delve deeper.

R66-12752 ASQC 813; 844
Litton Systems, Inc., Beverly Hills, Calif. Guidance and Control Systems Div.
A SEMICONDUCTOR DEVICE RELIABILITY IMPROVEMENT PROGRAM FOR SEMICONDUCTOR USERS
D. E. Barnes and C. W. Brands (Litton Systems, Inc.) [1964] 30 p refs Presented at IEE Group Meeting, Los Angeles, 17 Feb. 1964

A semiconductor device reliability program is described which supplements the existing Darnell concept of reliability and is considered to better meet the needs of systems manufacturers. The program plan, based on a concept of identification and control of failure mechanisms, includes a research phase, an identification phase, quick decision tests for failure detection, and special reliability tests. A means of estimating the validity of the hypothesis is reported, and examples are included to show how various problems can be treated. Small-sample destructive testing and large-scale nondestructive testing are discussed, and a method for enforcement of manufacturing controls is given. M.W.R.

Review: This paper deals with problems of deciding how to insure reliability when you do not really know how, but when you must do the best you can. The programs that are suggested certainly appear reasonable and are about all that can be done in view of the state-of-the-art. (Some of the early discussion is not very pertinent and is rather narrow.)

82 MATHEMATICAL THEORY OF RELIABILITY

R66-12734 ASQC 824; 553
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
ESTIMATION OF THE SCALE PARAMETER OF THE LOG-NORMAL DISTRIBUTION BY M ORDER STATISTICS
Eugene Raymond Highfield (M.S. Thesis) Aug. 1964 66 p refs
(GRE-MATH-64-8; AD-610770; N65-28211)

Unbiased single order statistic and m-order statistic estimators of the scale parameter of a truncated lognormal probability density function are developed. It is assumed that the location parameter is known and that if it is not zero, a transformed variable with a location parameter approximately zero can be obtained. The development method of the single-order-statistic estimator was to consider the expected value of the i-th order statistic. The m-order-statistic estimator development uses the development of the single-order-statistic estimator and then considers the variance of the m-order-statistic estimator as a Lagrangian function which is minimized to obtain the necessary weighting factors. These weighting factors are then combined with the other coefficients to obtain the desired multipliers. The multipliers used to obtain the estimators, the variance of the estimators, and their relative efficiencies are tabulated. R.N.A.

Review: This paper will be useful to reliability engineers and statisticians interested in life testing when the underlying failure distribution can reasonably be assumed to be lognormal and when the data are truncated. The estimates based on using the first order statistic only will probably be very crude but may be useful in some contexts. There are some slight slips in the theory section of the paper. For example, the function F of equation (3.12) is not the same as the function F of equation (3.13), as the notation implies. Also the x_{in} on the top of page 18 is not a standard normal variable but rather the i-th order statistic from such a population. However, the explanation of the use of the tables, the useful part of the paper, is very good indeed and should enable the practicing engineer to use them correctly.

R66-12744 ASQC 824; 553
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
ESTIMATION OF THE SCALE PARAMETER OF THE GAMMA DISTRIBUTION BY USE OF M ORDER STATISTICS
Richard Alan Bruce (M.S. Thesis) Aug. 1964 142 p refs
(GRE-MATH-64-2; AD-610768; N65-28210)

A technique is developed for estimating the scale parameter of a Gamma distribution with known shape parameter using m order statistics. Basic properties of the Gamma distribution and certain theoretical concepts of order statistics are presented. A linear unbiased minimum variance estimate can be computed by applying tabulated multiplying factors to the first m ordered observations. Multiplying factors which yield one-order-statistic estimates are also tabled. Two efficiencies for the one-order-statistic estimators are given: the first is based on the m-order-statistic estimator and the second is based on the maximum likelihood estimator. Table ranges include shape parameters $\alpha=1(1)3$ for sample sizes $n=1(1)20$ and $\alpha=4(1)6$ for $n=1(1)15$. Author

Review: This is a useful paper for reliability personnel interested in estimating the scale parameter from small samples when the lifetime distribution is the Gamma with *known* shape parameter. The estimates are easy to obtain, being simply linear combinations of the order statistics. The bulk of the thesis is devoted to tables of the required coefficients. Two typographical errors in the theory section might be noted. On page 9 the right side of Eq. (2.15) should be divided by 0 and on page 17, Eq. (3.21) should have $B_p(n-i+1, i)$ in the numerator. The explanation of the use of the tables is very helpful. The author in a private communication has mentioned that this paper was only one step in the process to enable a more widespread application of order statistics. Continuing effort in this area is being conducted by Dr. H. Leon Harter, Aerospace Research Laboratory, and Professor Albert H. Moore, Air Force Institute of Technology, both located at Wright Patterson Air Force Base, Ohio.

R66-12747 ASQC 820; 711; 712
Columbia Univ., New York.
THE EFFECTS OF RESIDUAL STRESS ON RANDOM FATIGUE LIFE
R. A. Heller, M. Seki, and A. M. Freudenthal [1964] 19 p Presented at the 67th Ann. Meeting of the Am. Soc. for Testing and Mater., 21–26 Jun. 1964

Effects of residual stresses on fatigue damage accumulation and fatigue life of 7075-T6 circumferentially notched rotating bending specimens under constant-amplitude and randomized exponential stress distributions are presented. The variation of the strength reduction factor as a function of prestress and load spectrum is examined. An approximate analysis of the elastic-plastic stress distribution at the minimum cross section is suggested on the basis of which fatigue behavior can be predicted. Results indicate that the linear (Miner) cumulative damage rule quite generally overestimates fatigue lives except in the alternating plasticity range. The endurance limit is considerably reduced as a result of stress interaction if in applying the linear damage rule the *S-N* diagram for the prestressed specimen is used. In the range of alternating plasticity at the root of the notch, $10^3<N<10^4$, the linear rule consistently underestimates the fatigue life. Author

Review: This paper is well documented with illustrations and references; but certain portions of it are somewhat difficult to follow because, perhaps, of the mathematics or the complex subject matter. It is however, recommended reading and reference material for persons having responsibility in the area. The sections on strength reduction factors and on the beneficial or detrimental effects of residual stresses should alert design engineers, particularly the beginners, to the dangers of using fatigue data obtained from smooth specimens. The authors have demonstrated, as have many others, that the linear or Miner rule of cumulative damage generally overestimates the life of notched parts. (The mathematics of the paper was not checked in its entirety.)

R66-12751 ASQC 824; 821
A PITFALL IN ACCELERATED LIFE TESTING.
W. R. Allen (Princeton University, Princeton, N. J.)
Repr. from *Naval Res. Logistics Quart.*, vol. 10, no. 2, Sep. 1963, p 271–273.

Simple probability is used to illustrate a major pitfall which can occur through the use of standardized accelerated life tests for acceptance testing or estimating life. An example is given which has more than a single mode of failure, and it is shown that misleading conclusions can result when pertinent failure modes are not accelerated equally. In the example cited, it is seen that an artificially dominant failure mode is found which does not agree with actual use conditions; and a mean life under actual use conditions is estimated which is, in fact, three times the true mean life for the example used. M.W.R.

Review: The author has used simple probability to illustrate a major pitfall in accelerated testing: the danger of entirely misleading conclusions when the pertinent failure modes are not accelerated equally. The major point applies to any accelerated-life-test situation—not just the one illustrated. However, in many practical situations the "truth" regarding the effects of acceleration can be quite elusive. This point is worth bearing in mind, with a view to giving it as much attention as available time and effort permit. This paper was published three years ago, and the author has indicated that the example was constructed some five years before that. However, for those concerned with accelerated life tests the point made is still very timely.

R66-12753 ASQC 824; 413
SEQUENTIAL LIFE TESTS FOR THE EXPONENTIAL DISTRIBUTION WITH CHANGING PARAMETER.
L. A. Aroian and D. E. Robison (TRW Systems Group, Redondo Beach, Calif.).
Technometrics, vol. 8, no. 2, May 1966, p. 217–227. 14 ref

A life test on n independent and identical items having exponential distribution of life with probability density function is considered. The sequential probability ratio (SPR) test region is derived for testing hypotheses in which the exponential parameter and its alternatives change value a finite number of times. The operating characteristic function is defined, and the average time to termination of the test is determined by the sum of the average time to terminate the test by acceptance plus the average time to terminate the test by rejection. A technique for applying SPR test regions to the normal or Weibull distributions is proposed. M.G.J.

Review: This is a mathematical paper which makes a contribution to the theory of life testing based on the exponential distribution. Applications to nonexponential life distributions are mentioned briefly. An approximation to the average time to termination is given. Additionally, the article makes it clear how to find the exact average time to termination. It is indicated that the difficulties encountered in constructing sequential probability ratio test regions for distributions such as the Normal or Weibull can be circumvented by approximation $\lambda(t)$ by a step function having constant λ_i in the i th subinterval. The references cited include a number of other papers on various aspects of sequential life testing.

83 DESIGN

R66-12738 ASQC 833; 871
ELECTROMECHANICAL SWITCHING DEVICES—RELIABILITY, LIFE AND THE RELEVANCE OF CIRCUIT DESIGN.
A. G. Leighton (General Post Office, Engineering Dept., London, England).
(Symposium on Engineering for Reliability in the Design of Semiconductor Equipment, Hatfield College of Technology, Hatfield, Herts., England, May 13, 14, 1965, Paper.)
Radio and Electronic Engineer, vol. 31, Feb. 1966, p. 99–109. Research supported by the Hatfield College of Technology, Institution of Electrical Engineers, and the Institution of Electronic and Radio Engineers.

Discussion, with reference to electromechanical switching devices, of those aspects affecting reliability which are within the orbit of influence of the user rather than those within that of the designer or manufacturer. General considerations include mechanical wear and tear. Many EM devices are affected by a comparatively short early failure period, followed by a longer period during which a lower but constant failure rate can be expected. Extensive consideration is given to the maintenance organization setup, which plays a large part in establishing the overall reliability. Two-motion selectors, uniselectors, relays and electrical contacts are described. Attention is given to the quenching of electrical contacts and to circuit design. F.R.L.

Review: This paper will be of interest and value to those concerned with the reliable operation of rotary switches and relays. It is written from the point of view of the user rather than the designer or manufacturer of these devices. While the reference in the paper is to devices of British manufacture, the principles and ideas advanced obviously have wider applicability.

R66-12739 ASQC 830; 835; 838
LONG-LIFE ELECTRONICS.
D. S. Peck and R. H. Shennum (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).
Space/Aeronautics, vol. 45, Mar. 1966, p. 81–87.
(A66-25690)

Discussion of ways to attain the high reliability and long lifetime which will be necessary for electronic systems in long-term space experiments. It is suggested that too much emphasis is currently being placed on redundancy. The calculation of failure rates is reviewed. The importance of proper screening and testing is stressed. Integrated circuits are seen to be of great value in increasing lifetime. R.A.F.

Review: This is a well-written discussion of the reliability and life requirements for spacecraft electronics, and some of the means available for meeting them. Not least among these means is careful work—careful qualification, screening, selection, and assembly of parts. Scientific breakthroughs are important, of course, but without painstaking attention to detail their potential will not be realized. Other points which are discussed effectively in the paper include analysis of mission objectives, the pros and cons of redundancy, and design based on integrated circuitry. While none of these points are treated in great detail, the paper will be worthwhile reading for designers of spacecraft electronic equipment.

R66-12740 ASQC 837; 844
SEMICONDUCTOR DIODES FOR POWER RECTIFICATION.
E. E. von Zastrow (General Electric Co., Semiconductor Products Dept., Auburn, N.Y.).
Machine Design, vol. 37, Feb. 18, 1965, p. 191–198. 10 refs.
(A65-17193)

Survey of the performance characteristics of the modern silicon diode. Typical diodes rated from about one-half to several hundred amp at 50 to over 1000 volts are illustrated and discussed. Power-rectifier circuits are examined and the key ratings and characteristics as well as possible applications are discussed. Simple guidelines for the selection of diode stacks for ac-to-dc rectifier applications are presented. V.P.

Review: This phenomenon certainly has been a problem and this article does discuss a traditional method for alleviating it. The assumptions are, of course, only an approximation to the actual conditions; when using the formulas, attention should be paid to their derivation. While several transient conditions are mentioned, not all of them are accounted for in the analysis, e.g., corona and capacitance-to-ground. However, the author in a private communication has pointed out that these are of interest only in specialized "high-voltage" applications. The use of avalanche rectifiers is expected to reduce the need for compensation in properly designed systems. The article does point up how much power is wasted in the compensation.

R66-12741 ASQC 835; 844
WHAT IS MEANINGFUL INTEGRATED-CIRCUIT RELIABILITY?

J. D. Adams and P. L. Holden (Texas Instruments, Inc., Dallas, Tex.).
Electronic Design, vol. 13, Nov. 22, 1965, p. 54, 56, 57.
(A66-15369)

Study of the use of step-stress techniques to induce failures and thus pinpoint sources of reliability problems regarding integrated circuits. Cumulative test results from 2354 devices that were tested at various temperatures over a two-year period are tabulated, as are reliability data on specific logic types, derating factors for integrated circuits, a step-stress test schedule, and sources of failure in integrated devices. B.B.

Review: This is a worthwhile report of some results of accelerated testing of integrated devices. The authors have packed a considerable amount of detail into a rather short paper, which should be of interest and value to designers dealing with integrated circuits. There appears to be an error or misprint in Fig. 4 (erroneously referred to as Fig. 6 near the end of the paper). The percentages add up to 80.2%, in spite of an implication of exhaustiveness in the sources of failure which are represented.

R66-12742 ASQC 830; 844
GREMLIN-PROOFING: SOME ANSWERS TO NATURE'S SNEAKIEST TRICKS.
George H. Gill (Naval Ordnance Test Station, China Lake, Calif.)
Electronic Design, vol. 13, Nov. 22, 1965, p 42–47.

The electronic equipment designer is cautioned to pay attention to details, including those which are not obvious trouble sources. A few of these unusual "gremlins" are discussed; and it is pointed out that because more failures are probably caused by voltage spikes or surges than by any other individual factor, inspection for such surges should be made in any situation where the source impedance is high. Transistors which operate at microvolt levels can have thermo-, piezo-, tribo-, or chemoelectric effects that produce voltages to upset circuit operations. Some of the more volatile metals associated with electronic components produce hot whiskers which must be avoided. Interactions between mechanical structures and the electronic circuit can bring on "gremlins" due to vibration and shock; and many more subtle interactions can cause difficulty, such as alteration of current-division between parallel paths of different metals due to temperature changes. Avoidance of mutual heating of closely-mounted parts is discussed. M.W.R.

Review: This paper has a good message for the designer of electronic equipment. Briefly, it is this: pay attention to the details, including those which are not obvious sources of trouble. This in itself is worth pointing out, and the paper presents a number of specific troubles of which to be wary. The experienced designer could no doubt add others to the list.

R66-12743 ASQC 838; 844
Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
RELIABILITY OF SERIES, PARALLEL, AND QUAD REDUNDANCIES WITH DEPENDABILITY FAILING COMPONENTS
Harvey B. Blanton, Jr. (M.S. Thesis) Aug. 1963 77 p refs
(GRE/MATH/63-3; AD-425718; N65-85636)

General reliability equations are developed for redundancy networks of the series, parallel, and quad configurations composed of components which may fail in an open or short mode. The dependence of component failure frequencies is considered; i.e., the fact that when one redundant component fails, the failure frequencies of the remaining components in the network may change due to a change in component operating stress level. Specific networks are analyzed using the derived equations, and the resulting reliability figures are compared with results obtained when independence of component failure frequencies is assumed. Author

Review: This paper contains a rather fundamental difficulty very near the beginning and is an example of the fact that faculty supervisors do not always critically read theses. Most probably the difficulty is caused by poor notation which in turn reflects a lack of rigor in defining events and in associating probabilities with them. The item in question is $R(t|t_1)=R(t)/R(t_1)$ which is formally true if R(x) stands for the probability of the event x. But $R(t|t_1)$ stands for the probability of the item's surviving to time t given that it survived to $t_1<t$ and also that the failure behavior in 0 to t_1 may be different from that in t_1 to t. The same confusion is apparent in an example, which precedes the above formula, where the failure probability density function (pdf) is $f(t)=1,\ 0<t<1;\ g(t)=2,\ 0<t<1/2$, and both $f(t), g(t)=0$ elsewhere (f holds from 0 to t_1 and g holds from t_1 to t). The author asserts that the item must fail for $t\leq1$. But if this is true, the variable t in g(t) has a most unusual definition. About the only thing he can mean is $f(t_1)=1,\ 0<t_1<1;\ g(t-t_1)=2,\ 0<t_1-t<1/2$, and both f and g=0 elsewhere, in which case the item need not fail until t=1-1/2. Obviously this was not intended and just as obviously, the notation has confused the author. He has also not given consideration to the combined pdf since the combination is not normalized. The problem tackled here is most difficult and once a general equation has been recorded, there is not much that can be done with it without assuming some theory of damage or of failure behavior. Shorthand notations and lack of rigor are not condemned because of excessive zeal on the part of theorists, but they are condemned because they can so easily be misleading. It is not so bad when you mislead others, but when you mislead yourself too it is quite discouraging.

R66-12745 ASQC 830; 782
Filtron Co., Inc., Flushing, N. Y.
INTERFERENCE REDUCTION GUIDE FOR DESIGN ENGINEERS, VOLUME I
Ft. Monmouth, N. J., Army Electron. Labs., 1 Aug. 1964 376 p
(Contract DA-36-039-SC-90707)
(AD-619666; N66-14925) CFSTI: HC $7.00/MF $1.75

As the design engineer must consider how the functional requirements of equipment are affected by interference characteristics, the necessary background information and techniques for minimizing interference generation and susceptibility are presented as a guide. The terms peculiar to interference engineering are defined and the general characteristics of interference are described. Interference sources are categorized as natural, inherent, and manmade, and transfer media are identified as conducted or radiated interference. Electromagnetic compatibility control and test plans are given as typical examples of the procedures necessary for determining radio frequency interference. Two approaches to interference reduction are discussed: initial design for optimum interference reduction (from electronic equipment design through final production), and application of remedial interference control measures after equipment has become operational. The first approach is given preference. Details are also given on design considerations for grounding, bonding, shielding, cabling, and equipment mounting. M.G.J.

Review: These two volumes represent a very impressive summary of practical considerations in designing to minimize interference. Interference, a curse to engineers, is just one of many important environments and has generally received less than adequate attention in the past. This guide will be a distinct asset to circuit and package designers. The text is well written in understandable, everyday engineering language. It wastes no time in getting down to practical, clearcut considerations. The detailed index which is found in Volume II will contribute to the acceptance of this guide as a ready reference. The extensive bibliography will also be very helpful.

R66-12746 ASQC 830; 782

Filtron Co., Inc., Flushing, N.Y.

INTERFERENCE REDUCTION GUIDE FOR DESIGN ENGINEERS, VOLUME II. CHAPTER III: CIRCUIT DESIGN

Ft. Monmouth, N. J., Army Electron. Lab., 1 Aug. 1964 445 p refs

(Contract DA-36-039-SC-90707)

(AD-619667; N66-14226) CFSTI: HC $7.50/MF $2.00

For abstract and review see R66-12745.

R66-12748 ASQC 831; 612; 817; 844

PREDICTION OF DESIGN RELIABILITY OF VERY LARGE SOLID-ROCKET MOTORS.

P. Kluger (Aerojet-General Corp., Liquid-Rocket Plant, Propulsion Systems Analysis, Sacramento, Calif.).

American Rocket Society, Solid Propellant Rocket Conference, Philadelphia, Pa., Jan. 30–Feb. 1, 1963, Preprint 2755-63.) Journal of Spacecraft and Rockets, vol. 1, Mar.–Apr. 1964, p. 139–142.

(ARS Paper 2755-63; A64-16634)

Presentation of a technique for predicting the a priori design reliability of large solid-propellant rocket motors. It is postulated that motor reliability may be expressed as the product of its structural reliability and its performance reliability. Structural reliability, defined as the probability that the structure will successfully retain the motive elements for the intended duration within the environmental envelope, is computed by making use of the distributions of environmental stresses and material strengths. Performance reliability, or the probability that the motor will perform within established performance limits, is estimated using computer simulated firings of the motor. The independent computer input variables, expressed stochastically, are used in conjunction with Monte-Carlo-type random sampling. An arbitrary number of such computer firings are run, and the performance reliability is calculated on the basis of the number of times specified performance parameters have been satisfied. The application of the prediction technique to design-tradeoff and system-optimization studies is discussed. IAA

Review: The paper is an example of the use of equations to predict performance or reliability. There is little new in it (even at the time of publication) but the work appears to be accurate. (The term "independence" of failures refers to statistical independence which may well be different from physical independence. There are a few unimportant misprints in the equations.) Anyone who would like to see an illustration of these techniques will find this paper adequate, though brief.

R66-12750 ASQC 831

RAND Corp., Santa Monica, Calif.

AN INTRODUCTION TO SYSTEM EFFECTIVENESS

H. S. Dordick Oct. 1965 9 p

(AD-622417) CFSTI: HC $1.00/MF $0.50

System effectiveness is defined as a measure of the extent to which a system can be expected to complete its assigned mission within an estimated time frame under stated environmental conditions. For systems effectiveness, reliability and maintainability parameters must be considered and traded off with performance criteria. Defining effectiveness measures for the designer shifts from the research-orientation of looking for basic principles to techniques for organizing design performance, managing design performance, and setting up a structure of project management within which the designer must work. Author

Review: This is a short rather challenging paper. It emphasizes the problems caused by the theoreticians having devised conceptual models for the designers to follow wherein the required numbers are not available to the designers. There seems to be an implication that a single Figure of Merit (FOM) for a system is not feasible; yet we eventually must make a choice based on preference and preference is a simple ordering of values by its very nature. If we have to make a decision we use some FOM, however ill-defined, qualitative, and personal it may be.

R66-12754 ASQC 830; 612; 740

DESIGNING EQUIPMENT WITH COMPUTERS.

R. T. Herbst (Bell Telephone Labs., Inc., New York).

Bell Laboratories Record, vol. 44, no. 4, Apr. 1966, p 129–134.

The potential of using computer simulation for complex digital information processing systems is assessed, and the basic features of two design-aid computer programs are described. One was used to help design logic chassis for military equipment; the other is a rack-wiring program for the electrical design of racks used in UNICOM equipment. Methods of preparing input information are discussed, along with the assembly process in which the computer finds the best way of placing functional packages on a chassis so that the electrical and mechanical design rules are satisfied. Mechanical and electrical constraints on the wiring program are examined, and manufacturing techniques are summarized. The problems involved in computer program designs are considered. The input systems for both programs are outlined. Although problem areas are identified, it is pointed out that eventually the use of computers may prove to be the most practical way to insure the accurate generation of information for manufacturing data processing equipment. M.G.J.

Review: As a contribution to the reliability literature, this paper serves mainly to illustrate another example of the elimination of the possibility of human error in design by the use of automated techniques. The description of the computer programs is general but adequate for understanding the concepts. Programs of this type are well-suited for design situations typical of that described here, i.e., the design of several equipments having similar functional and physical configurations. They do not replace the designer but do free him from much mental drudgery in performing design detail. The author acknowledges that many basic engineering problems still require solution before these programs can be used. For example, the actual hardware structure and certain electrical and mechanical rules must be established. Also, allocation of various system functions to specific hardware must be performed.

R66-12755 ASQC 830; 612; 740

AUTOMATED DESIGN.

Lucien A. Schmit (Case Institute of Technology, Cleveland, Ohio).

International Science and Technology, no. 54, Jun. 1966, p. 63–66, 68, 70–71, 74, 76, 78.

The concepts of automated design are described in relation to the use of digital computers for predicting the behavior of proposed designs, and for testing and evaluating these designs against clearly defined constraints. A simple example involving a planar three-bar truss is given to show how engineering design problems can be converted into mathematical programming problems. The distinction between automated optimum design and computer-aided design is delineated. The three basic needs of automating design, defined as a specified list of restrictions, a good analytical method, and an objective function, are examined, and the steps involved in organizing a design problem for automating are detailed. Methods of redesign by computer are also considered, including the methods of random steps and of constrained steepest descent. The potential of these design synthesis techniques is assessed in terms of cost and time savings, and the need for more effective communication between the design engineers and mathematical programmers in advancing computer technology is stressed. M.G.J.

Review: This paper is a good general description of the concepts of automated design but will provide little enlightenment for persons already engaged in automated design practice. It can serve as a good introduction to the problem, for example, in informing management personnel about what automated design involves and what it can do. With due warning, however, there is a tendency to over-simplify the problem. The full potential of automated design is far from being realized. A major application of optimization techniques to date has been for sophistication of system effectiveness studies. The practice is becoming more widespread, however, at the hardware design level. Advantages cited are cost and time savings, elimination of drudgery for the designer, and decrease in the possibility of human error. Even with automated design, there still remains a tremendous amount of engineering design effort in formulating the problem for computer solution. Clear distinction is made in the paper between computer-aided design (primarily analysis) and automated optimum design. The former is an inherent part of the latter, and analysis modeling and programming advancements will enhance automated design practice. In addition to the two optimization schemes discussed in the body of the paper others are identified in the references cited under "To Dig Deeper" on p. 115–116 in the same issue of the magazine.

R66-12756 ASQC 830
NEW LONG-LIFE GREASES MAKE POSSIBLE PERMANENT LUBRICATION.
R. I. Potter, E. J. Schanilec (Ford Motor Co., Dearborn, Mich.), and C. L. Knighton.
The SAE Journal, vol. 73, no. 8, Aug. 1965, p. 48–50.

The properties which make high density polyethylene, lithium, and molybdenum disulfide suitable for life-long lubrication are defined as low wear, oxidation stability, corrosion resistance, low oil separation, shear stability, water resistance, and high dropping point. The performances of three lithium greases and a typical calcium chassis lubricant, subjected to 100,000 mile tests, are compared; satisfactory performance was obtained with the lithium soap grease containing additives. The composition and performance requirement specifications for three chassis lubrication greases are listed. The thickening effect of high density polyethylene and lithium soap in several oils was also studied. Findings indicate that the high density polyethylene is an effective grease thickener, and that its inherent chemical stability and low friction characteristics result in better performance than conventional greases thickened entirely with metallic soaps. M.G.J.

Review: This is a brief report on long-life lubricants. While the results are of the most direct interest in the automotive industry, they will be useful to others concerned with the lubrication of mechanical systems. More details may be found in three SAE publications (Papers 640841, 640784, and 640785) which are referenced in the paper.

84 METHODS OF RELIABILITY ANALYSIS

R66-12735 ASQC 844; 770
MICROELECTRONICS AND RELIABILITY ASSESSMENT.
Joseph B. Brauer (USAF, Systems Command, Electronic Systems Div., Rome Air Development Center, Griffiss AFB, N.Y.).
Electronic Industries, vol. 25, Apr. 1966, p. 67–71. 11 refs.
(A66-26226)

Study of reliability assessment techniques for microelectronics. The "inherent reliability" of integrated circuits is considered and the problem of predicting system reliability is discussed. It is noted that effective screen tests are necessary to give the best possible reliability of the basic product. Accelerated testing techniques of various kinds have been devised that provide economical means for measuring this reliability. It is concluded that some significant changes are needed in the precise methods of reliability assessment. M.F.

Review: This is a good paper for the purpose; it is clearly written, well documented, and nicely illustrated. It conveys a worthwhile message. Perhaps outside the terms of reference of the paper, but certainly pertinent to the problem, is the matter of having effective nondestructive screening tests which really do the job of identifying the early failures. The setting up of these will make demands on the knowledge, ingenuity, and judgment of the test engineer. Similarly, the drawing of valid conclusions from accelerated tests is not generally a simple matter. The author in a private communication has commented on the rarity of tests with wide variations in applicability and effectiveness. One of the purposes of this paper was to charge the industry with the responsibility of doing constructive work in this area rather than merely responding to individual customer demands. RADC is currently initiating a program to shed some light on this problem.

R66-12737 ASQC 844; 774
DEFECT ANALYSIS BY DEVICE SECTIONING.
Murray Siegal (Fairchild Camera and Instrument Corp., Fairchild Semiconductor Div., Mountain View, Calif.) and Roger Crosby.
Semiconductor Products and Solid State Technology, vol. 9, Mar. 1966, p. 35–37.
(A66-24849)

Outline of simple sectioning techniques which can be utilized without either extensive knowledge of the preparation of metallurgical specimens or the possession of excessively expensive equipment. When very small structures are to be sectioned, and it is desirable to "magnify" them, angle sectioning techniques can be used. A convenient way to angle section a sample uses a stainless steel block on which a ramp has been machined at some desired angle. In addition to showing the electrical damage, the sectioning technique can also be used to study bond shape, bond–surface contact intersection, junction depths and widths, device crystallography, solder joint between device and header—in short, any substructure characteristic which lies within the resolution limit of the microscope. M.F.

Review: This paper points out the value of sectioning as a failure analysis tool in dealing with semiconductors. The steps in the process are clearly described and summarized. The paper can be understood readily by the person not previously familiar with the process, but effective application will require some experience in identifying the conditions being sought together with their probable causes.

R66-12757 ASQC 845
THE NEED FOR CENTRAL ASSESSMENT OF RELIABILITY DATA.
Crawford Robb (Belling and Lee, Ltd., Enfield, England).
Electronic Components, vol. 6, no. 5, May, 1965, p. 430–437. 11 refs.

The importance of establishing a national assessment center is emphasized, based on the premise that the reliability statistics will be crucial in establishing the proportions of good design and in governing final success on the many rapidly moving technological projects. Concepts are assessed, and the point is made that the ultimate factor in determining electronic equipment reliability may not be related to the design; it may directly reflect the attitude of the user toward his equipment. The inadequacies inherent in mathematical models used for computing component reliability are discussed, and the main sources of error in product specifications are outlined. The basic relationship between a manufacturer and his market is considered, and the way in which a complex industrial dynamic network develops is depicted. The points are made that information feedback to design sources must be greatly increased to improve the correlation between model building studies and user experience, and that data classification and assessment are of critical importance. M.G.J.

Review: This is a well-written paper which is addressed to an important problem. Conceptually, the proposal put forward is excellent. However, certain difficulties will have to be overcome before it can be implemented. These include adequate and equitable financing by the users of the center, security for proprietary information, and some way of summarizing the data. The uses of masses of raw, rather unrelated, data on a component are quite limited. It would seem that the proposal calls for something in the nature of the Electronic Component Reliability Center at the Battelle Memorial Institute (see RATR 54), rather than an operation such as PRINCE, FARADA, or IDEP. The author in a private communication has expressed the belief that the important difficulties in operating an assessment centre relate to specification limits and to the interpretation of failure, rather than to the financial and proprietary problems.

R66-12758 ASQC 844; 543; 775
A METHOD FOR CORRELATING DEFECTS DETECTED BY NONDESTRUCTIVE TESTS WITH SYSTEM PERFORMANCE.
R. W. Cribbs (Aerojet-General Corp., Sacramento, Calif.).
Materials Evaluation, vol. 22, Oct. 1964, p. 473–478.
(A65-10461)

Description of a system for arriving at standards and specifications by using nondestructive test inspection results, statistical methods, and engineering fundamentals. The technique is said to utilize methods that are applicable to large masses of data (requiring automatic computers), ill-defined performance requirements, and a qualitative relationship between defects and system performance. Two illustrations indicating a successful resolution of these factors are demonstrated. The first example traces the course of establishing the effect of multiple defects on the performance of a large ring conductor for use in a hypothetical flying saucer. The second example involves the vehicle assembly for the flying saucer. In this case the number of defects is greater, and engineering knowledge is less. A data-collection system amenable to statistical analysis is described. (Author)

Review: This paper is concerned with a topic of importance in the testing of aerospace systems—the quantification of the results of nondestructive testing. The need for simplicity in the model is discussed and two statistical models are introduced: the contingency table and multiple linear regression. The first of these would seem to be too simple to be of great value. The second provides a means of obtaining a "best" linear relationship between a chosen performance parameter and certain "defect indices." This can give misleading results if in fact the true underlying relationship is not linear. A way of overcoming this would be to use a model involving quadratic and higher-order terms. Furthermore, careful attention should be paid to the underlying assumptions if statistical inference is to be applied to the results. The ideas presented in the paper are basically good, and it would be interesting to see them applied to an actual system on which appropriate data are available.

R66-12759 ASQC 844; 711; 713
CHARACTERISTICS OF MATERIALS FOR UNDERWATER USE.
J. H. Cunningham and H. R. Jacobson (Douglas Aircraft Co., Missile and Space Systems Div., Advance Missile Technology, Airframe and Propulsion Branch, Santa Monica, Calif.).
American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, Ill., May 11–14, 1964, Paper 64-MD-62. 10 p. 13 refs.
(ASME Paper-64-MD-62; A64-24333)
Members, $0.50; nonmembers, $1.00.

Review of the material characteristics, design factors, and trade-off considerations which are involved in the selection and application of materials for use in deep submergence vehicle structure. It is stated that the exploitation of the ocean will require the development of self-buoyant vehicles capable of operating at great depths. In order to undertake the types of missions contemplated, the use of more structurally efficient materials in such vehicles is required to reduce hull weight and increase payload carrying capability. It is noted that, while a strength and stiffness are the most obvious material parameters involved, for a given vehicle, the selection of a material cannot be made without reference to the structural configuration, its feasibility, and cost of fabrication.

Review: The paper presents a general discussion and overview of the considerations involved with deep-diving vehicular hull design. It is brief and well written in simple semi-technical terms. The emphasis is not particularly quantitative; the value of the paper is apparently confined to the field and to persons who have responsibility in this area or to persons seeking basic orientation in the topic. There are lessons to be learned from this for structures designers in general, namely, ways of finding the best uses for materials when the environment is a limited one. One learns that rules of thumb can be inadequate. The paper is informative and easy to read.

R66-12760 ASQC 844; 714; 716; 760; 782
AIRCRAFT CORROSION.
C. Bradley Ward (USAF, Systems Command Research and Technology Div., Materials Laboratory, Wright-Patterson AFB, Ohio). *(Society of Automotive Engineers, National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., Oct. 5–9, 1964, Paper 922A.* 10 p.). Summarized in *SAE Journal,* vol. 73, Feb. 1965, p. 70–73.
(SAE Paper-922A; A65-12816)
Members, $0.75; nonmembers, $1.00.

Brief review of Air Force experience with aircraft corrosion problems. Problem areas discussed include integral fuel tank corrosion, stress corrosion, exfoliation corrosion, and general corrosion. Specific examples considered include contamination on the surface of integral fuel tank, corrosion pits on 5052 aluminum tubing removed from an integral fuel tank, stress corrosion crack in wing-to-body terminal forging, exfoliation blisters in clad 7075-T6 aluminum fuselage side skin, and severe pitting of thinclad 7075-T6. Experience with the use of "wet" fasteners and complete painting to minimize exfoliation corrosion is presented, and corrosion problems experienced with clad skins are discussed. M.G.

Review: This paper is well documented with interesting examples and case histories, but there is little if any new information presented. The paper would normally be most useful to the beginning aircraft design engineer; however, it points out to the seasoned aircraft design engineer that corrosion resistance has not been properly considered in previous designs. This paper is for general reading and not for reference. One or two typographical errors were detected.

R66-12761 ASQC 844; 712; 755; 775
THE USE OF ULTRASONICS IN FATIGUE TESTING.
Richard B. Socky (General Electric Co., Missile and Space Div., Valley Forge Space Technology Center, Valley Forge, Pa.).
Materials Evaluation, vol. 22, Nov. 1964, p. 509–515. 21 refs.
(A65-14657)

Description of a case of the effective use of ultrasonics in fatigue testing, despite a limited understanding of transverse wave phenomena and the incomplete development of angle-beam testing. A brief survey is given of such phenomena and of angle beam theory. The initiation of hot cracks and the spread of fatigue cracks in welded carbon steel pipe were investigated. From characteristic response curves, critical crack size could be determined. By making more exact measurements of ultrasonic response, quantitative determinations of the rate of fatigue crack growth could be made. From the crack growth rate, fundamental properties of the material being tested related to brittle fracture, notch sensitivity, and stress energy propagation could be deduced. It is thought that ultrasonic testing can be a valuable adjunct in the correlation of material characteristics. D.H.

Review: This paper is particularly good for the beginner or the partially informed person. It is well written, easy to follow, thoroughly documented with references and supplementary references, and well illustrated. It will be of greater value to the test engineer than to the design engineer.

R66-12762 ASQC 844; 520; 712; 770
STATISTICAL ASPECTS OF FAILURE ANALYSIS—CASE HISTORY OF A PART.
J. Forgione (Ford Motor Co., Engineering and Research Staff, Dearborn, Mich.).
(National Metals/Materials Congress, Cleveland, Ohio, Oct. 23, 1963.)
Metals Engineering Quarterly, vol. 4, Nov. 1964, p 18–22. 4 refs.

Details are given on a typical laboratory life test in which the Weibull distribution was applied to analyze the data. The device used was an experimental door lock assembly, and the tests were designed to determine the life characteristics or failure mode of each component. To eliminate the problems connected with individual testing, the total assembly was tested and failures were analyzed on a system basis. Fundamentals relating to the Weibull distribution are reviewed, and the general distribution for the Weibull cumulative distribution function is formulated. Test data on the mechanism are tabulated, and the frequency of failure is discussed. The failure mode was examined, and results indicate that the failures were attributable to the actuating link. Evaluation of the mechanism, and corrective measures are discussed. In evaluating the use of the Weibull distribution, it was concluded that the laboratory test should be designed to provide statistically meaningful data; and that laboratory test data can be rapidly converted into useful and easily interpreted engineering information. M.G.J.

Review: This article is recommened reading for design engineers and test engineers. The ideas which are presented are not new, but they are presented with simplicity. The reader should keep in mind that the data pertaining to the life of the door mechanism is not the significant point of the paper. The author uses the door lock mechanism as a case history to illustrate the steps required to design a test which will yield statistically-meaningful data. Furthermore, he uses this paper to demonstrate the value of the Weibull distribution as a statistical tool.

R66-12763 ASQC 844; 712; 713; 716
FAILURE IN AIRCRAFT PARTS MADE OF ULTRA-HIGH-STRENGTH STEEL.
William L. Holshouser (Civil Aeronautics Board, Bureau of Safety, Engineering Div., Washington, D.C.).
(National Metals/Materials Congress, Cleveland, Ohio, Oct. 23, 1963.)
Metals Engineering Quarterly, vol. 4, Aug. 1964, p 8–14.

An overall review is presented of the methods used in investigating failures in aircraft parts made of ultrahigh strength steel. Two failures occurred in the main landing gear truck beams, the major strength members of the four-wheel truck assembly; the other was in a shock strut cylinder, the primary vertical load-bearing member of the landing gear assembly. Details on each failure are given, and the findings from laboratory examinations of each part are discussed. Based on experience with landing gear components and the investigation of service failures, it was concluded that quenched and tempered steels can be used successfully at ultrahigh stress levels if extreme care is taken in their processing and fabrication, and in the design and maintenance of the structures in which they are used. Precautions are recommended, including sensitive inspection techniques to assure the use of clean steel and freedom from significant surface and subsurface defects; conservative designs allowing for the limitations of stress analysis and load determination methods; precise control of heat treating, cleaning, and plating procedures; adequate protective coatings; frequently cleaned lubricated surfaces; and prevention of mechanical damage in service. M.G.J.

Review: This paper is interesting, well written and easy to read. It is not for reference, but it is recommended for general reading. The paper is well illustrated with photographs, and it should be particularly useful to the beginning design or materials engineer.

R66-12765 ASQC 844; 775
A NEW APPROACH TO THE ATTAINMENT OF THE HIGHEST POSSIBLE RELIABILITY IN TANTALUM CAPACITORS.
John Burnham (Ti-Tal, Inc., Santa Monica, Calif.).
IEEE Transactions on Component Parts, vol. CP-12, Mar. 1965, p. 21–29.
(A65-26622)

Discussion of the question of how to achieve the highest possible reliability for tantalum capacitors, from both the theoretical and practical points of view. A method of achieving reliabilities of the order of 95% at a confidence level of 95% or better is described which involves an analytical treatment of the physics of the main mode of failure, all accounting for over 95%; and a statistical model is derived which demonstrates this reliability on a highly accelerated test. The test is applicable on a 100% basis to the test capacitors and, as it is nondestructive, it allows the attainment of a reliability figure for each individual unit. This also provides a method of attaining very high reliabilities at a low cost and the test can be carried out in 24 hr or less. Author

Review: While the general nature of the procedure can be followed from the text, it is difficult to understand the exact statistical procedure followed and the reasons for it. No formula is given for life in terms of the measured variables and population parameters. Some of these parameters for the particular unit are approximated by the population average with a variance, and others are presumed to be known exactly. But it is difficult to get a clear reading on what is what. (There are several misprints involving subscripts and superscripts. The word permeability is used to mean weight loss, which makes for awkward reading.) After a long derivation showing that the solvent loss rate has the form exp(−W/RT), it is replaced by the form exp(BT) in a mysterious way; obviously they are not equivalent. There is an undue emphasis on the exactness of the reliability calculation and on what has been established. The above may be only editorial difficulties; the original method and reasoning per se may well be quite satisfactory for the purposes at hand.

R66-12766 ASQC 844; 712; 713; 716; 782

DELAYED STATIC FAILURE.

T. R. Croucher (Northrop Corp., Norair Div., Metallurgical Section, Hawthorne, Calif.).

(Western Metal and Tool Exposition and Conference, Los Angeles, Calif., Mar. 18, 1964.)

Metals Engineering Quarterly, vol. 4, Nov. 1964, p. 51–56. 7 refs.

The susceptibility of high strength materials to possible delayed failure is considered, with particular emphasis placed on failures where a static stress is prevalent such as stress corrosion and hydrogen embrittlement. Fatigue is also considered for identification and comparison. Both failure phenomena are examined, and the causes for each are detailed. Stress corrosion environments for high performance alloys are listed. Ways of avoiding stress corrosion and hydrogen embrittlement problems are discussed, and several design and processing procedures are recommended. The factors to be considered in identifying failures are delineated, and the necessity for strict manufacturing specifications is pointed out. The test techniques used for identification and material evaluation are reviewed, and graphs are included to plot the typical failure curve obtained in stress corrosion studies, and the stress rupture curves obtained in hydrogen embrittlement tests. It was concluded that most problems of delayed failure can be avoided if precautions are taken in the design, material selection, heat treatment, machining, and chemical treatment of the part. M.G.J.

Review: This article is rather general in nature, but it is an excellent summary of the current situation involving structural delayed static failures. The paper is recommended to beginning design, material selection, and materials processing engineers, especially those not familiar with the inadequacies of the term "high-strength materials."

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Reliability Abstracts and Technical Reviews

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72 PROCESS CONTROL

R66-12776 ASQC 720; 763; 775
NONDESTRUCTIVE SOLDERABILITY CHECK: A KEY TO RELIABILITY AND ECONOMY.
H. H. Manko (Alpha Metals, Inc., Solder Research and Development, Jersey City, N. J.).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 6 p.
Available from ASQC, New York: $6.00.

Adequate control of solderability in the manufacturing process can result in economy and increased reliability by reducing the number of rejects and re-work and touch-up problems that occur when improper solder materials are selected. Solderability tests available to industry for determining how well a base metal is going to solder are discussed. By employing such testing, parts that might later result in rejects can be corrected prior to assembly and final soldering. M.W.R.

Review: The testing referred to in this paper determines how well a base metal is going to solder, and the tests are intended for application prior to the actual assembly soldering operation. Thus these tests are the preventive sort which unfortunately can so easily be dropped under normal schedule and cost reduction pressures. This paper presents some background and summarizes various ways of testing for solderability. Those persons desiring detailed information on solderability and other facets of soldering will find it in a book by the author which is referenced in the paper. An earlier paper on reliability in soldering by this author was covered by RATR R66-12105.

80 RELIABILITY

R66-12784 ASQC 801
RELIABILITY CONCEPTS IN GERMANY.
A. Etzrodt (Chief of the Reliability Working Groups of Siemens and Halske Ag, Munchen and Nachrichtentechnische Gesellschaft (NTG), Frankfurt, West Germany).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 7 p. 2 refs.
Available from ASQC, New York: $6.00.

Difficulties involved in defining reliability solely in terms of failure probability are discussed, and it stressed that the German approach to reliability takes on a broader base. It is pointed out that reliability can be defined by quoting any one of several parameters, including failure probability, survival probability, average life, or mean time between failures. Change in behavior of critical characteristics can also be taken into account in defining reliability. Reliability concepts as employed in the United States and Germany are discussed. M.W.R.

Review: The discussion of reliability concepts is done in a mature fashion. Some history is given to assist in understanding the discussion. Many of the points are subtle and perhaps have to do as much with language and cultural distinctions as with technology. The difficulties involved with defining reliability solely as a probability are mentioned; that practice is not followed in Germany. A partial list of concepts is given and they are somewhat different from those used in this country. But it is impossible, of course, to say they are right or wrong and even their usefulness or adequacy is impossible to assess. Perhaps the important point is that the effort is there and that progress is being made.

R66-21769 ASQC 801; 340
NEW DEVELOPMENTS IN AEROSPACE QUALITY CONTROL.
K. Buchele and K. A. Frederiksen (Douglas Aircraft Co., Inc., Missile and Space Systems Div., Newport Beach, Calif.).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 14 p.
Available from ASQC, New York: $6.00.

Techniques for establishing reliability critical items during the design phase are described along with methods for assigning relative reliability values. A total quality control program incorporating a control plan based on the reliability critical items is then developed. Essentially the program defines the special emphasis given during procurement, inspection and test of these items and subsequent testing and evaluation during successive levels of assembly both in-plant and at field stations. The specific activities of a quality engineering operation are detailed showing how emphasis can be tailored to both the design and manufacturing process. With more and more attention being directed to cost analysis and reliability incentives, intelligent use of resources on major programs is mandatory. Placing emphasis where the maximum benefits can be derived is one long step in that direction. Author

Review: Using the reliability engineering analysis to identify critical inspection and test requirements as described in this paper appears to be an effective approach. Some hardware producers approach this task by having the designer designate this criticality, while others make no designation. The cooperative attitude between reliability engineering and quality engineering which is described in this paper could well be duplicated by others to alleviate the friction which sometimes exists. There may be some ideas here for those interested in quality engineering, but the detail is limited since the paper is short.

81 MANAGEMENT OF RELIABILITY FUNCTION

R66-12774 ASQC 810; 340
PRODUCT "TRACEABILITY" FOR NASA SPACE SYSTEMS.
Morris K. Dyer (Georce C. Marshall Space Flight Center, NASA, Huntsville, Ala.).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 7 p.
Available from ASQC, New York: $6.00.

Identification and traceability are discussed in relation to the manned space program. Identification is defined as a controlled number which relates an item to other items, processes, components, or systems; and traceability is the ability to trace the history, application, use, and location of an item or items through the recorded identification numbers. It is noted that raw material identification must be considered separately from fabricated article identification; and that NASA does not require separate identification and traceability systems for configuration management, quality assurance, and reliability. The contents of some applicable NASA documents as well as related experiences are discussed. M.W.R.

Review: An introduction to the traceability or identification area with respect to the manned space flight program and NASA in general is given in this paper. The controversial nature of this subject makes this paper required reading for those who are professionally involved in quality assurance where reliability is emphasized. Certain supplementary documents are referenced in the body of the paper. It is encouraging to see that these supplementary documents have been prepared and that changes are being made in the basic NASA quality specification. A lesson to be learned from the experiences described in this paper is that if a purchaser has unique requirements, then he should spell them out at the earliest time to the best of his ability. The fact that unique requirements are implicit in some overall requirement (as the author notes in the fourth paragraph on traceability and the initial version of NPC 200-2) is of little consolation when the inevitable and costly controversy arises.

R66-12780 ASQC 810; 811
THE APPROACH TO RELIABILITY PROBLEMS IN A EUROPEAN SEMICONDUCTOR COMPANY.
G. Costamagna (Societa Generale Semiconduttori, International Operations, Agrate, Italy).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 15 p. 3 refs.
Available from ASQC, New York: $6.00.

Reliability requirements, assurance, and philosophy are discussed in terms of the approach followed by a European semiconductor manufacturing establishment, and a comparison is made between their approach and that in the United States. Design improvement and process control are stressed in the European approach rather than estimates of failure. In a report dealing with *Quality Reporting, Quality Auditing, and Quality Achievements in European Countries,* it is stated that only 15% of 43 case histories use the word reliability; and it is stressed that European companies emphasize the word quality as opposed to reliability. M.W.R.

Review: This is a light essay-type paper which gives a comparison between U. S. and European approaches to Reliability. Apparently the emphasis in Europe has been on improving designs and process-controls rather than on the generation of estimates of failure-rates. It is difficult to get any depth of understanding from the paper, but it is easy to read and does leave one with the feeling that everything is all right. The massive reliability effort in this country is denigrated somewhat, and the reasons for its existence are passed over—apparently never having appeared in Europe. But this massive effort was in response to a real need wherein conventional designs must have vastly improved lives and new designs must be good from the word GO with a high degree of certainty. The thinking of most engineers and managements had to be completely redone, and a shotgun approach to cover everything at once was essential. There are, of course, many ways to fall by the wayside and we have done our share. Critics of the reliability effort in this country (one in particular is admired by the author) have been performing a valuable service (even when not always right) by trying to keep the ultimate goals in mind and pointing out areas of oversight or overemphasis. Europe is, perhaps, fortunate to have not had the massive rigorous production effort which called forth the corresponding massive reliability effort.

R66-12787 ASQC 810
RELIABILITY IN ACTION: THE TRANSITION FROM DESIGN TO PRODUCTION.
B. A. Sisco and H. A. Van Dine, Jr. (General Electric Co., Missile and Armament Dept., Reliability Assurance Engineering, Burlington, Vt.).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 8 p.
Available from ASQC, New York: $6.00.

Transition procedures and considerations which have been found to be effective in development, preproduction, production, and field reliability phases are explored; and some methods that have been employed in the solution of problems arising in the transition are described. Primary reliability relationships are outlined for a missile and space division as well as for reentry vehicle reliability relationships for two departments. Various charts depict an integrated test program board, attributes data accumulation, a failure report flow chart, and a failure analysis and corrective action flow. M.W.R.

Review: This paper is directed primarily toward management personnel. It describes various company organizational features for implementing a reliability program plan with emphasis on those elements formed to insure a smooth transition from design to production with consistent attention to reliability. The organizational structure described represents an evolvement over several generations of hardware programs. It is a clearly written paper, but is rendered somewhat laborious to read by the lack of an orderly outline and the fact that there is no breakdown into sections. Many good points are made as to what constitutes a good organizational structure, extending beyond normal contractual requirements. Even though many companies do not operate in the manner described, they do, in fact, automatically incorporate many of the features in practice. One notable feature described is the significant involvement of the production group in the early design and planning stage. Unfortunately, this is not always possible. Also, the Integrated Test Program Board, if it operates as effectively as described, can greatly benefit the transition from design to production. Emphasis is placed on interdepartmental cooperation.

R66-12793 ASQC 814; 351; 815; 816

TARZAN (THE VENDOR) MEETS THE SAFARI (THE VENDEE).

Alfred R. Pennell (Motorola, Inc., Quality Assurance, Scottsdale, Ariz.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 4 p. 2 refs.

Available from ASQC, New York: $6.00.

Adequate communication between vendee and vendor is discussed, with special consideration given to making vendee parts specifications intelligible to the vendor. The example is presented of specifications set for a hi-rel transistor that were so unique that the vendor, who already had a transistor line, established an entire new line at considerable delay in scheduling and additional cost. Investigating equipment performance and reliability requirements and better communications prior to this change would have indicated the existing line to be adequate. M.W.R.

Review: The case study which comprises this paper contains a solid cost-effectiveness or value-engineering message. The author appropriately points the finger at the buyer rather than the vendor for instigating unique requirements in the name of reliability at a sometimes-staggering increase in price and schedule, where the requirements are not first discussed with the vendor who often has an existing hi-rel line which is close to the buyer's unique requirement. The roots of the problem may well lie in the rapid growth of both electronics and NASA, where common practice is for the buyer to have purchasing agents with no technical background and engineers with little experience preparing specifications. Reasons also exist for the vendor not being too aggressive about suggesting alternate approaches. One is that after trying this a number of times and the buyer stands firms, the vendor gets discouraged. After all, why should he devote time to reducing his dollar sale value by a factor of three or four. This brief paper is presented in simple language and would be educational for purchasing, sales, and management persons.

R66-12799 ASQC 814; 612; 822; 824

MITRE Corp., Bedford, Mass.

A COMPUTERIZED TECHNIQUE TO EXPRESS UNCERTAINTY IN ADVANCED SYSTEM COST ESTIMATES

S. A. Sobel Nov. 1965 121 p refs

(Contract AF 19(628)-2390)

(TM-03728; ESD-TR-65-79; AD-624894; N66-30561) CFSTI: HC $4.00/MF $0.75

The technique described presents a method to express uncertainty quantitatively in advanced system cost estimates. In particular, the technique suggests the employment of subjective probability distributions, which describe the uncertainty in each system element, to determine an approximate distribution for total system cost. A 7090 program has been written to perform the computational operations. Author

Review: Although the application area cited in this paper is cost estimating, the basic mathematical problem is propagation of distributions, which has received considerable attention in reliability for application to performance variation analyses. In this paper a method is proposed which is not among those generally used in reliability, e.g., Taylor Series and moments or Monte Carlo, nor among others which have been proposed in reliability but are not in general use. A computer program in FORTRAN II has been prepared on the proposed method. The advantage of the approach in this paper relative to the popular approaches in reliability is that a variety of distributions can be handled without using the computer time required by Monte Carlo; the disadvantages are limitations on the deterministic equation and restrictions imposed by independence of the elements. Thus this report would be of interest to those concerned with the development of techniques for performance variation analyses. This document contains numerous typographical errors and the author has suggested that the original MITRE version, TEM-3728 dated Sep. 63, be used.

R66-12800 ASQC 810; 830

RAND Corp., Santa Monica, Calif.

SOME SOURCES OF UNCERTAINTY IN ENGINEERING DESIGN PROJECTS

H. B. Eyring Oct. 1965 47 p

(Contract AF 49(638)-66-C-001; Project RAND)

(RM-4503-PR; AD-623275)

A study, based on interviews and observations of engineering projects, describing how first level technical supervisors perceive causes of uncertainty in their design work. Sources of uncertainty are defined as factors (including interpersonal relations), which might cause group leaders to see more than one solution to problems in design. Two primary sources of uncertainty are: (1) unknown problem difficulty and (2) possible changes in specifications defining the problem. The author concludes that while his findings are tentative, they do question some current practices in obtaining information about uncertainty. Author (TAB)

Review: This paper is directed to designers of management information systems. It should also be of value to project managers involved in the design of complex systems. While reliability per se is not considered directly, many of the ideas discussed have important implications for reliability. Since the report is based on interviews with group leaders and project managers, an element of subjectivity is present. The author has identified the findings as tentative; they should serve to stimulate further research in this area.

82 MATHEMATICAL THEORY OF RELIABILITY

R66-12772 ASQC 824
RELIABILITY GROWTH MODELS.
J. E. Bresenham (IBM Corp., San Jose, Calif.).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 9 p. 17 refs.
Available from ASQC, New York: $6.00.

Two reliability growth models are presented whose use depends on the use of a product and the nature of available test data. In Model I, probability of failure is partitioned into an inherent component and a transient part. The inherent probability of failure is the portion of unreliability that cannot be eliminated or modified and is due to overall design limitations; the transient component is amenable to engineering change. Maximum likelihood estimates of the inherent and transient parameters are obtained simultaneously. The log-likelihood function is strictly concave if at least one failure results and the individual effort factors are not all identically equal to one; and when the conditions for strict concavity are not met, the model reverts to a binomial and a different estimate. Model I concludes with specialization from the arbitrary effort sequence to a constant effort for which the probability failure can be computed from a normal density. In Model II, equipment failure is assumed to follow a Poisson law with changing mean time to failure, and reliability growth characterization is dependent upon known variables. M.W.R.

Review: This is a brief mathematical paper which will be of interest to the theoretician rather than the reliability engineer. Those who wish to delve into the details will wish to refer to the longer work on which it is based (a Ph.D. dissertation by the author). The references to related material cited in the paper will also be helpful. From the practical point of view, the proposed models seem reasonable, although their applicability to any specific situation will depend on the extent to which the underlying assumptions agree with the physical facts. In any event, as the author has indicated, they can offer a first-order approximation to the reliability and possibly help to provide insight into the relationships of the activities affecting reliability improvement.

R66-12773 ASQC 824; 433
A NEW RELIABILITY ASSESSMENT TECHNIQUE.
A. N. Pozner (Hughes Aircraft Co., Space Systems Div., El Segundo, Calif.).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 14 p.
Available from ASQC, New York: $6.00.

Quantitative reliability assessment can be made by replacing prior subsystem reliability estimates in the mathematical model with Bayesian estimates. Processing of test data into a useable form and combining these data with prior information to arrive at Bayes estimates are discussed; and a hypothetical hypervelocity reentry experiment (HRE) spacecraft is analyzed to illustrate the assessment technique thus obtained. Accumulated operating time and environmental exposure history for flight hardware are tabulated for the HRE vehicle subsystems; and reliability estimates are then determined. Calculations for the eight subsystems result in a combined reliability assessment of 0.824. It is noted that a particular reliability number determined by this Bayesian technique is sensitive to imperfect factors such as the (1) choice of the Bayes divisor for the prior estimate, (2) choice of K factors, (3) realism of the underlying mathematical model, and (4) definitions of success and failure. It is further noted that statistical estimates of reliability are always very costly and ignore prior information. M.W.R.

Review: This is an introductory paper, designed to make the manipulations appear plausible and to illustrate their use. The second paper covered by RATR 2564 gives much more detail on the theory as does a growing body of literature on the subject (see, for example, RATR items bearing ASQC Code 433). Being able to use prior information in making reliability estimates is essential if progress is to be made. Bayesian statistics provides one method of doing this and intensive investigation of ways to use available engineering information should be encouraged.

R66-12778 ASQC 820; 870
ANALYSIS OF RELIABILITY AND MAINTAINABILITY MODELS.
Masafumi Sasaki (New York University, Department of Industrial Engineering and Operations Research).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 49 p. 4 refs.
(Contracts Nonr-285(62); DA-31-124-D-338)
Available from ASQC, New York: $6.00.

Properties of mathematical models for system reliability and maintainability are discussed. Since improved availability is achievable by a higher degree of inherent reliability or a combination of lower reliability and specified maintainability, consideration is given to whether it is better to (1) design higher reliability into the system or (2) resort to maintainable systems as a function of the mission and subject to cost, weight, volume, and similar constraints. Theorems are treated which discuss the relations between failure rate, maintenance action rate, and maintenance time constraints and system and subsystem availability. Some typical examples are solved to illustrate the use of these theorems. M.W.R.

Review: The author references two previous papers (see RATR 496 and 978). The approach in those two papers is adapted to the present subject, and is largely one of comparing changes in system Figure-of-Merit (such as Reliability) due to changes in two system-parameters. This is a formal paper; the material is presented in the form of theorems (about 40 of them) with proofs and remarks. Unfortunately, the language problem, noted in the earlier reviews, is still present. Few if any of the theorems are sentences, for example, which makes their intent difficult to decipher. None of the mathematics was checked since the paper is not expected to have wide readership. The organizers of symposia and conferences would do well to offer assistance to authors who need help with the English language, rather than to embarrass those authors by letting them publish papers of which it is difficult to make sense.

R66-12786 ASQC 824
GENERAL EQUATION FOR RELIABILITY OF PARALLEL NETWORKS.
V. B. Parr (Collins Radio Co., Reliability Data Analysis Dept., Dallas, Tex.).
American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 7 p.
Available from ASQC, New York: $6.00.

A general equation is presented which will yield the parameters for the failure density functions of the parallel units of a network, and a specific equation is shown for determination of the reliability of the network itself. An example is included for use of the general equation; and while this example assumes an exponential distribution for the failure density distribution, the general methods are considered useable for any failure density function. Details are included for the determination of the coefficients with the aid of a table, determination of combinations of failure rates, construction of a so-called family tree of indicator numbers, and construction of the required E matrix. It is noted that the techniques presented are of an iterative nature and well suited to digital computer applications; and that the computer can generate and evaluate the specific equation. M.W.R.

Review: This paper is a manipulation of standard theory into a form which is presumably more suitable for computation. To quote the author: "At first glance the method . . . might appear cumbersome, but with a little practicing one can become adept. . . ." The method does appear cumbersome and, especially for computer use, it is not immediately obvious why it is easier than the original probability expressions. However, the author feels that his expression is much easier to use, and those with long computations might want to give it a try. Where all units have the same reliability, the expressions are considerably simplified and these manipulations become pointless.

R66-12789 ASQC 823

A CONSTANT STRESS MODEL BASED ON INTERFERENCE THEORY.

Howard N. Punches (Motorola, Inc., Military Electronics Div., Scottsdale, Ariz.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 5 p. 3 refs.

Available from ASQC, New York: $6.00.

A technique for estimating reliability using interference theory concepts is applied here to the limited case of electrically stressed components. The application stems from a study involving time-dependent degradation effects in the analysis of data from overstress testing. The data were obtained in the course of some preliminary work in developing accelerated test techniques. The simple case of stress-strength interference is first presented, followed by the development of a constant stress interference model, then a combination of interference with degradation of strength is considered. The versatility of the approach is demonstrated by generalized distribution functions. Finally, a more detailed study considers an application of the constant stress model to recent test data, generates suitable distribution functions, and investigates the validity of the resulting failure probability distribution. Author

Review: It is difficult to tell just what the author was trying to do; the whole thing seems more complicated than necessary. The author appears to be somewhat confused about the difference between the simple stress-strength model for failure and the cumulative-damage model. He suggests at one point that the peak voltage on the capacitor is the important thing; yet all the tests seem to be run at constant voltage. He could have made the results of his Weibull analysis and the "interference" model agree by appropriately choosing the behavior of the mean and variance of the Normal distribution. The paper contributes little to the advancement of failure models, but may have some value as a short illustrative example.

R66-12791 ASQC 824

RELIABILITY IN COMPLEX SYSTEMS.

A. Clifford Cohen (Georgia University).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 7 p. 2 refs.

Available from ASQC, New York: $6.00.

Exponential models of monotone increasing and decreasing reliability are considered for complex systems. Maximum likelihood estimates of these parameters are made by introducing the initial reliability which existed when the system was placed into service. Procedure for selecting between the increasing and decreasing reliability models is suggested, and asymptotic variances and covariances of estimates are discussed for both models. Illustrative examples are included to indicate the application of the procedure and the selection of the appropriate model, along with the mathematical solutions. M.W.R.

Review: This paper is concerned with the estimation of the parameters in two models: one for monotone increasing reliability, and one for monotone decreasing reliability. They are obtained from the exponential reliability model through the appropriate introduction of a parameter R_0 representing initial reliability at the time that the system is placed in service. Maximum likelihood estimates for the two parameters in each model are derived, and their properties are investigated. Thus the paper constitutes a useful addition to the theory of models available for reliability estimation. The appropriateness of these models for practical application is a problem regarding which the reliability analyst must make a decision. In this connection, the author has made some useful suggestions and has given a practical example. The paper is a competent treatment of mathematical statistics directed at the solution of a practical problem.

R66-12792 ASQC 820; 838

INTEGER PROGRAMMING SOLUTIONS TO CONSTRAINED RELIABILITY OPTIMIZATION PROBLEMS.

Frank A. Tillman (Kansas State University).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 18 p. 22 refs.

Available from ASQC, New York: $6.00.

Reliability optimization problems which utilize parallel and standby redundancies and are subject to both linear and nonlinear constraints are shown to be amenable to integer programming solutions. It is noted that these optimization and constraint functions are of the separable type and need not satisfy any convexity or concavity conditions. Examples are solved for the following problems: (1) maximizing reliability for a parallel redundancy system subject to multiple linear restraints, (2) minimizing cost of a parallel redundancy subject to multiple nonlinear and separable restraint functions while maintaining an acceptable level of reliability, and (3) optimal choice of design for a parallel redundancy system. Necessary alterations to the above formulations are considered for standby redundancies. M.W.R.

Review: Anyone interested in solving reliability optimization problems who has an elementary knowledge of integer programming will find this paper interesting and useful. It investigates the solution, by integer programming, of reliability optimization problems with parallel and standby redundancies when the systems may be subject to linear and nonlinear separable restraints. The presentation is quite clear with four examples being given. It should be noted that particular algorithms or computational methods for solving integer programming problems are not discussed. Rather it is shown how certain reliability problems may be put into the integer programming format.

R66-12795 ASQC 820; 831; 840; 880

SYSTEM ANALYSIS TO INCREASE RELIABILITY.

Irving Bosinoff and Sidney Greenberg (MITRE Corp., Bedford, Mass.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 14 p. 6 refs.
Available from ASQC, New York: $6.00.

Procedures for performing a system and/or subsystem reliability analysis are presented. These techniques establish relationships between the reliability parameters of the basic units that make up the system and the system proper. The use of these analytic techniques permits an optimum design in the sense that (1) limited resources can be allocated where they do the most good, and/or (2) trade-off studies may be conducted so that parameters such as reliability, maintainability, cost and weight may be balanced against each other.
Author

Review: This paper illustrates rather than describes the techniques, but still serves a useful purpose in the illustrations. (Not all the mathematics was checked, but it appears to be good.) None of the techniques, flow graphs especially, are illustrated in enough detail for a person to learn about using them. The use of MTBF as a system figure of merit is often not as good as the failure rate or hazard function, especially for redundant systems. The definition of failure rate in the paper is the one often used for hazard function (a conditional probability of failure). The section entitled Exponential Approximation is not at all clear. The usefulness of the paper seems confined to interesting an engineer enough in one of the topics so that he wants to learn more about it. Toward this end, a more extensive bibliography would have been helpful.

83 DESIGN

R66-12776 ASQC 830

RELIABILITY AND MANUFACTURING CHANGES.

August B. Mundel (Sonotone Corp., Elmsford, N. Y.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 7 p.
Available from ASQC, New York: $6.00.

Reliability of commercial and aerospace products which use nickel cadmium sealed batteries is considered from the point-of-view of the manufacturing establishment. A systematic review of reliability, delivery, and cost data is considered essential; and it is recommended that management develop standard procedures for reviewing all manufacturing changes. Consideration is given to unreliability indications that emanate from the field, as well as to the field reliability versus synthetic testing. General methods are suggested for reliability control and product acceptance procedures.
M.W.R.

Review: This paper frankly discusses some of the day-to-day problems encountered in holding the reliability of a product. The examples are refreshing since they show that the company involved has made mistakes and some got into the market. Most papers are usually thoroughly sanitized before publication and read like a text on the scientific method from a philosophy book. The points made are good ones and show the many facets of the problem of producing a good product at a fair profit.

R66-12777 ASQC 832; 837

RELIABILITY AND MAN–MACHINE RELATIONSHIP.

Howard C. Roberts (Consultant, Urbana, Ill.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 7 p. 9 refs
Available from ASQC, New York: $6.00.

Despite the great potentialities of computer technology, it is pointed out that there are areas in which a human operator aided by a machine can do a better job than the computer can do by itself; and one of these areas is in the anticipation and correction of failures that might occur under emergency conditions. Requirements for reliability are treated under the categories of negligible risk, moderate risk, and high risk; and an example is presented of an incorrectly labeled fluid which represents a system involving loosely connected operations where monitoring is not possible. Modes for control of fully-automatic, operator supervised, dispatcher, and monitored systems are discussed; and the magnitude of the control task in man–machine systems is considered. It is emphasized that the human element is necessary in the operation of simple as well as the highest level machines and systems. Special attention is given to the design of systems so that the human operator is made a part of the control loop. M.W.R.

Review: This paper is addressed to an important topic: increasing the reliability of a small system through the use of a human operator. It has relevance to the mission reliability of manned vs. unmanned spacecraft, for example. However, the paper does not treat the subject in depth, but presents a qualitative discussion of some rather general considerations. It is easy to read and the ideas should be of interest to designers. The principal message is that despite the capabilities of the modern computer, there are still areas in which a human operator can do a better job than can the computer alone. Two papers which go into more detail on man's relationship to the reliability of aerospace systems were covered by RATR R66-12715.

R66-12779 ASQC 831; 840; 850

RELIABILITY CONTROL OF COMPONENT RELIABILITY TESTING SYSTEM.

H. Shiomi, S. Shiota, T. Harada, and K. Takahisa (Ministry of International Trade and Industry, Electrotechnical Lab., Tokyo, Japan).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 7 p. 9 refs.
Available from ASQC, New York: $6.00.

System failure analysis and its effective feedback to reliability control of the system are emphasized in a paper dealing with component reliability testing. Unreliable parts, poor design, inadequate maintenance, human inexperience, and management deficiencies are mentioned as possible causes of test failures; and it is stressed that the testing equipment itself can cause difficulties. Various indices for the test system are presented, and examples of failure analysis are included.
M.W.R.

Review: This paper emphasizes the fact that in testing for very high reliability, especially where long life is concerned, the testing equipment itself can cause problems. Those with experience in using the testing equipment, and perhaps even in manufacturing the testing equipment, will find little that is new in the paper. It serves the most useful purpose for those who are beginning and may not realize that ovens, power suppliers, etc. may cause more problems than the item on test. This kind of paper again brings to mind the inadequacy of advertising as a medium of real communication; the ads in the professional and trade journals would certainly lead one to think that these problems with environmental equipment had long since been solved. The paper is necessarily brief and covers a wide field in an outline manner rather than going to any one problem in depth. The points made are good and there are several simple illustrative examples.

R66-12788 ASQC 838

TESTING FOR THE INDEPENDENCE OF FAILURES IN REDUNDANT SYSTEMS.

Mitchell O. Locks (North American Aviation, Inc., Space and Information Div., Downey, Calif.) and Arthur E. Bart (Rocketdyne, Canoga Park, Calif.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 6 p. 2 refs.
Available from ASQC, New York: $6.00.

Two methods are proposed for analyzing test data to determine whether or not there is a tendency for members of pairs of identical redundant components to fail jointly. The first of the methods proposed is a nonparametric test of the independence of the failures of the members of a component pair; both exact and approximate solutions are obtained. The second is a maximum-likelihood technique for jointly estimating the probability that a single member of a component pair will fail and the conditional probability that the other member also will fail, given that a first has failed. From the latter method, a chi-square test for independence is also obtained. Author

Review: This paper proposes a useful non-parametric method for testing the independence of failures in certain redundant systems. As the authors point out, the technique is limited to systems where the redundant components are subjected to the same operating hazards at all times. The paper is basically very good but a few flaws should be noted. First, there seems to be little need to introduce (in this sort of paper) a *randomized* decision rule (p. 526). Also the limiting results on p. 527 are not strictly correct but the intended meaning should be clear. Lastly, the chi-square test should more properly be called the likelihood ratio test, and it is not clear why the normal approximation (which is also an asymptotic result) should be better than the likelihood ratio test.

R66-12790 ASQC 837

TOLERANCE LIMITS FOR ASSEMBLIES AND ENGINEERING RELATIONSHIPS.

G. Mouradian (Aerojet-General Corp., Propulsion Systems Reliability Dept., Statistic Group, Sacramento, Calif.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 9 p. 2 refs.
Available from ASQC, New York: $6.00.

Techniques for the propagation of errors and tolerance analysis are detailed to aid design and reliability engineers in determining (1) specification limits when several dimensions are involved or (2) amount of gross errors that can be expected when several variables define a relationship. Areas where these techniques can be used and examples of their successful use are included. Attention is given to stack up of tolerances, error analysis, propagation of errors development; and the appropriate equations are evolved for each. These examples show how tolerance and error limits can be calculated for design type criteria. M.W.R.

Review: This paper appears to be correct and is intended to help reliability engineers make useful calculations on tolerances. It is not too clear to whom the paper is directed—but one might guess that it is intended for the engineer who still remembers about differentiation, but has forgotten about a lot of other things. Tolerance is used in a special sense here, but is never discussed. Generally (whether wisely or not is something else again) engineers use a tolerance as a maximum or minimum for the dimension in a part and the parts can be checked or sorted on this basis. The author implicitly defines tolerance as the standard deviation (σ) of a dimension. It should be noted that a unique probability is not associated with $k\sigma$ since the probability distribution is not known (and can easily be non-Normal). Statistical independence is not required—only that the measurements be uncorrelated, for the simple formula. The propagation of errors described here is the fairly standard treatment given in most physics courses and elsewhere. It does not require a knowledge of differential equations—only of differentials, which are much simpler. The person applying this to real parts should be sure he is using the dimensioning technique actually employed in the shop. This is not necessarily the one implied by the drawing at all. The example on the gas generator is not at all clear.

R66-12794 ASQC 831; 850

USE OF SYSTEM EFFECTIVENESS AS A QUALITY CONTROL TOOL.

Stephen W. Leibholz (AUERBACH Corp.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 6 p. 8 refs.
Available from ASQC, New York: $6.00.

Quality control of complex systems is considered a unique problem because the reliability of such a system is ordinarily not well-defined and does not lend itself to classical testing procedures. The following steps are considered necessary for the development of an adequate quality control program: (1) redefine concepts of system performance and reliability by using multi-valued performance parameters to take into account statistical performance, (2) manage quality control by inference on the basis of testing subsystems and units, and (3) devise a mathematical model to serve as the basis for such inferences. System effectiveness is considered to be the result of probabilistic analyses involving three basic interrelated parameters, namely capability, state probability distributions, and vulnerability. The logic of system effectiveness evaluation is illustrated, and it is noted that there is considerable variation in methodologies, details, and results obtained by the currently used mathematical models used for system effectiveness. M.W.R.

Review: This paper appears directed toward broadening the outlook of the quality control specialist from the traditional emphasis on quality control for components of systems to a view of the quality of entire systems. There are several good points presented; however, they are not easily discerned. The author purports to "have shown how the deficiencies associated with reliability and quality assurance of complex systems may be relieved via the discipline of system effectiveness, used in the role of a framework for translating realizable test data into quality-assurance information meaningful at the system level." He has discussed this in an essay but has not shown it. The application of some of the concepts presented is not obvious and there are no examples to illustrate any of his points. However, the references on which the paper is based do contain illustrative examples which develop more fully the concepts presented. The terms *effectiveness* and *quality* are used synonymously. This is perfectly acceptable in the broad sense since all figures of merit are measures of actual quality. The management of system quality by inference is not a new concept; however, there is considerable potential recognized in using systems effectiveness models to make judgments of overall system quality. The best data, whether based on theory or experiment, to use in the models have been, and will continue to be, a factor of prime concern. The reader should be aware that the effectiveness model described is only one of many in current usage; another popular one is that described in the Air Force Weapon System Effectiveness Industry Advisory Committee (WSEIAC) reports (see RATR 2200).

R66-12796 ASQC 831; 844
A NEW METHOD FOR PREDICTING RELIABILITY.
Eli J. Dworkin (Army Electronics Command, Ft. Monmouth, N. J.), and Raj P. Misra (Newark College of Engineering, N. J.). *Electronic Industries,* vol. 25, Jun. 1966, p. 54–59, 121–122. 22 refs. See also R66-12609.

Review: This paper is essentially the same as the one covered by RATR R66-12609.

R66-12798 ASQC 830; 612; 838
Westinghouse Electric Corp., Baltimore, Md. Electronics Div.
SELF-REPAIR TECHNIQUES FOR FAILURE-FREE SYSTEMS Special Technical Report No. 2
M. R. Cosgrove and C. G. Masters Sep. 1963 40 p refs
(Contract NASw-572)
(NASA-CR-55267; N64-13916) CFSTI: HC $3.60/MF $1.40

Several classes of "repair" strategies under consideration and the computer simulation program which is used to determine the performance of the systems for each strategy are described. The computer simulation program determines the performance of a particular strategy by injecting random failures throughout the system and simulating system reaction according to the "repair" pattern of the strategy in question. The program prints out system performance in terms of: (1) total time to failure; (2) average time to failure; (3) number of failures to system failure; and (4) number of switches affected. The results for the two classes of strategies for which curves were drawn show that with the addition of a minimal amount of self-repair capability, the reliability of the system can be substantially increased over that of a comparable system using fixed redundancy alone for failure protection. Author

Review: This is a theoretical paper which explores the logical implications of a set of assumptions, rather than a report of experimental work. The basic idea is that majority voting redundancy exists and that spares can be switched around. No concern is given here to the switching problem, which is reasonable considering the stage of the idea. The report explores the concepts in a preliminary way and they are found to have merit. Further reasonable steps are indicated in the text. Should someone try to implement the idea with hardware, the switching problem will certainly be formidable (but this is beside the point for the present work), and as a practical matter may well cause the idea to be abandoned until further hardware advances considerably simplify the switching problem. Ideas of this type are worth exploring in this preliminary fashion and such work should be encouraged.

R66-12801 ASQC 832
Johns Hopkins Univ., Baltimore, Md. Dept. of Psychology.
ON THE ALLOCATION OF FUNCTIONS BETWEEN MEN AND MACHINES
Alphonse Chapanis Jan. 1965 12 p refs
(Contract Nonr-4010(03))
(Rept.-8; AD-626311)

The nature of the problem involved in the allocation of functions between men and machines is discussed, approaches that have been taken in handling this problem are mentioned, and strategy for dealing with the problem is considered. The allocation problem, which is also referred to as the allocation model or assignment model, is the concern of industrial engineers and operations researchers who want to combine activities and resources to maximize the effectiveness of a system. Since the particular man–machine problem does not lend itself to a mathematical solution, general statements about men and machines are of little value in practical situations. It is pointed out that the allocation of functions in a man–machine system is determined, in part, by social, economic, and political values which are usually unstated but implicit; and that assignment functions must be continually re-evaluated. Basic steps suggested for handling allocation problems are: (1) prepare a complete and detailed system specification, (2) analyze and list system functions, (3) make tentative assignments for each function, and (4) evaluate the sum total of functions assigned to man. M.W.R.

Review: The allocation of functions between men and machines is an important consideration in the design of aerospace systems. This paper deals with principles which have over-all applicability. When it comes to specifics, there is a need for good empirical data on the actual functioning of the human in particular man–machine situations. In this connection see, for example, R66-12715. This general problem is very important for many high-reliability projects.

84 METHODS OF RELIABILITY ANALYSIS

R66-12771 ASQC 840; 813; 836
MULTIPLE CORRELATION APPLICATIONS IN DESIGN ANALYSIS.
J. Russell Chasteen, Robert S. Koontz, and Steven S. Y. Tung (Sperry Rand Corp., Space Support Div., Huntsville, Ala.). *American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966.* 10 p. 10 refs.
Available from ASQC, New York: $6.00.

Theory and background of multiple correlation analysis are summarized, and results of an application in high reliability critical circuit design analysis are presented. Behavior of a transistor astable multivibrator circuit is analyzed; and results of 120 measurements indicate the degree of impact one component part has on another. Change in parameter of a component part can be estimated in terms of the regression equations when the value of the other component parts is varied; and determination can thus be made of nominal operating values, the full operating range, and failure points. Component part parameter variance can also be estimated. It is concluded that the multiple correlation analysis method can enhance values obtained by marginal checking techniques. The assumption of linear relationship between variables, the requirement for normal distribution for each variable, and the tedious calculation of constants are noted as the more important limitations of multiple correlations. M.W.R.

Review: The major points made by the authors are good; however, the specific statistical tests and estimation procedures are not based on well-known results of modern statistical theory. All of the confidence interval estimation techniques cited are based on large-sample asymptotic theory using the Normal distribution approximation. Better procedures are available in almost any statistical textbook on the subject of regression theory. The limitations on the applications of a multiple correlation analysis as cited by the authors are not really important for most of the intended uses. Prediction equations can be obtained for non-linear relationships; the Normality assumption is needed only when making tests of significance or confidence interval estimates, and the tediousness of the calculations is a minor point with the availability of many computer programs and the appropriate digital computers for such analyses.

R66-12783 ASQC 845; 853

THE TREATMENT OF FAILURE RATES IN THE AIR FORCE RELIABILITY CENTRAL.

R. S. Hollitch, G. T. Jacobi, and H. A. Lauffenburger (IIT Research Institute, Chicago, Ill.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 17 p. 5 refs.
(Contracts AF 30(602)-3426; AF 30(602)-3621)
Available from ASQC, New York: $6.00.

The needs of the user community are emphasized in the treatment of failure rates by the Reliability Central program of the Air Force. The approach taken is a computer-aided analysis facility with an up-to-date dynamic data base that will permit generation of valid periodic information outputs as well as special outputs in response to queries from users. At present, data for electronic component parts, with the emphasis on semiconductor devices, has been accumulated and placed in the system. Efforts are underway for the test operation of these semiconductor devices, which will provide the information outputs with data on capabilities. M.W.R.

Review: An introduction to the AF Reliability Central is presented in this paper. The Central is an attempt to satisfy a large and historical need in reliability for a more rigorous data base. No single contractor and few government agencies have the breadth of subject coverage necessary to support an analysis center. The study and work leading to the current status appear sound. Note that it is planned to supply certain analyses to users of the center, and not merely a copy of the input information. This center should significantly contribute to an increase in the quality of reliability analyses, particularly at the parts and equipment levels. References 2 and 3 in the paper are reports on progress of the Central which are listed in DDC as AD-623 195 and AD-620 025 respectively; a report accompanying reference 2, which is not referenced in this paper, is listed in DDC as AD-623 196.

R66-12785 ASQC 844; 835

MARINER IV SPACE DATA AUTOMATION SYSTEM (SDAS) COMPUTER RELIABILITY.

Robert P. Berkowitz, John W. Chapin, Harvey G. Berig, and Anthony J. Nasuti (Computer Control Co., Inc., Framingham, Mass.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 17 p. Prepared for JPL.
(Contract NAS7-100)
Available from ASQC, New York: $6.00.

Among the techniques developed and evaluated in connection with the Mariner IV Space Data Automation System (SDAS) computer reliability program are (1) encapsulation of pellet components, (2) vacuum deposition and interconnection in an epoxy substrate, and (3) a versatile high-density mechanical package. Design and production were monitored with an integrated reliability program to develop test data at all steps from component screening and burn-in to the final system. The results of these reliability evaluations are then rapidly fed back to permit real time corrective action. Pellet selection and characteristics are described, including the fixed film resistor, capacitor, and silicon switch diode. Details of the construction of the SDAS are given; and the screening and burn-in program is discussed. Failure analysis on the Mariner IV SDAS was conducted on modules and envelopes; and reports are presented for the diode failure evaluation, diode X-ray analysis, and resistor failure analysis. M.W.R.

Review: What makes this paper unique in reliability literature is that it is about the pellet class of electronic component, which is basically the standard component packaged as a cylinder 50 mils in diameter and 30 mils high with electrical contact made at the flat ends. The authors note that the choice of pellets offered design flexibility, batch-type assembly, and conduciveness to microscopic examination. The evaluations of vacuum deposition and low-temperature soldering on an epoxy substrate are also significant. The use of vacuum deposition with epoxy and low-temperature solders is not limited to pellet components but is applicable to other types of miniature components and encapsulated circuits. There is very little information in the reliability literature concerning vacuum deposition on epoxy and low-temperature solders. Reliability program elements which are cited are mainly some of the standard ones associated with fabrication, such as traceability, screening, burn-in, and failure analysis. Adequate discussion and illustration are presented in the paper to give some insight into what happens when the typical reliability program is applied to the not so typical pellet configuration. The pellet approach has apparently resulted in reliable operation of the on-board computer for the Mariner IV spacecraft. The paper will be of interest to someone who is just curious about pellel packaging as well as to someone with a reliability interest in pellets.

85 DEMONSTRATION/MEASUREMENT

R66-12768 ASQC 851

MECHANICAL ASPECTS OF AIRCRAFT RELIABILITY.

Frank Nixon (Rolls-Royce Limited, Derby, England).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 15 p. 8 refs.
Available from ASQC, New York: $6.00.

Attention is given to activities in which the application of engineering principles and particles can contribute to reliability; and primary reliability achievement and reliability improvement are considered as the two major phases in any mechanical engineering program. The first covers activities to insure adequate reliability of products that reach the customer; the latter deals with improvements to products already on the market. With regard to aircraft reliability it is concluded that aircraft engines are superior to the aircraft and its accessories. Simple difficulties revealed during testing although not seen during the design phase are cited. Greater effectiveness of reliability measures is noted in civilian than in military aircraft development; and the need to measure realibility and provide incentives for its achievement and improvement is stressed. M.W.R.

Review: The author is certainly correct in his contention that there is more to reliability than a probability. But there seems to be an implication that probabilities have no place in reliability; this is as wrong as the first statement is right because we just do not know enough about many materials and processes to make accurate predictions and to plan complete non-destructive tests. The overall viewpoint of the paper is that of aircraft engines where reliability improvement is a decisive factor. On some missiles and space flights there is very little chance for improvement during service. The emphasis on foolish failures is good; many problems are obvious, both as to causes and cures, when they are once pointed out. Much of the design and production review effort is devoted to eliminating as many of these idiocies as possible. Analysis methods which are routinized on a computer can also be a big help in improving reliability.

R66-12781 ASQC 851

SELECTING CONSUMER'S RISK TO MINIMIZE COST.

H. C. Jones (Westinghouse Electric Corp., Defense and Space Center, Baltimore, Md.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 9 p. 3 refs.
Available from ASQC, New York: $6.00.

A method is presented for selecting customer's risk based on minimum overall costs to a program, and the conditions are shown when such a test is economically unfeasible. The basic methodology involves considering the cost of testing all equipment, adding this to the cost that would be incurred if any equipment failed during testing, and minimizing the total cost. It is assumed that all equipment is subjected a sequential testing with a producer's risk fixed at 10% and a consumer's risk which will be optimized for minimum cost to the program. Further, when a reject decision is reached during subsystem testing, the cause can be traced and the program will be delayed until the necessary modifications can be made. The sequential testing procedure is detailed and the necessary equations are derived. It is concluded that the most important result from the study was the sensitivity of the optimum test program to factors which are not within the domain of the reliability engineer; and program management must provide accurate information concerning the cost of test failure. M.W.R.

Review: The method presented in this paper for selecting the consumer's risk on the basis of overall costs to the program constitutes a good and useful idea. The derivation of the optimum risk is presented in a straightforward manner, and adequate references are cited for the underlying theory. For the implementation of this method, it will be necessary that program management supply the reliability engineer with accurate information concerning the cost to the program of a test failure. There are times, of course, when criteria other than overall program costs will be more important.

R66-12782 ASQC 850

AN INTEGRATED PLAN FOR RELIABILITY DEMONSTRATION THROUGH SAFETY MARGIN TESTING.

Robert J. Schulhof and I. Paul Sternberg (Hughes Aircraft Co., Space Systems Div., El Segundo, Calif.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1-3, 1966. 6 p.
Available from ASQC, New York: $6.00.

Knowledge and experience are incorporated into an integrated planning and evaluation effort to demonstrate reliability via safety margin testing. A system model is developed which accounts for all hardware elements and defines mission success; and each of the units of the system are apportioned reliability requirements based on overall system requirements. Unit apportionment must assume that all units do not have the same reliability and that all units and failures do not have the same effect on the system. A failure mode versus stressor matrix is developed, and each stressor column is given a reliability requirement. Only the so-called critical stressors must be tested; and the selection criteria for critical versus noncritical is considered to be apparent when the weighting factors for the likelihood of occurrence and severity effect are multiplied together. M.W.R.

Review: The methodology presented here may be good, but the explanation is too poor to tell. Words such as "stressor" are used but never defined and words such as "critical" are defined somewhat after being used. The matrix which is presumed to give weighting factors, W, for each stressor and failure mode turns out not to be defined at all. The equations which purport to describe the restrictions:

$$\prod_{q=1}^{Q} e^{-\left[\frac{\sum_{r=1}^{R} W_{rq}}{\sum_{r=1}^{R}\sum_{q=1}^{Q} W_{rq}}\right]\lambda t} = R_i \equiv e^{-\lambda t}$$

are a tautology and are true with complete indifference to the values of W_{rq}. Interaction effects, such as between temperature and vibration, may be quite important and are not generally negligible (contrary to the statement in the text). The chance of occurrence of a 4σ or 5σ event is given for the Normal distribution, but it is easy to infer that the probability was distribution-free. (There is an important misprint in Appendix A, Case 1: X_i should be $X_i = 1/2(L_i + l_i)$, not the difference as shown).

R66-12797 ASQC 850; 612

A PRACTICAL METHOD OF DEMONSTRATING RELIABILITY.

Edwin D. Karmiol, W. Thomas Weir, and John S. Youtcheff (General Electric Co., Re-Entry Systems Dept., Philadelphia, Pa.).

Electronic Industries, vol. 25, Jun. 1966, p. 66-71 See also R66-12659.

Review: This paper is essentially the same as the one covered by RATR R66-12659.

87 MAINTAINABILITY

R66-12770 ASQC 870

MAINTAINABILITY IN SPACE—A SURVEY.

Thomas L. Fagan (General Electric Co., Spacecraft Dept., Philadelphia, Pa.), and Myron A. Wilson (General Electric Co., Re-Entry Systems Dept., Philadelphia, Pa.).

American Society for Quality Control, Annual Technical Conference, 20th, New York, Jun. 1–3, 1966. 16 p. 92 refs
Available from ASQC, New York: $6.00.

The multiple problems of maintenance, assembly, and construction in space are surveyed; and consideration is given to the parameters that interact critically with structures, subsystems, and components, namely: (1) zero gravity, (2) radiation, (3) high vacuum, and (4) meteoroids. Automatic maintenance and remote handling techniques and their inherent problems are discussed, and a review is included of developments in zero-reaction tools and space suits. Pyrotechnic, elastomeric, and fusion methods for assembly and fastening techniques are discussed, as are structural repair capabilities and construction in space. Economic aspects of various cost effectiveness concepts, orbiting payloads, and manned stations are mentioned. M.W.R.

Review: This is a survey of a range of topics of importance to the reliability and safety of spacecraft. The paper presents a good bird's-eye view of the topics and provides an extensive bibliography for those who wish to obtain more detail on any of them.

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80 RELIABILITY

R66-12808 ASQC 800

RELIABILITY HAS FAILED TO MEET ITS GOALS.

A. J. Finocchi (IIT Federal Laboratories, Nutlet, N. J.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 7 p.

Various ways in which reliability predictions have failed to meet expected goals are listed, and the pitfalls considered to be inherent in reliability and maintainability programs are discussed. Rapid changes in the electronics industry and other highly technical endeavors make validation programs almost impossible; and the author questions the prediction of reliability at very high confidence levels, the use of mathematical models and other numerical data, and various failure rate data. M.W.R.

Review: This is an essay in which the author brings out all the discouragements about the practice of Reliability. He does it rather well and the points are generally valid. It is not the whole story by any means; for example, papers continue to be presented which show excellent agreement between predicted and observed MTBF. But anyone who uses Reliability numbers should be familiar with the deficiencies which are expounded upon at length in this paper. The numbers, when wisely arrived at and properly interpreted, can have value in a Reliability program, the negative tone of this essay not withstanding. A somewhat different attitude is expressed in the paper by Herd on p. 103 in the same volume.

R66-12809 ASQC 800

RELIABILITY CAN BE PREDICTED?—A NEGATIVE POSITION.

Vernon L. Grose (Rocketdyne, Spacecraft Engine Div., Canoga Park, Calif.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 11 p. 8 refs.

A negative point of view is taken toward the prediction of reliability in general, and fallacies in the use of mathematical models and numerical analyses are emphasized. Questionable numerology elements discussed are: (1) robustness of mathematical models, (2) concept of failure rate, (3) applicability of a specific failure rate, (4) time-dependency aspect of failure rate, (5) manipulation of data such as K factors, and (6) meaning of reliability numbers. The hopelessness of numerolgy is considered, and the article concludes that numerology in reliability is on the way out. An appendix deals with a discussion on the prediction of income, and an effort is made to show how useless and expensive the computation of predictions can be. M.W.R.

Review: This, like the paper by Finocchi immediately preceding it in the same volume, is a paper filled with discouragement and disgust, all directed at Reliability numbers. Virtually all of it is deserved and most engineers have felt this way about them often during their careers. But this is not to say it is the whole story. A loser at the gambling tables can have a true long sad story about the inadequacies of statistics and numbers; yet the owners of the casino would have a different outlook. These negative attitudes need to be expressed; the meaningless rites need to be examined and improved. There is much more to Reliability than tables full of 10^{-6} probability of failure. But calculations can be valuable. Competent Reliability engineers know when reliability numbers, k factors, etc. are useful and how much weight to give them. Examples of both adequate and inadequate uses of probability numbers abound in the Reliability literature. Proponents even on both sides of the question of the usefulness of a prediction of 10^{-8} vs. 10^{-10} failure probability argue vociferously. Each good engineer must understand enough about the subject to make his own adequate judgments on the matter.

R66-12810 ASQC 801

THE OBLIGATIONS OF A RELIABILITY ORGANIZATION.

L. N. St. James (Bell Telephone Laboratories, Inc., Whippany, N. J.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 4 p. 5 refs.

The relative newness of the concept of reliability is discussed, along with the limited concept of reliability that has evolved during the last ten or fifteen years. The standard military definition of reliability, the probability that material will perform its intended function for a certain time and under specified conditions, is considered adequate in terms of meeting the needs of the user. But it is pointed out that the implementation of reliablity in the standard MIL specification covering reliability prediction and demonstration has essentially ignored this definition and has defined system reliability in terms of failure of its parts. As a case in point, attention is given to a hypothetical defensive guided missile system, for which there is a considerable difference between the reliability of the "product" and the probability of kill. In other words, system reliability is found to be considerably higher than system effectivenesss. M.W.R.

Review: This paper deals little with the title and almost exclusively with semantic but nonetheless real problems associated with the definitions of reliability. The definition in MIL-STD-721A " . . . the probability that material will perform its intended function for a specified period under stated conditions" is used as a basis for the discussion and is considered adequate to describe the necessary concept. The points made are good and the paper is short—both are admirable qualities. The final message essentially is to quit fooling around with technicalities and get on with making stuff that will do the job as defined above. (There are a few bad typographical errors that disturb the train of thought in one section.)

81 MANAGEMENT OF RELIABILITY FUNCTIONS

R66-12802 ASQC 815
THE FUTURE OF RESEARCH, RELIABILITY, AND PROFITS UNDER FIXED PRICE CONTRACTING.
Allen E. Puckett (Hughes Aircraft Co., Culver City, Calif.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28-30, 1965. 3 p.

The ballistic missile and space programs have emphasized the absolute necessity of establishing precise requirements for reliability of material and equipment; and since reliability costs money, reliabilty incentive contracting would be welcomed by industry. It is pointed out that such contracting can be of benefit to both contractor and customer, particularly since the achievement of proper reliability goals reflects directly in operating costs to the customer. It is also stressed that reliability goals of the future may be at a level which is difficult to visualize at the present time, and that new concepts in fabrication and assembly, with reliability as the primary purpose, will receive increasing attention. M.W.R.

Review: The author, an executive of a major government contractor, concisely identifies the crux of the reliability situation. The onus for general improvement in reliability is said to be with government procurement practices, where the government must clearly define the reliability level it wants and how it will be measured, and then pay for it. Reliability incentive contracts are welcomed by industry. Although there is nothing new here for reliability workers, it is encouraging to hear essentially this message stated with increased frequency by management-level persons in both industry and government. This is the sort of paper which is well-suited for passing on to higher level government management, as it is short, to the point, and was written by a representative of their industry counterpart.

R66-12804 ASQC 815
INTERPRETATION OF RELIABILITY, MAINTAINABILITY AND SAFETY REQUIREMENTS.
W. L. Hurd, Jr. (Lockheed Missiles and Space Co., Sunnyvale, Calif.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28-30, 1965. 7 p.

Reliability, maintainability, and safety requirements and specifications are discussed in relation to contractual considerations between government and industry. Suggestions are offered for both customers and contractors in the interests of better communications and greater cost effectiveness; and questions are included for the contractor to consider with regard to contractural requirements and bidding dangers. M.W.R.

Review: A timely overview of the contractual climate between government and industry in the areas of reliability, maintainability, and safety is given in this paper. Note that in addition to the identification of applicable specifications and standards, government plants are cited for the consolidation of many of these documents. The impression is given that reliability is in reasonable control from a contractual viewpoint, with maintainability on the way and safety barely started. The discussion is frank and is from the perspective of a major prime contractor, although many of the remarks are also applicable to lower-tier hardware levels. An implicit message to government is that the numerical requirement with defined demonstration is the best approach to motivate the contractor and that the mere statement of a numerical requirement will result only in that which would otherwise have resulted even if the requirement had not been stated. Unfortunately numerous typographical errors detract from the readability of this paper.

R66-12805 ASQC 810;813
RELIABILITY IN PRACTICE.
Andrew C. Gorski (Autonetics, Data Systems Div., Predictions Unit, Anaheim, Calif.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28-30, 1965. 5 p.

Various aspects of reliability programs are discussed, and the importance of the reliability engineer's judgment is stressed over the use of mathematical confidence statements. Predictions are considered to represent the most pervasive single activity within the reliability organization, and typical decisions facing reliability management are outlined in light of the predictions function. Apportionments, reliability-improvement programs, manufacturing degradation, and random failure are among the topics discussed. Attention is given to reliability organization, and preference is voiced for placing reliability within the engineering organization. M.W.R.

Review: This is a brief and general paper which covers a number of topics of interest to reliability management personnel. It covers none of those topics in any detail, but does introduce a number of points worthy of consideration. Some of these may be controversial, but even they serve a useful purpose.

R66-12811 ASQC 815; 850
EXPERIENCES IN THE USE OF MIL-R-26667, WITH COMMENTS ON CONTRACTUAL RELIABILITY TEST REQUIREMENTS AND MIL-STD-781.
Griffith W. Lindsay (Air Force Systems Command, Aeronautical Systems Div., Wright-Patterson Air Force Base, Ohio).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28-30, 1965. 5 p. 6 refs.

Basic definitions are presented for terms associated with the concept of military reliability; and general experiences are discussed resulting from the use of MIL-R-26667, the principal Air Force specification for reliability testing of electronic equipment. System effectiveness is considered in terms of availability, dependability, and capability; and specifically defined as the product of capability and reliability. It is noted that certain experiences have resulted in amendments to MIL-R-26667, and these are described along with the changes they have made in the specification. Mention is made of MIL-STD-781, which consolidates the various electronic reliability test specifications and includes most of the problem solutions included in amendment 2 of MIL-R-26667. It is concluded that in view of the high quality of

MIL-STD-781, the Air Force will have no objective to the cancellation of the earlier specification. M.W.R.

Review: A collection of brief descriptions of reliability demonstration experiences and some related general observations comprise this paper. It is this "corrective action" or "feedback" process associated with experience which is bringing about a technical-business base for reliability demonstration. A communications problem does exist here because of the fact that most contractor locations have had only a limited experience with reliability demonstration, as compared to traditional qualification tests which are commonplace. Thus those persons involved in planning and conducting reliability demonstration tests will want to see this paper in order to try to avoid the problems reported here. Note that MIL-STD-781 is a document with which reliability engineers will want to become thoroughly familiar, as it will consolidate the various DoD electronic reliability test specifications. This paper, as well as others from the same volume, is plagued with typographical errors which are a serious nuisance in technical documents.

R66-12812 ASQC 815

COMMENTS ON MIL-HDBK-127 AND MIL-R-22256, 22973, AND 23094A.

Henry R. Thoman (Bureau of Naval Weapons, Avionics Div., Washington, D. C.)

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 9 p.

Three specifications and a handbook dealing with reliability are considered in relation to the design of aircraft electronic equipment. The MIL-HDBK-217 (*Reliability Stress and Failure Rate Data for Electronic Equipment*) applies to electronic parts in general; and the specifications (MIL-R-22256, 22973, and 23904A) specifically apply to aircraft electronic equipment contracts or the electronic portions of aircraft contracts. Some experiences are cited, and it is concluded that the age of improved electronics has arrived and that DOD reliability programs have made a significant contribution to this arrival. It is noted that a two to one difference between test result and actual flight result experience does not exist; and that high performance aircraft seem to have equipment failure rates close to those experienced in laboratory testing. Results are illustrated for the contractor's classification of failures in a recent test program; distribution of failures are given for over 100 equipments for a total of 12,000 operating hours during an eight-month period. M.W.R.

Review: Formal reliability demonstration of avionics equipment is the main topic of the military reliability documents to which this paper is addressed. Some of the controversial aspects are cited, but the theme is that contractual reliability demonstration is neither difficult nor expensive, and is extremely valuable in bringing about improved reliability. A paper of this sort gives encouragement to the reliability discipline. These accomplishments have been managerially spear-headed by the government reliability programs, with most of the technical progress provided by industry. A few significant technical conclusions are cited, such as observed differences of not over two to one between certain test levels and fleet experience; also some representative demonstration test data are given. These technical results are of wide interest, and the increased reporting of them in the literature is to be encouraged, particularly where they are supported by comprehensive analyses, which are also reported. The USAF Electronic Systems Division has also given some concentrated study to the topic of formal reliability demonstration; RATR 2352, 2532, and 2605 cover some of their results which broaden the perspective given in this Naval avionics paper. (Figure 6 is mislabeled; the word "equipment" should be substituted for "component.")

R66-12813 ASQC 810

THE FORD ENGINEERING RELIABILITY PROGRAM.

Bruce H. Simpson (Ford Motor Co., Engineering and Research Staff, Dearborn, Mich.)

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 11 p. 8 refs.

The rationale and engineering responsibility behind an operational reliability program in the automobile industry is presented, and the various aspects of the overall program are covered in relation to the manufacturing procedure. Five steps are considered basic to the program: (1) specific reliability requirements for each system and subsystem; (2) design of components, subsystems, and systems to meet these; (3) testing to verify designs; (4) precise specification of part requirements; and (5) monitoring at all levels to anticipate problems and provide feedback for necessary modifications. It is noted that once the required component part reliability is established, it is the job of the design engineer to evaluate the complete design. Laboratory and proving ground testing are discussed; as are interpretation of test results, specifying reliability requirements to manufacturing, engineering signoff, and validation testing. Customer feedback devices are considered, and an extract is included from a typical warranty analysis. M.W.R.

Review: This appears to be a soundly conceived reliability program. The idea of having the design engineer concerned with reliability is a good one since it is he who must meet the other design criteria and make the necessary tradeoffs. No mention is made of design reviews which can be effective economical tools for seeing that design requirements are being met in a reasonable way. The mathematical techniques are intentionally rather simple: a good tradeoff between ease and likelihood of use vs. exactness. Of course it is impossible to tell from the paper what the program is really like. In many such descriptions there is often an element of describing what one would like the program to be.

R66-12814 ASQC 813;770;844

A PRACTICAL SYSTEM FOR ACHIEVING RELIABILITY ASSURANCE.

Norman F. Larson (Pratt and Whitney Aircraft, East Hartford, Conn.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 16 p.

Design, development, and production methods are described for a practical system to attain effective product reliability in a large engine manufacturing complex. Product reliability assurance is basically the result of comprehensive and continuous attention to all details of the design phase, exhaustive component and full-scale testing during the development and manufacturing process, and utilization of the feedback from service experiences. It is noted that management has created an organizational structure to accomplish this reliability goal, and a strong and thorough follow-up program in the application and operational areas is part of this program. The reliability network for such a program is diagrammed, as are project design group support functions. A typical failure-mode analysis and a system and subsystem failure-effect analysis are shown. Mention is made of some of the new techniques that are available; and it is stressed that every possible means for product improvement and greater reliability assurance should be exploited. M.W.R.

Review: The steps taken to achieve engine reliability which are described in this paper are indeed practical; the title is most appropriate. The paper convinces the reader that what is said here is actually practiced as a way of life on each engine program, as opposed to many reliability program papers which give the impression of wishful thinking or at best limited applicability. According to the author, reliability is achieved through an all-consuming effort of the entire organization, which results when management really has the desire for reliability. There is no mention in the paper of any government reliability specification, but the tasks described in this paper would be a solid implementation of the intent of this type specification on a reliability program.

R66-12818 ASQC 810; 870; 880

THE RELIABILITY/MAINTAINABILITY RELATIONSHIP IN AEROSPACE PROGRAMS.

E. D. Karmiol, W. T. Weir, and J. S. Youtcheff (General Electric Co., Re-Entry Systems Dept., Philadelphia).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 12 p.

Interrelationships between reliability and maintainability in aerospace programs are discussed to provide the basis for a sound availability program, which optimizes ability to prevent, detect, locate, and correct failures. It is concluded that the availability concept will continue to grow because of increased complexity of equipment and because it is an important part of the total system effectiveness. The discussion centers around techniques and methods which have been used in numerous reentry and space vehicle programs over a seven-year period. Attention is given to the design criteria and trade-off analysis, logistic planning, and operating and maintenance personnel requirements; as well to apportionment, design analysis estimates, and parts application. An expression is given for the availability measurement index, as well as maintainability or availability index. A failure analysis and reporting system is outlined, and an equipment availability report is discussed. M.W.R.

Review: This paper does a good job of presenting the similarities, differences, and complementary features of the reliability and maintainability technologies, and their roles in an availability program. As the authors have pointed out, the availability concept will take on increased importance as equipment complexity continues to increase, and also as a result of emphasis on the concept of total system effectiveness. In general the paper is clearly written and well illustrated. However, a typesetter's error mars the first column on p. 267. The bottom half of the column (lines 22 and below) should be moved to the top of the page and then followed by the first 21 lines.

R66-12828 ASQC 813

THE DC-9 RELIABILITY PROGRAM.

Harlan A. Reesing (Douglas Aircraft Company, Inc., Aircraft Div., Long Beach, Calif.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 10 p.

Various aspects of the reliability program for the DC-9 aircraft, now under development, are discussed; including dispatch reliability, system simplification and component selection and improvement. It is noted that the design goal is a one percent maximum delay-at-takeoff rate, and a current estimate of 0.96 is given. Air lines participation has been quite extensive throughout the reliability development program, which has emphasized improvements on existing proven equipment. It is concluded that the DC-9 with its emphasis on reliability during the design phase and the early development phase, which is currently in progress, promises to produce a reliability level higher than that achieved by any airliner in service at the present time. M.W.R.

Review: It is encouraging from the professional reliability viewpoint, as well as an airline passenger's viewpoint, to see the concentrated application of reliability concepts to commercial aircraft. This paper is a case report describing the application to a major commerical system of reliability concepts developed mainly under government auspices. (In a private communication the author notes that whereas formalized reliability work has been mainly on government contracts, a lot of the basic approaches have been used in the commercial aircraft business for quite a while.) The fact that airlines typically keep good reliability and maintenance records resulted in a situation where some faith can be placed in the quantitative reliability analyses. The reliability program details are the logical actions based on these analyses. The paper mentions milestones of a first- and a third-year reliability objective to be measured by the performance of aircraft in airline use. Hopefully, the results will be published for the benefit of the reliability discipline. Papers pertaining to commercial reliability are in the minority in the reliability literature, and perhaps this paper will encourage others to report on their reliability achievements and will encourage still others to implement sensible reliability programs in the commercial field.

R66-12829 ASQC 816

SUPPLIER RELIABILITY CONTROL: THE GRASS ROOTS FOUNDATION OF SYSTEMS RELIABILITY.

Milt W. Mc Kenzie (Martin Co., Denver, Colo.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 8 p.

Reliability control is discussed from the point of view of the procurement person or the material director who must see that suppliers provide quality materials. A Reliability Program Functional Responsibilities Matrix is presented which defines line and assist duties for (1) proposal, (2) system criteria and design, (3) hardware development, (4) hardware production, (5) system test, and (6) customer utilization. Functional operations, the advanced reliability program plan, areas where reliability improvement could be improved by controlling functional efforts, and specifications and compliance are discussed. Material reliability maturity index charts to collect data on suppliers are mentioned, and it is noted that these charts later became part of a zero defects program. It is emphasized that materiel management must implement the reliability program and that the main effort must be directed at selecting suppliers on the basis of past performance and technical capabilities. M.W.R.

Review: Reliability is difficult enough for the technical engineering person, but it is even more of an obstacle for the Materiel (or purchasing) person to grasp and then to obtain control of his reliability responsibilities. A point to note initially is the reason why the Materiel department becomes concerned with reliability; it is because the government is, to an increasing extent, relating profit to measured reliability. Apparently when this happens, company management really becomes serious, and Materiel is among the departments which are in the reliability business via management dictate.

Typically, it is not known how to pass the reliability-incentive contract down the sub-contracting and supplier tier because of the inverse relationship between the depth of the supplier tier and reliability measurement problem, which aggravates Materiel's problem. This paper reflects the thrashing around which occurs when Materiel comes to grips with its reliability responsibilities. The result, however, is that reliability need not be all "cloud-nine-ing" and "wand-waving" when an honest attempt is made to understand the subject and to contribute toward enhancing it. The author, who is a member of Materiel, concludes that his department can best contribute to (1) selecting the most reliable suppliers based on their past performance and present capabilities, and (2) controlling the supplier's specifically-defined reliability program.

R66-12830 ASQC 810

MANUFACTURING RELIABILITY CONTROL THROUGH PRACTICAL MANAGEMENT.

J. D. Eagen and V. M. Werbach (Martin Co., Manufacturing Engineering, Denver, Colo.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 25 p.

Several examples are presented to show how manufacturing reliability control is achieved in a three-phase program, which includes: (1) indoctrination of people, (2) action of potential and actual problems observed on hardware, and (3) continuous measurement of critical manufacturing operations. Failure rate data is collected for each manufacturing operation to provide data for a reliability trend indicator; preventive action within the manufacturing department is applied to procedures, plans, or methods, or a combination of any of these, if the indicator is above the critical value previously determined. Analyses and reliability improvements are discussed for (1) a major weld area, (2) machined barrel skin panels, (3) assembly and installation of electrical panels, (4) a booster integrity test of final vehicle production assembly, (5) chemical milling, and (6) dome skin segment detail requirements. M.W.R.

Review: This paper describes a program established to assure thehhhievement of an acceptable degree of reliability in manufacturing. The main points of the program are personnel indoctrination, action on actual and potential problems with the hardware, and continuous measurement of the critical manufacturing operations. The bulk of the presentation consists of a series of examples which are clearly presented and well illustrated. It will be of value to those who may wish to implement similar ideas on other manufacturing programs. (The paper contains a number of typographical errors, the most important of which have been cited in errata accompanying the volume.)

R66-12831 ASQC 813; 816

QUALITY INNOVATIONS PROMOTE PRODUCT RELIABILITY.

L. G. C. Peirce (Martin Co., Denver, Colo.)

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 6 p. 2 refs.

Five quality motivating programs to promote product reliability are described; and specific cases are mentioned to illustrate the ever-increasing need for new programs that will promote production efficiency, cost reduction, and higher product reliability. Supplier quality assurance and perpetual evaluation, quality measurement of management effectiveness, a quality audit operation, a reliability achievement program using a team approach, and an incremental summary review are discussed. The responsibilities for achieving reliability in manned space programs are stressed, as is the need for proper tools to accomplish the necessary reliability. M.W.R.

Review: This paper is a brief summary of five reliability motivating programs which have apparently proven their effectiveness. Collectively they illustrate things which can be done to motivate people toward better product reliability. More of the type of thinking described in this paper is needed if the challenges of manned space programs are to be met.

R66-12833 ASQC 813

RELIABILITY REQUIREMENTS AND PRACTICE.

R. L. Body (Apollo Reliability and Quality Assurance Office, Kennedy Space Center, Fla.)

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 10 p. 1 ref.

The Apollo reliability program at the Kennedy Space Center, which is concerned with both the design and operational phases, is described. It is noted that the program includes integrated management organization, data management, and center reliability plans and procedures. Reliability requirements for off-the-shelf procurements are detailed. Aspects of design reliability which are discussed include Failure Mode and Effects Analysis (FMEA), criticality determination, maintainability analysis, alternate modes of operation, and qualification and reliability test programs. Operational realiability procedures include failure reporting and data exchange, utilization of the FMEAs, time and cycle data, and equipment logs. In summary, the KSC reliability program is developed around design assessment to identify trouble spots in time to take the necessary corrective action; these assessments are compared with actual test and checkout of systems and subsystems; and there is continuous monitoring of all operations. M.W.R.

Review: The general description of the Apollo reliability program at the Kennedy Space Center (KSC) which is given in this paper indicates a considerable continuity of organized reliability efforts after equipment leaves the manufacturer's facility. The uniqueness of NASA stands out when it is realized that much of the NASA operational hardware will funnel through KSC. This affords NASA an opportunity to enhance reliability, and this paper gives an overview of how NASA is going about this at KSC on the Apollo program. An interesting feature for a NASA effort is the inclusion of a maintainability analysis on support hardware, which is aimed at reducing the severity of prelaunch check-out failures when a small launch window exists. To date, NASA has emphasized reliability much more than maintainability.

R66-12837 ASQC 813; 820; 844

RELIABILITY CONSIDERATIONS IN A DEVELOPMENT PROGRAM.

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 19 p. Prepared by the Statistical Engineering Methods Group, Pratt and Whitney Aircraft, East Hartford, Conn.

Failure phenomena are considered as a function of time and stress, the relationship between component and system behavior is discussed, and probe testing procedures are presented in a paper which was prepared as a supplement to a film, entitled *"Reliability Considerations in a Development Program."* A mathematical model of systems with many components is described, and attention is given to the concept of unequal component reliability. Probe testing is considered to involve isolation of the so-called vital few failure modes, determination of existing design margins, and demonstration of reliability with stated statistical confidence; and applications of probe testing are mentioned. Typical application of Weibull analysis techniques is discussed and illustrated; and 5%, median, and 95% rank tables are included for various samples of ball bearings. M.W.R.

Review: This is a supplement to a film and thus is not expected to be self-contained. A large portion of it is quite elementary and rough, i.e., it can be used to get a feel for the concepts, but should not be taken literally. For example: (1) The word "random" is incorrectly used to imply an underlying Poisson distribution. (2) It is incorrectly implied that one should strive for a constant failure rate during the useful life. (3) It is not clear just how the confidence is derived for the tolerance limit. (4) Statistical independence is not the same as physical independence. The concept of probe testing (not clearly presented here) is a good one and can be used profitably. The problem of how best to figure the direction for the combined stress vector may be formidable at times, but does not detract from the usefulness of the method.

82 MATHEMATICAL THEORY OF RELIABILITY

R66-12806 ASQC 820; 844

THE CASE FOR RELIABILITY MODELING AND ANALYSIS.

G. Ronald Herd (Kaman Aircraft Corp., Bethesda, Md.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 2 p.

One of the main advantages of mathematical modeling for reliability analysis is considered to lie in the fact that it necessitates a detailed, systematic examination of every aspect of a design, thereby indicating almost all of the problems that might be encountered. Modeling is said to introduce discipline into the assessment of a design; and high reliability in many current weapon systems is attributed to the use of mathematical modeling. It is concluded that without the mathematical model as a basis, testing evaluation is simply not possible for any large-scale system. M.W.R.

Review: This is an essay which exhorts people to use mathematical/statistical models in their reliability analysis; it does not give examples of how to do it. Certainly, mathematical models are valuable, but often it is difficult, if not impossible, to write performance equations for complex systems. Data are often not available to use in the equations even if they can be written down. Other types of models, such as reliability logic diagrams can be used effectively, but these rarely account well for degradation. Other reliability efforts, such as failure modes and effects analysis, can be more profitable sometimes rather than trying to develop a straight mathematical model. But modeling should certainly be considered one of the valuable weapons in the arsenal and should not be glossed over because of laziness. For a rather different point of view, see the paper by Finocchi on p. 111 in the same volume.

R66-12821 ASQC 824; 433

APPLICATION OF BAYESIAN STATISTICS IN RELIABILITY MEASUREMENT.

R. A. Babillis and A. M. Smith (General Electric Co., Spacecraft Dept., Philadelphia).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 9 p.

An approach utilizing Bayes' theorem combines analytically derived design reliability data with available test data, and selection of the distribution to represent the prior estimate of a component's reliability is considered the heart of the problem. It is noted that the use of a maximum entropy prior distribution does not always lead to a convenient mathematical expression when combined with the data, and so a trade-off is made between exactness and ease of calculation. A variety of possible forms of prior knowledge is tabulated, along with the resulting maximum entropy prior distributions, for application to a constant failure rate device. Three examples from actual component test records illustrate how data tend to modify the prior estimate as well as to provide a comparison with classical results. Failures alone control the sharpness of the distribution. The Bayes posterior distribution is noticeably influenced by the prior estimate, a factor which makes the Bayesian estimate always higher than the classical estimate. M.W.R.

Review: The idea of using Bayesian methods in reliability estimation is a good one. There are several estimators possible (e.g., mean, mode) for any distribution and the use of a particular one is not determined by the use of Bayesian methods. The method of Jaynes' Maximum Entropy is interesting and perhaps fruitful, but all its logical implications are sometimes overlooked; it has some that cause grave disadvantages in its use. The Gamma distribution is a good one to use for the prior distribution, but the method of assigning values to the parameters does leave something to be desired. When the standard deviation is not small compared to the mean, the Gamma distribution is very unsymmetrical. The paradox involved with good test results and a very uncertain prior estimate is interesting, especially in view of some of the recent work on intuitive probabilities vs. Bayes' probabilities. Suppose an engineer estimates a prior distribution for failure rate and runs a test to get more data. He then combines them and does not like the answer. Obviously, then, the target of criticism is his prior distribution—and in the text example, the engineers knew more than they were willing to put into the distribution. In some of the examples confidence limits are calculated, for sequentially-obtained data, on the basis of single-sample statistics; that is wrong. (See RATR 1455 in connection with this problem.) The paper asserts that the Bayes posterior distribution is greatly influenced by the prior estimate when the actual test time is small compared to the equivalent test time in the estimate. Actually, the reverse is true and provides the paradox the authors did not like. If you say, "I haven't the vaguest idea of the true failure rate," and then run a test and get zero failures, do not be surprised that the posterior estimate of failure rate is much less than the original, since the test showed zero. There seems to be some confusion about whether or not the Bayes estimate is supposed to take into account reliability growth, and, if so, just how it would do that.

R66-12824 ASQC 824; 831; 844

DEVELOPMENT EFFORT TO ACHIEVE RELIABILITY.

G. M. Clark and K. B. Haigler (Rocketdyne, Canoga Park, Calif.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 9 p. 7 refs.

A reliability growth model is presented which starts with initial-failure symptom and failure-cause estimates, and uses previously obtained development efficiencies to predict ultimate design reliability. An engineering appraisal of the design concept and the development plan is converted into quantitative estimates of the development method to realize reliability goals. The mathematical model developed assumes that a liquid rocket engine system may exhibit failure during the start–stop transient or during steady-state operation. To illustrate the potential effects from variation in operating level, an example is presented for single failure symptom; and to assess its impact, an engine design requirement is translated into an operating level for each failure symptom. Development testing and cost for reliability goals are graphed for small, medium, and large turbopumps; and a cost-reliability trade-off is diagrammed. The instantaneous rate of reliability growth is shown at the early, middle, and late stages of a typical development program. M.W.R.

Review: The development and use of reliability growth models as tools for estimating system reliability and allocating development resources are receiving more emphasis. This paper presents a reliability growth model and discusses its use in the development of large liquid rocket engines. The model is practical and applicable to any system which lends itself to using a test-fail-fix cycle during development. As usual for practical models, many simplifying assumptions are required and are explicitly stated in this paper. The mathematics of the model appears acceptable; however, the formulation is not easily followed because of the methods of presentation whereby the assumptions, definitions and derivations are presented separately, causing the reader to have to refer back and forth. Even though no fault of the author, printing errors detract from the readability. Descriptions of other reliability growth models are presented in the papers covered by RATR 2476 and 2663.

R66-12835 ASQC 822; 412; 824; 844

RELATIONSHIPS OF HAZARD RATE DISTRIBUTIONS TO RELIABILITY GROWTH AND CONFIDENCE COMPUTATIONS.

Theodore C. Bowling (Boeing Co., Airplane Div., Wichita, Kans.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 14 p. 3 refs.

A mathematical model is constructed to establish hazard rates of the parts failing in a system test, and an analysis is included which provides best estimates of the combined true hazard rates for each of the failure groups. In order to make reliability growth computations, it is necessary to make some kind of reasonable assumptions regarding the true hazard rates of the improved parts that will replace those that failed; and one of the assumptions is that the replacement parts will have a mean rate equal to the mean rate of the unfailed parts. A solution is evolved on this basis, and it is noted that the method is not applicable when the sample is very small or for a system that has not as yet been tested. Several reliability growth factors are graphed, the application of typical system failure data is considered, and results of the method at the 90% confidence level are illustrated. M.W.R.

Review: This paper is extremely difficult to read. The first page and a half are devoted to notation which, at this stage of the reading, have very little meaning for the reader. Further, many of the basic assumptions of the paper are made implicitly in the notation (and nowhere else). Other specific difficulties may be noted, such as defining Z, the true hazard rate of the system (presumably a population parameter), as that which "would be measured with a sample size approaching infinity." All in all this paper cannot be recommended to reliability research workers. However, some of the above difficulties are alleviated in the original paper, available from the author.

R66-12827 ASQC 821; 431

MISSILE AND SPACECRAFT COUNTDOWN PROBABILITIES BY MARKOV CHAIN TECHNIQUES.

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

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 10 p. 8 refs.

Mathematical prediction of the countdown probabilities of spacecraft launch vehicles is considered in terms of a Markov chain process. The numerical probabilities for estimating countdown progress and performance are presented for a four-day period as to launch window, day of launch, and relations of attempted launch on any day with respect to real time. With a time scale and repair times, probability of launch on a subsequent day can be quickly estimated following a scrub on the scheduled launch day. Countdown probabilities are graphed with corrections for scrub effect, and details are given for the development of the countdown probability model. M.W.R.

Review: This paper points out the applicability of the Markov chain model to the important problem of estimating countdown probabilities. The discussion is generally good, but the presence of many typographical errors is a bit disturbing. This would be especially so for the research workers desiring to apply the method without fully understanding the theory. Some of the clarity of the paper is lost near the end (for example, what is h?).

R66-12839 ASQC 822; 552; 844

FAILURE DISTRIBUTION ANALYSIS.

Richard B. Schwartz, Sol M. Seltzer (Computer Applications, Inc., New York), and Frederick N. Stehle (Bureau of Ships, Electronics Div., Fleet Electronics Effectiveness Branch, Reliability Unit, Washington, D. C.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jun. 28–30, 1965. 22 p. 20 refs.

Sensitivity measurements indicate that significant errors can occur in exponential life-characteristics estimated from failure data when the underlying distribution is truncated normal, logarithmic normal, gamma, or Weibull. A unified procedure for analyzing time-to-failure is presented which cover the above-mentioned and exponential and normal distribution; and exponential probability paper and gamma-probability contours were developed. Analyses indicate that a different set of plotting positions is applicable to each distribution and for each shape parameter within the distributions. Optimal sets of plotting positions were determined for each distribution from three sets of currently used positions. The recommended decision rule is to use median-rank plotting positions with all the distributions when the shape parameters is equal to or greater than one, and to use linear-scale rank positions with gamma and Weibull when the shape parameter is less than one. A nonparametric reliability analysis procedure is incorporated with the parametric procedures; and fifteen tables of plotting positions (percent failure) are presented for different confidence levels. M.W.R.

Review: The paper deals with the important problem of non-exponential failure data. Unfortunately the paper is full of major typographical errors (which were not corrected in the subsequently published errata for this volume). Hence the reading is rendered quite difficult. Presumably the graphs given are correct and will provide useful information. The section on graphical analysis procedures seems less prone to typographical errors and is thus more readable. The "theory" of such procedures, however, is not given here and one must refer to an earlier report for these details. A numerical example illustrates the methods. The first author in a private communication has indicated that he will be glad to send errata and a copy of the Final Technical Report of the study to interested readers of the paper.

R66-12840 ASQC 824; 844
STATISTICAL ANALYSIS OF FIELD DATA.
James R. Taylor, Jr. and Robert H. Lochner (General Motors Corp., AC Spark Plug Div., Milwaukee, Wis.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965 9 p 9 refs

A life-testing model for analyzing reliability data obtained in the field is described, and the selection of proper analysis techniques is detailed. Analyses based on exponential and Weibull distributions as well as distribution-free techniques are discussed along with the procedure for organizing the data. In the case of the latter, attention is given to confidence limits and bands on reliability and estimating reliability from incomplete data. A comparison is made of a life test model and a field data model, and a discussion is included on ordering of observed failures and determining proper sample sizes. M.W.R.

Review: This paper will be useful to reliability personnel desiring to analyze field data with valid statistical methods. The authors have given precise assumptions under which the results are true and have presented the material in a nice way. The reader should be warned that, as originally published, this paper contained many typographical errors (and some of the pages were out of order). Errata for this volume have subsequently been published and should be consulted.

R66-12841 ASQC 824
LINEAR ESTIMATION FOR THE LOG WEIBULL DISTRIBUTION.
John S. White (General Motors Research Laboratories, Mathematics Dept., Warren, Mich.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 9 p. 7 refs.

Consideration is given to the linear estimation of Weibull parameters (slope and characteristic life) from a random sample of ordered failure times in order to provide a model for use with wearout or fatigue type failures. Minimum variance linear estimations, least-squares estimators, log Weibull estimations, and Blom's method are discussed. An example is presented of a random sample which is cycled until all of its nine parts have failed; and results obtained by the various methods are tabulated and compared. These techniques are considered applicable to the reliability analysis of censored samples, and a set of Monte Carlo computations is being made. M.W.R.

Review: This paper is addressed to an important problem, since the Weibull distribution is frequently used as a model for wearout and fatigue-type failures. The paper contains several interesting results, but the reading is rendered extremely difficult by the presence of many typographical errors. The author in a private communication has indicated that the papers in this volume were retyped and published with no galley proofs being sent to the authors. Interested readers may obtain an original copy of this paper (General Motors Corporation Research Publication GMR-481) from the author.

83 DESIGN

R66-12815 ASQC 838
MAINTAINABILITY AND RELIABILITY COST EFFECTIVENESS PROGRAM (MARCEP).
E. P. Trott (Boeing Co., Aero-Space Div., Maintainability Research Staff, Seattle, Wash.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 10 p. 3 refs.

Cost effectiveness considerations, basic program logic, and required program inputs are among the topics considered for the Maintainability and Reliability Cost Effectiveness Program (MARCAP), a computer technique for improving system reliability by using parallel standby, and spares redundancy. Selecting the right type of redundancy is discussed, as is the effect of operating conditions of safety criticality and repairability on the selection of redundancy. Mathematical and logical foundations of the selection criteria used by MARCEP are given, and failure distributions used to generate component reliabilities in MARCEP are shown. Determination of probability of repair is shown by an example, and it is noted that MARCEP is programmed to consider repair time as a truncated exponential distribution. M.W.R.

Review: This appears to be a useful addition to the group of techniques for improving reliability by the use of redundancy. Even though the technique "... does not require the lengthy process of system modeling" in one sense of the phrase, its use does imply a particular and restrictive model for the system. The optimization criterion (This word is often used in Reliability literature. If authors would learn that criteria is plural and criterion is singular, their papers would be easier to read.) is also restrictive and other criteria might give different results. (Not all the formulas were checked, but they appear to be reasonable. The headings for failure rates in Fig. 5 "hours $\times$ 10^{-7}" are obviously wrong.) The paper gives a reasonably good description of MARCEP and the reader should be able to determine from the paper how much help the technique would be in his work.

R66-12817 ASQC 837; 821
AN APPRAISAL OF "FAIL-SAFE" AND "SAFE-LIFE" DESIGNS.
Harold Switzky (Republic Aviation Corp., Aircraft Div., Farmingdale, N. Y.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965 12 p

Failure probability is calculated for a structure which consists of multiple paths of elements whose statistical ultimate strength distribution is known, and thettthod for determining ultimate strength of equally loaded paths is given. It is noted that in usual structural experiences the damaging load is not maintained for any great time and failure can take place over a period time with small detrimental redistributions of load, especially in the case of a multiple load-path structure fabricated with ductile materials. For these the restrictive conditions, a fail-safe design is considered more advantageous than a safe-life design; and two cases are cited to make this point. The fail-safe concept is considered worthy of consideration for ductile materials, especially when failure criteria are goverened by fatigue, creep, yield, or stiffness. Unless high safety factors are employed, this concept is considered of questionable value for brittle materials. In either case, further investigations are recommended. The mathematics required for the determination of failure probability are included. M.W.R.

Review: The paper is more limited than the title might imply. The probabilities of failure of a few cases for multiple load-paths are calculated and some advantages of fail-safe design are listed. Any such analysis is quite sensitive to the assumptions, and the outcome of the analysis is likely to be much more sensitive to the exact nature of the assumptions than is usually appreciated. The paper is somewhat mathematical and will be difficult to follow for someone not well versed in probability theory. (There are some editorial problems, e.g., the references are not listed; the meanings of deviation and path-length are not clear.)

R66-12820 ASQC 832; 844
A METHOD OF PREDICTING HUMAN RELIABILITY.
A. B. Pontecorvo (Aerojet-General Corp., Liquid Rocket Operations, Sacramento, Calif.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 6 p. 4 refs.

A method by which a reliability estimate can be derived for human performance for use as a design tool, is presented which combines task ratings with empirically based data to derive a regression equation. By analyzing man's function in a system, existing data is extrapolated to conditions or procedures not previously observed or recorded in order to make provisions for human factors solutions. The method described is considered to have applicability during the early design phases to quantitatively assess the interaction of men and machines and to provide data on detailed task analyses. A table presents means and standard deviations of ratings and reliability estimates for various task estimates. The outlined method was validated through the use of performance data during testing of the Titan II propulsion system. M.W.R.

Review: This paper is addressed to an important problem—a practical method for predicting human performance reliability for use as a design tool. The method proposed involves the fitting of a regression equation, the input data for which are empirically-derived reliability figures and subjectively-assigned ratings of error potential. A pitfall in this type of analysis is that of assigning to the results an aura of precision which they do not merit. In the example given, the regression coefficients are carried to five and four significant figures respectively, a precision far beyond that which the input data would seem to justify. The plot of the data and the regression line is not indicative of a very good fit. It would be of interest to the reader to know the standard error of estimate for the error rate in this situation. The fact that the derived line was a "best fit" in the least squares sense does not in itself say very much, since a "best-fitting" line can be calculated for any scatter of points in a plane. From the information given in the paper, it would appear that the method can give, at best, only very gross reliability estimates. It would be unwise to place faith in these before determining the possible error associated with them. Near the end of the paper a reference is made to extrapolation to conditions or procedures not previously observed or recorded. It should be kept in mind that the regression analysis technique lends no validity to such extrapolation.

R66-12822 ASQC 830; 844
ELECTRONIC DESIGN CALCULATED VERSUS OBSERVED RELIABILITY.
R. H. Wagner and E. H. Purvis (Sperry Phoenix Co., Ariz.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 8 p. 1 ref.

Discrepencies between predicted and observed reliability are discussed for SP-50 electronics during its first year of airline service. Observed reliability exceeded predicted reliability for 1961 by 120%, and for 1964 by 50%. Distribution of failures by part classification differed sufficiently from predictions to warrant further analysis. It is noted that the prediction calculations were made at 71°C ambient temperature, whereas operating temperature was only between 35° and 50°C; and tabular data indicate that the improvement in observed reliability was primarily due to passive electronic elements, solder joints, and connectors. It is, therefore, concluded that the inherent reliability of a design based on the summation of random detail-part failure rates can be exceeded operationally. The use of application factors for vehicle environment or adjustment factors for system complexity is not considered valid for avionics systems for commerical jet aircraft. However, adjustments are recommended in the reliability predictions for designs using new techniques or devices. M.W.R.

Review: The frustrations experienced in trying to reconcile predicted reliability with that which is actually experienced by the resulting hardware are exemplified in this paper. It is not that the overall reliability figure is very far amiss based on what can be expected in this situation, but rather that the detailed failure causes are not those which were expected. The prediction here is based on several military handbooks. There is undue concern in this situation with the quantitative detail, such as carrying failure rate predictions and observations to four significant figures. Equipment manufacturers can expect to use the industry-wide data which are presented in handbooks only in a loose manner, as there are just too many variables involved which cannot be quantitatively treated on an industry-wide basis. However, when an equipment manufacturer is fortunate enough to be able to develop his own data, as in the case described in the paper, then he has some chance of developing a more accurate prediction technique. This paper is somewhat of a progress report on one of the early contractual reliability requirements in commercial avionics; RATR 1029 covers the paper describing the situation.

R66-12826 ASQC 831; 713; 817
STRUCTURAL SYSTEM DESIGN TECHNIQUE FOR RELIABILITY AND WEIGHT TRADEOFFS.
C. Dicks and S. Wilson (General Electric Co., Apollo Support Dept., Daytona Beach, Fla.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 10 p. 9 refs.

A technique is presented which uses designer's equations, the probabilistic characteristics of structural materials, geometry, and operational loads to provide a quantitative structural reliability number. These structural reliability numbers can be used to make structural weight trade-off studies and to achieve a more uniform reliability of weight allocation among the various systems. The reliability methodology includes: (1) identification of design parameters, (2) using designer's equations and data, (3) establishing statistical properties for each variable, (4) preparation of load and logic flow diagrams, (5) setting up the computer program, (6) calculation of allowable and actual stresses for randomly selected values of each variable, (7) comparison of allowable and actual stresses for success and failure probabilities, (8) recording the comparison and repeating the procedure for the number of trials desired, generally n=10,000, (9) computing reliability from the 10,000 trials, and (10) applying the results to the overall reliability system model. The technique is illustrated by intertank analysis data, which show the effects of skin-thickness number on reliability numbers and weight changes. M.W.R.

Review: This is very similar to the paper by the same authors covered by RATR 1893 which was presented six months earlier at the Winter Reliability Symposium, although it is not quite as long. The example is essentially the same. The modeling done here and its solution by Monte Carlo are reasonable enough. The difficulty arises in being sure enough of the distributions that are used, especially far out in the tail regions.

R66-12832 ASQC 831; 770

SYSTEMS TESTING—FINAL CHECK ON TITAN RELIABILITY.

Donald L. Schmidt (Martin Co., Denver, Colo.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28-30, 1965. 6 p.

System testing is considered as the final reliability filter for space hardware, and results are discussed for reliability problems and their solutions for the Titan ICBM program. Problems in the Titan II hypergolic propellants and inertial guidance systems are mentioned, along with the improved failure analysis techniques that were developed for Titan II. Systems testing for Titan III is reviewed in light of knowledge gained from the earlier Titans. Emphasis is placed on the concept that reliability is a product of people and of management controls. The development and application of practice reliability and its contribution to system testing are discussed; dynamic failures documented from the systems approach are reported, and the importance of the system failure analysis report is stressed. M.W.R.

Review: This is a rather brief and general description of systems-testing as applied in the Titan missile and space booster program. The pursuit of failure causes and the recognition that reliability is a product of people are significant aspects of the program. The need for adequate documentation to permit a systems approach to failure analyses is clearly brought out.

R66-12834 ASQC 831; 770

SOME TESTING ASPECTS OF RELIABILITY FOR A MAN RATED LAUNCH VEHICLE.

J. W. Carter (Martin Co., Reliability and Test Dept., Baltimore, Md.), and R. L. Schlechter (Martin Co., Test Integration, Gemini Launch Vehicle, Baltimore, Md.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28-30, 1965. 9 p.

Analysis, hardware design and testing, and discipline are considered the three phases of the reliability implementation for a man-rated launch vehicle; and testing aspects of reliability are reviewed for a manned booster. Tests, location, and phasing are tabulated for the Gemini launch vehicle total test program; the component test program and component failures are detailed; and percentage of failures by environment are given. Booster-test program flow is discussed; and qualification and production monitoring test vibration levels and a component malfunction summary of the airborne systems functional test stand program are tabulated. It is concluded that the reliability benefits from the testing program can be measured in terms of actual component performance in the booster throughout its test history, and that the testing depth and performance criteria were valuable for detecting substandard components. M.W.R.

Review: This paper will be of interest to those who wish to have a quick look at the more significant aspects of a comprehensive test program for a manned booster. It presents actual data (only too rare in reliability papers) bearing on the Gemini Launch Vehicle program. Since this vehicle has an excellent reliability history, these data should be of value to those concerned with similar testing programs. The results are also of interest in connection with the optimum test sequence to be employed for manned rockets. (Like many other papers in this volume, this one is marred by many typographical errors. The more important of these have been corrected in errata accompanying the volume; corrections for the others may generally be inferred from context.)

R66-12838 ASQC 832

MEASUREMENT AND PREDICTION OF HUMAN PERFORMANCE AS A QUANTITATIVE FACTOR IN SYSTEM EFFECTIVENESS.

Wilton P. Chase (TRW Space Technology Laboratories, Redondo Beach, Calif.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28-30, 1965. 14 p. 6 refs.

Mathematical modeling of system effectiveness in combination with the system functional model is considered a vital tool for determining human performance reliability, as are computer simulations which take into account both equipment and human components. The essential theorem for equating human component outputs with equipment component outputs is to identify those performance dimensions for which an ordinary numerical value can be assigned, and can be handled mathematically as equal datum units for statistical analysis. Attention is, therefore, given to methodologies for the measurement and prediction of human performance reliability. General trade-off considerations between equipment and personnel are summarized in a table of factors to be considered in allocating functional decision requirements to men and machines. A summary is also included of various progressive methodological approaches used in system development and their significance for human error prediction; these approaches are in addition to the mathematical models, these approaches include logical system analysis and synthesis, engineering drawings, simulations and laboratory tests, end item and system tests, and operational tests. M.W.R.

Review: This paper is concerned with the methodologies which must be applied in system development programs in order to increase the reliability of human performance in systems. The view that the performance of the human component in a man–machine system should receive as much consideration as the performance of hardware components is worthwhile, and should receive more attention from management. This paper illustrates a basic approach. The details of application in any specific program would have to be worked out. Consequently the paper serves a purpose for those concerned with planning for the effective operation of man and machine as a team in future aerospace projects.

84 METHODS OF RELIABILITY ANALYSIS

R66-12816 ASQC 844

PREDELIVERY STEPS TOWARD RELIABLE COMPUTERS.

M. A. Young (International Business Machines Corp., Space Guidance Center, Owego, N. Y.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 11 p. 3 refs.

A reliability program keyed to a comprehensive understanding of past failure experiences is considered to form one of the best predelivery assurances of reliability in aerospace computers. Detailed and systematic study of failure sources, modes, and causes provides the basis for immediate corrective action as well as data for future designs. Failure rates of elemental components are considered the most important parameters for reliable design; and failure rate estimates must be directly related to data obtained from similar equipments. Possible effects of equipment duty cycle, or fraction of power-on time, must be analyzed to establish its effect on failure rate estimates. The point is made that in almost all cases, a part that became a failure-source was different from a failure-free item. Analysis of reliability requirements are made, and the feasibility of 0.95 reliability requirement for digital computer equipment is shown. M.W.R.

Review: A meaningful data-base coupled with sound reasoning combine to make this a readable paper. The viewpoint which is adopted—that there is no random failure in the classification of failure causes—is to be applauded. Those concerned with failure analysis and corrective action will particularly want to read this paper. However, one should keep in the mind that the quantitative observations which are reported here are for digital systems, and it is the approach rather than the numerical results which will be of value to analog systems. The two principal applications of failure understanding which are cited in the paper are the institution of screening techniques aimed at reducing the dominating failure cause of material imperfection, and the development of failure rate prediction approaches which are reasonably accurate because they reflect the uniqueness of this particular hardware producer. Some additional candidates for applications of failure understandings would be emphasized quality control at the material level aimed at cause elimination rather than sorting, and investigation to determine if the near elimination of the tolerance failure mode has perhaps resulted in a higher total failure rate than would be achieved if there were proportionally more tolerance failures and less catastrophic or intermittent failures.

R66-12819 ASQC 844; 770

TEST TECHNIQUES APPLICABLE TO RELIABILITY PREDICTION AND PRODUCTION CONTROL.

B. Tiger and R. A. Geshner (Radio Corporation of America, Defense Electronic Products, Camden, N. J.).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 7 p.

Strength variables sampling is discussed as a technique for reliability prediction and production control of devices which do not effectively degrade in strength under ordinary and proper applications; and the Stress Survival Matrix Test is shown to be a practical technique to evaluate whether any device type is effectively free of degradation. Using these techniques, a program is described for the development of more meaningful electrical connection reliability prediction data than results from conventional life testing. The Stress Survival Matrix Test is used in combination with a special strength control chart for variables sampling; and the method is considered to be of value for devices such as integrated circuits which have low failure rates and minimal historical backup data. Production control is accomplished by determining the strength variables and using strength testing for Process Mean (X) and Process Standard Deviation (S) charts. Reliability is predicted by using X and S, knowledge of the underlying probability distribution, and appropriate acceptability limits. Reliability can also be predicted by estimating X and S from the sample, and these data form the basis for the strength control charts. M.W.R.

Review: This paper is a concise description of two test techniques applicable to reliability prediction. The first, strength variables sampling, is applicable to devices which do not degrade substantially in usual and proper application. The second, the stress survival matrix test, can be used to verify lack of degradation, or to measure its extent if present. The latter technique was described in the paper covered by RATR 1525. The problem of substantiating the underlying distribution, mentioned in that paper and review, is briefly discussed in the present paper. These are good practical techniques which have applicability to a variety of component types, although the description in the paper is given in terms of electrical connections. Numerical data in the paper serve to illustrate their application and the references cited will be useful to those who desire more details.

R66-12823 ASQC 844; 821

PROBABILISTIC LIFE CONSUMED ANALYSIS ON HIGH TEMPERATURE, HIGHLY STRESSED STRUCTURAL PARTS.

G. W. Weber (General Electric Co., Large Jet Engine Dept., Cincinnati, Ohio).

Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 7 p. 5 refs.

Model-sampling methods are considered for use in high-speed computers for full probabilistic simulation of critical design relationships to predict failure rates, and an example is presented whereby a costly program to redesign and qualify a new casing was avoided. It is noted that while the overall method for probabilistic life consumed analysis on high temperature, highly stressed structural parts is by no means fully developed; the general method presented is applicable to any mode of failure whose basic failure physics or chemistry is understood, or for which a failure parameter can be calculated. Greatest probable errors may occur in the following aspects of the method: (1) inaccurate input distributions, (2) imperfection in the life consumed concept, and (3) extrapolating theoretical distributions to the 100% life consumed value. M.W.R.

Review: This is generally a good approach to evaluating the life of a part wen the failure mechanism is known in a deterministic way. The probability comes in by way of fabrication, materials, and environmental factors. The discussion of problem areas with the method is good. Some of the labels on the graphs are not clear; e.g., failures per life. It would seem that calculation of the instantaneous failure rate (hazard function) from the cumulative curve might have been more profitable than the use of the average failure rate. The extrapolation to small probabilities of failure and the presumption that the distribution of life in log Normal are rather shaky procedures. But part of the essence of engineering is doing the best you can with what you have. This method of analysis seems to do that.

R66-12836 ASQC 844
SYSTEM SURVIVAL IN THE NONOPERATIVE STATE.
W. L. Hadley and R. T. Patterson (Martin Co., Orlando, Fla.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 7 p.

The technology needed for nonoperating survival is considered to be the major gap to be closed in the field of reliability; and it is noted that program emphasis should be shifted to include the use of complete system evaluation models, detailed nonoperative failure rate data, and new design approaches to system storage reliability. Development of the nonoperating rate reliability model is detailed, as is technology needed to design systems for storage survival. The later deals with prediction of nonoperating failure mechanisms, technical development plans, data collection, and storage survival mathematics. M.W.R.

Review: As is common with papers on the subject of non-operating failures, most of the discussion concerns the problems involved in analyzing the subject. This paper is a good one and treats rather well what is known. The tables of nonoperating failure rates represent an important starting point for reliability analyses under nonoperating conditions. It will apparently be quite a while before precise knowledge in this field catches up with that for operating failures (which in itself is none too good). The first author in a private communication has advised that superseding data will become available shortly in the final report of contract AF 30(602)-3772 (Rome Air Development Center) Report No. RADC TR-66-348 entitled "Dormant Operating and Storage Effects on Electronic Equipment and Part Reliability."

86 FIELD/CONSUMER ACTIVITY

R66-12803 ASQC 863; 814; 815
QUALITY AND RELIABILITY—ITS ROLE IN LOGISTICS.
George E. Fouch (Office of the Assistant Secretary of Defense, Washington, D. C.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 6 p.

Developments and innovations in logistics which pertain to quality and reliability policies, planning, and procedures are reviewed. Logistics, which is used to include procurement, production, maintenance, and supply support, is both responding to and helping to make far-reaching changes in military technology. There is a broad trend toward contracting formats which emphasize economic ownership; and, therefore, contracts are increasingly taking account of supply support and maintainability. Under the influence of incentive contracting and within the context of a philosophy of economic ownership, contractors can be expected to accent quality, reliability, and maintainability because of enlightened self-interest. Attention is given to value engineering, contractor performance evaluation and weighted average share, zero defects, and the defense contract administration service; and the need to integrate the various functions necessary to design, procurement, production, and maintenance of products and systems is stressed. M.W.R.

Review: Quality and reliability are key words in the title of this paper, but it has little explicit content relative to the popular use of these words. However, it does address itself to the purpose stated in the paper—that of reviewing some logistics developments which have some impact on reliability. Logistics as used in the paper has reference to defense procurement in the broadest sense. An overview is presented of currently-popular policies and techniques for DoD procurement, such as value engineering and contractors weighted average share. Collectively, these are the means of pursuing the current DoD policy of economic ownership. The policies and techniques are said to be based on (1) recognition of profit as the motive of business enterprise, and (2) recognition that profit will encompass post-factory history. The solution of reliability problems can be enhanced only by the enlightened pursual of this policy. The author gives recognition to the "cult" tendencies of the various technique groups which have appeared in recent years. He apparently has some favorites among the "cults," as he has kind words about some, such as value engineering and Zero Defects, and takes a few "pot-shots" at reliability.

R66-12807 ASQC 863; 871; 881
RELIABILITY CONTRIBUTION TO MINUTEMAN LOGISTICS.
Leonard L. Schneider (TRW Space Technology Laboratories, Redondo Beach, Calif.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 6 p. 1 ref.

Reliability and in-commission rate for the Minuteman weapon system are found to be higher than requirements set by the Air Force. The weapons system and its operational concepts and maintenance philosophy are reviewed, along with the development of logistics. The unusually high in-commission rate for Minuteman is attributed to extensive planning early in the program, and the publication and consistent use of operational support failure rates by all of the principal agencies involved is considered a major determinant of Minuteman's operational capability. Experience indicates that it is possible to make predictions of operational failure rates long before the actual operational data are available. M.W.R.

Review: This paper presents a brief description of the contribution made by Reliability to the logistics planning for Minuteman. Emphasis is placed on the availability of realistic failure rates for use in operational support planning. Among other things, this calls for proper planning early in the program. The principles described could well have applicability to other programs.

88 AVAILABILITY

R66-12825 ASQC 883
RELIABILITY FOR MANNED INTERPLANETARY TRAVEL.
Roy B. Carpenter, Jr. (North American Aviation, Inc., Space and Information Div., Downey, Calif.).
Reliability and Maintainability, Annual Conference, 4th, Los Angeles, Jul. 28–30, 1965. 8 p. 1 ref.

It is shown that the future for long manned space flights cannot depend upon high reliability alone, but requires a design optimized around the availability concept. The recommended approach to reliability design for spacecraft requires the establishment of an optimum balance between high reliability and good maintainability characteristics, with the emphasis on maximizing effectiveness. System availability is defined as the percentage of the total mission time during which the system is completely operable, and limitations which must be considered are listed. The availability concept, applied to a space vehicle attitude control system which might be used for a Martian expedition, requires designing within all of the constraints introduced by the necessity for maintenance. Discussed are the maintenance-time constraint, critical action constraints, spares weight/volume limitations, and astronaut maintenance capability. M.W.R.

Review: The theme of this paper is that high reliability alone will be insufficient for the success of long manned space flights. The author's solution to this problem is a design optimized around the availability concept. The ideas and arguments presented appear reasonable. The paper is worthwhile reading for designers of future spacecraft systems. It points up the need for designing with a view to the necessity for maintenance, and indicates some of the more important constraints which must be taken into account.

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77 TEST ENGINEERING

R66-12851 ASQC 770
Naval Missile Center, Point Mugu, Calif.
ELIMINATION OF SUBSTANDARD PARTS BY ENVIRONMENTAL TESTING
Lyle E. Matthews and Raymond C. Binder (Univ. of Southern Calif., Los Angeles)
20 Jan. 1966 15 p refs Also *In NRL* The Shock and Vibration Bull., no. 35, pt. 3 Jan. 1966 p 227–233 refs
(NMC-MP-66-1; AD-626842; N66-19963; N66-24039) CFSTI: HC $1.00/MF $0.50

This paper discusses objectives, laboratory tests associated with different design states, and possible gains of laboratory debugging tests or tests to eliminate substandard parts, the principle cause of early failures. In the laboratory, each of a set of missiles was subjected to two ten-minute vibration tests under a combined temperature-altitude environment. The temperature ranged from 180°F to −30°F, and the altitude was 40,000 feet. The missile was checked for acceptable operation before, during, and after the environmental test. The missiles were later flight tested. Missiles with no early failures which operated satisfactorily after the laboratory tests were satisfactory in the flight test (on the basis of having the capability of locking on the target and guide throughout the flight). Missiles which were early failures as a result of the laboratory test, and were subsequently corrected to pass the laboratory test, were satisfactory in the flight test. Although the sample size was small, there was correlation between the laboratory tests and flight tests. Author

Review: The topic to which this report is addressed, environmental laboratory techniques for investigating and improving system failure rate, could have much to contribute to the reliability of components and systems for aerospace applications. However, the report is very brief and much of the material in it is virtually axiomatic or at least well known to reliability engineers. It would have been more helpful to present some case histories in reasonable detail describing actual laboratory techniques which have been effective in identifying and eliminating early failures. There is no doubt that such identification and elimination is worthwhile; the trick is in finding effective ways of doing it.

81 MANAGEMENT OF RELIABILITY FUNCTION

R66-12849 ASQC 813
Bureau of Ships, Washington, D. C.
RELIABILITY PROGRAM PLAN FOR A DEVELOPMENT SHIPBOARD SYSTEM
Murray Burger and S. Bruce Ensley [1966] 41 p refs
(AD-630821)

Difficulties were recently experienced by the assigned project engineer and Navy Project activity in establishing a reliability program plan for a development system. Much research and time were involved in analyzing Bureau directives and shipyard organization to satisfy reliability requirements. The results of this effort are outlined. Technical Development Plan requirements are identified. A total reliability program plan is defined. The sample development system and its reliability goals are described. The proposed shipyard reliability program covering organization, schedule and tasks assignments is outlined. Design review functions and design controls are reviewed to show how design assurance will be monitored. The plan requirements for design checkpoints, system review, data collection and reporting are described. The summary includes a brief analysis of the shipyard plan from the project engineer's viewpoint. Author (TAB)

Review: Typically the implementation of a hardware reliability program is automatically associated with an industrial organization. The situation in this paper is one in which the government will design and manufacture the hardware in addition to performing the other life-cycle elements. A modern reliability program plan is presented in this report, which is entirely qualitative discussion. The shipyard progress outlined in the summary indicates a broad qualitative scope, with heavy reliance on data feedback from quality control reporting and limited tests. It is suspected that the usual difficulties experienced in industry will similarly be experienced by the government. The main determination will, as usual, be made at the management level. Competent people and adequate resources must be provided and management must give consideration to what they say; otherwise whatever is done will do more harm than good. Of course, even with solid management backing, there will be problems. One will be in the initial applications of explicit quantitative reliability requirements to products for which no historical precedent has been established for such analyses, such as certain shipboard mechanical and hydraulic items. In this respect, the shipyard may be compelled to develop its own data by testing under simulated environmental conditions.

R66-12876 ASQC 813; 815; 844
ELECTRO-MECHANICAL RELIABILITY.
Floyd E. Wenger (USAF, Systems Command, Andrews AFB, Washington, D.C.).
In: National Aerospace Electronics Conference, Dayton, Ohio, May 11–13, 1964, Proceedings. Conference Sponsored by the Professional Group on Aerospace and Navigational Electronics, Dayton Section of the Institute of Electrical and Electronics Engineers, and American Institute of Aeronautics and Astronautics. Dayton, Institute of Electrical and Electronics Engineers, Dayton Section, 1964, p. 86–88.
(A65-24112)

Discussion of procedures involved in establishing the reliability of electromechanical components. The basic failure mechanisms for electromechanical devices are reviewed, and procedures for finding the environmental and operational stresses for given applications are discussed. The use of a reliability-oriented specification for procurement purposes is described. Such a specification would give the supplier the details necessary to produce and test devices to meet stated requirements. P.K.

Review: This report is interesting because it deals with a subject which is traditionally thought to be neglected and because it presents some views held by a government department. The emphasis on understanding the hows and whys of failure, as well as the wheres, is good and is in line with current thinking. The discussion of the specifications is brief and is difficult to evaluate. In a sense, the value of any of these programs depends more on how they are applied than on their internal details. Specifications which are reliability-oriented are slow in coming into wide use, probably because of the many economic, political, and engineering factors involved. The paper itself is intended only to be a general look at the subject and will be of use to those with a concern only at that level of generality (including the writers of specifications).

R66-12880 ASQC 813
OBTAINING AND DEMONSTRATING RELIABILITY IN ELECTROMECHANICAL COMPONENTS IN NUCLEAR WEAPONS SYSTEMS MANUFACTURED FOR THE ATOMIC ENERGY COMMISSION.
Lawrence E. Killion (Atomic Energy Commission, Albuquerque Operations Office, Albuquerque, N. Mex.).
In: National Aerospace Electronics Conference, Dayton, Ohio, May 11–13, 1964, Proceedings. Conference Sponsored by the Professional Group on Aerospace and Navigational Electronics, Dayton Section of the Institute Electrical and Electronics Engineers, and American Institute of Aeronautics and Astronautics. Dayton, Institute of Electrical and Electronics Engineers, Dayton Section, 1964, p. 89–94.

A distinction is made between quality control and quality assurance; control is considered the contractor's program to maintain quality in weapons materials during manufacture; assurance is considered as basically an audit program to ascertain that nuclear weapons material accepted by the AEC for delivery to DOD is of satisfactory quality and in conformity with design criteria. Quality assurance, specifically related to procurement of electromechanical components for nuclear weapons, is described as a continuing function that applies to both new production and the reserve stockpiles. In addition to the management audits and reviews, the quality assurance programs include weapon material evaluation for audit verification by inspections, product quality surveys, laboratory evaluations, stockpile sampling, and new materials testing. M.W.R.

Review: This is largely a description of administrative procedures rather than engineering methods. As such, it provides information to those who are concerned with organizing and managing a reliability function. It is difficult to evaluate a program from the paper description of it since one cannot tell how it works in practice. The paper will be of little interest to design engineers.

R66-12885 ASQC 817; 872
SYSTEM OPERATIONAL READINGS AND EQUIPMENT DEPENDABILITY.
Joseph G. Wohl (Dunlap and Associates, Darien, Conn.).
IEEE Transactions on Reliability, vol. R-15, no. 1, May 1966, p. 1–15. 3 refs.

Operational readiness of repairable systems is defined in terms of finite queueing theory as the probability of meeting specified operational requirements at any given time. Design and use parameters are considered the primary determinants; and the design parameters, which include reliability and maintainability, are developed into a single nondimensional parameter, the dependability ratio. A derivation of single-device availability, considered a special case of operational readiness in which full-time availability of a repairman is assumed; is given for Weibull-distributed time to failure and repair. An example is given to show the possibilities for tradeoffs among men, machines, and operational requirements; the dependability ratio is used as a system variable. Tradeoff possibilities between reliability and maintainability are indicated for repairable systems. M.W.R.

Review: This is intended to be a summary of the present knowledge about reliability/maintainability tradeoffs and the effects on system effectiveness. The mathematics was not checked in its entirety but appears to be of high quality. It should be remembered that any tradeoffs are based on a given picture of the way the world is. If that picture is inaccurate or incomplete, the tradeoff analysis is likely to be in error. For example, the designer can have (at least) an indirect effect on logistics problems involved in maintenance. Just as some designs are easy to maintain, some may well be easier to keep supplied with spares. Commonality of modules for different equipment is a case in point. The paper does not require a high degree of sophistication to read and can be useful to designers who are interested in reliability tradeoffs.

82 MATHEMATICAL THEORY OF RELIABILITY

R66-12846 ASQC 824; 831
General Electric Co., Syracuse, N. Y. Radio Guidance Operation.
ON THE INTERFERENCE OF SYSTEM RELIABILITY. REPORT I: MATHEMATICAL MODEL
David Rubinstein 19 Nov. 1965 38 p refs
(R65R605; N66-37601)

This report discusses the model for system reliability based on independent exponentially distributed failure times of components. The model is adapted to the usual complexity *of system environment. Some convenient formulas for system reliability are derived.* A summary of the entire series of reports is given. Author

Review: This, the first in a proposed series of reports on the inference of system reliability, treats the mathematical model to be used. It is the common exponential distribution based on assumptions of constant failure rates of components and independence of component failures. From the model the author derives various formulations (and their accuracy) for reliability analysis of complex systems. The merit of this report lies in the fact that the author presents a careful examination of the validity of these assumptions and suggests ways of overcoming difficulties arising when they do not conform to reality. This is in contrast to many papers, reports, and even textbooks in which these assumptions are made quite casually as though they represented an unqualified solution to the reliability estimation problem. The presentation is mathematical with a practical orientation, reflecting an acquaintance with real-life problems. The engineer or statistician concerned with the reliability analysis of complex systems should find it useful.

R66-12850 ASQC 824; 844

COMPUTING MTBF–LAPLACE TRANSFORM USED AS A MOMENT GENERATING FUNCTION.

S. L. Friedman (Hycon Manufacturing Co., Monrovia, Calif.). *Electromechanical Design*, vol. 10, no. 8, Aug. 1966, p. 48–49.

A derivation for the Mean-Time-to-Failure (MTTF) is presented which uses the Laplace transform as a moment generating function. The method consists of (1) determining the reliability function, (2) determining the Laplace transform of the reliability function, and (3) setting the image variable equal to zero and solving for MTTF. Formulas are also given for the computation of MTTF for a series configuration and for a parallel operating two-component redundant system. M.W.R.

Review: The main thesis of this note is correct, viz., the mean failure time is the Laplace transform of the reliability function with the transform variable set to zero; it takes but one-third of the note. The remainder tends to be confusing since the exponential assumption is needlessly introduced. There is inconsistent repetition and the theorem is all but ignored. The short section entitled "MTTF and the Reliability Function" should be ignored since it is incorrect. At this point, rigor enters the picture. Mean time to failure (MTTF) is, of course, defined only when the integral (in the definition) exists. If it exists, then MTFF=$\int_0^\infty R\,dt$, regardless of what the failure rate (hazard function) does. As with the Gaussian distribution, for example, it may become infinite, and still the mean exists.

R66-12854 ASQC 824; 711; 844

Republic Aviation Corp., Farmingdale, N. Y.

STATISTICAL METHODS FOR THE PREDICTION OF SAFE AIRCRAFT FATIGUE LIFE

Herbert Jaffe [1963] 14 p refs Presented at the Aircraft Structural Integrity Program Meeting, Wright-Patterson AFB, Ohio, 6 Feb. 1963

(RAC-1147; N63-13745)

Methods are given for computing the safe fatigue life of aircraft components from the results of fatigue tests which simulate aircraft usage. The predicted ratio of failures to the *total number of components in use for a given confidence level* is obtained as a function of the scatter factor, which is defined *as the ratio of the geometric mean of the sample life to the* life at which the components are removed from service. Both the case where the fatigue life standard deviation is estimated from the sample and the case where it is estimated from a large number of similar tests are considered. Author

Review: It is not clear to whom this report is directed. The applied research worker will find the methods confusing and the statistician will find the methods incorrectly stated and, indeed, in some places wrong (at least as given). For example, relation (13) on page 7 can be satisfied only if L=0.5, but we are told that L is to be chosen as a tolerance or confidence level. Definitions are similarly unclear. It is probably true that a reader with a good statistical background could sort out exactly what is meant in this report but then anyone able to do this need not read the report in the first place!

R66-12855 ASQC 822; 553; 844

Aerospace Corp., El Segundo, Calif.

TABLES OF FACTORS TO FIND CONFIDENCE LIMITS FOR θ (MTBF) ASSUMING THE POISSON FREQUENCY DISTRIBUTION

Josephine Block and Tedd K. Kawata 1 Dec. 1963 7 p refs

Prepared for AF

(TOR-269(4303)-5; AD-613619; N65-36855)

Tables have been constructed to find upper and lower confidence limits for MTBF (Mean Time Between Failures) at values α=0.5, 0.2, 0.1, 0.05, and 0.01; and for one-sided lower confidence limits at values α=0.5; 0.25, 0.1, 0.025, 0.01, and 0.005. The tables should help reliability engineers in more easily computing confidence limits from accumulated test data. Author

Review: As the authors point out, the theory for these tables has already been well worked out, but the calculations in a ready form are not widely available. The derivations are concise and accurate. The tables were spot-checked and appear satisfactory. An assumption should be added to those given for the test, viz., (4) there is absolutely no prior information about the outcome of the test, e.g., no one has any idea whether all or none of the samples will fail. It is obvious from the notation, but not otherwise stated, that the two-sided limits are symmetrical. The case for no failures is properly treated separately, but the condition (at least one failure) is not explicitly stated in the other derivations. For convenience of use, add to Table I the legend "One-sided limit, $r\neq o$" and to Table II "Symmetrical two-sided limits, $r\neq 0$." The copy from NASA STAR N65-36855 is a poor reproduction. The document is nominally available from DDC as AD-613619 but could not be obtained. The best source of a good copy is probably from the authors.

R66-12859 ASQC 824; 831; 833

General Electric Co., Syracuse, N. Y. Radio Guidance Operation.

ON THE INFERENCE OF SYSTEM RELIABILITY. REPORT IVA: ESTIMATION OF FAILURE RATES IN A DYNAMIC RELIABILITY PROGRAM

David Rubinstein 17 Dec. 1965 69 p refs

(TIS-65RG07; N66-37602)

This report is concerned with the estimation of system failure rates when the available life test data is used both for selecting components and for estimating system reliability. It is shown that the conventional estimates based only on life test data of accepted components are biased. Unbiased estimates are derived for the system failure rate and of the variance of the estimate of the system failure rate. Other topics pertinent to dynamic reliability programs are covered including: various pitfalls in dynamic reliability programs; combination of preselection and postselection data; and design of life tests. All of the formal derivations are related to the sequential selection of components, which is thoroughly discussed. Author

Review: This report is concerned with reliability estimation for systems in which components are selected sequentially as the program progresses. The contrast between this situation and that of the static reliability program in which all components are committed for system use before life testing is begun is very important. The conventional estimates appropriate in the static reliability program may lead to serious errors in dynamic reliability programs. Since reliability estimation in the dynamic situation has received little or no attention in the literature, this report fills a need. The technical parts of this report are primarily mathematical and will be of most interest and value to statisticians concerned with life-test design and data analysis in reliability-improvement programs. However, the more elementary treatment of the problem and some of the possible consequences of not treating it adequately can be appreciated by a more general class of readers.

R66-12861 ASQC 822; 844
Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
MODEL OF FAILURE IN COMPONENTS
S. E. Benesch and C. R. Gates [1966] 15 p
(Contract DA-04-495-ORD-18)
(AD-631495; N66-31574)

The theory of failure is fundamental in understanding the reliability of complex systems. This paper is a review of some aspects of the theory of failure of particular interest to statisticians. There are two approaches available in this theory: the phenomenological and the microscopic. Treated are models of failure leading to three frequency functions of failure: the normal, the logarithmic-normal, and the exponential. In each instance these three classes are treated from both the phenomenological and the microscopic aspect. In conclusion, a problem of particular interest to statisticians is presented which arises in failure theory. Author

Review: This paper gives some insight into the kinds of cumulative damage theories that cause particular time-to-failure distributions; there appears to be a derivation of the Weibull distribution. The paper contains some editorial errors which are somewhat confusing but not insurmountable. Those concerned with the theoretical development of reliability may find the paper interesting.

R66-12863 ASQC 824; 412; 423; 821
Air Force Systems Command, Kirtland AFB N. Mex. AF Weapons Lab.
SAMPLING FOR RELIABILITY DETERMINATION—AN IMPROVED SCHEME Technical Report, May–Sep. 1964
W. C. Beckham Oct. 1964 55 p refs
(WL-TR-64-116; AD-607909; N65-14754)

A unique solution is presented for the ancient sampling problem posed as follows: A finite random sample from a large population is to be tested for some property that an unknown fraction of the population possesses. It is required to deduce the most accurate possible probabilistic statements in the following sense. For a specified probability that the unknown fraction be larger than some lower limit, calculate from the test result the largest possible lower limit that will have at least this probability and the smallest possible upper limit that will have at most this probability. Similarly, specify narrowest possible ranges for upper limits. These formulas can then be applied to determine for specified lower and upper limits two probabilities for their enclosure of the unknown fraction, the larger of which is the lowest possible upper limit and the smaller of which is the largest possible lower limit. Author

Review: It is well known that confidence interval estimation of reliability by conventional methods based on the binomial distribution yields pessimistic results. For example, in finding a lower confidence limit on reliability the standard result is pessimistic in the sense that one overstates the probability that the true reliability is less than the specified lower limit (except for the isolated values for which the probability statement is exact). The standard defense of this procedure is that it is conservative—tends to err in the "safe" direction. This report is addressed to the problem of removing this pessimism. Through the analysis of error, formulations are given for making probability statements concerning the real reliability which are (a) optimistic and (b) best in the sense of being less prone to error in an average sense. The paper is well written and can be followed by a reader with a knowledge of elementary statistics. Though not based on theoretical derivations, the results obtained are reasonable and can be applied by the use of standard tables of the cumulative binomial distribution. It might be argued that the refinement which this paper presents is unnecessary, since the conservative results of the standard procedure are adequate for all practical purposes. Not to be overlooked, however, is the sampling economy which the proposed technique makes possible as compared to the use of the standard technique. This is illustrated in the paper and could be of importance in cases involving high cost of samples.

R66-12870 ASQC 822; 552; 553
Computer Applications, Inc., New York.
FAILURE DISTRIBUTION ANALYSES STUDY. VOLUME ONE: STUDY AND ANALYSES
10 Aug. 1964 98 p refs
(Contract NObsr-89126)
(CAI-NY-6052, Vol. 1; AD-631525; N66-84531)

A unified graphical reliability analysis procedure is developed for analyzing time to failure data for exponential, truncated normal, normal, logarithmic normal, gamma, and Weibull distributions. Both exponential probability paper and gamma probability contours were developed. Since analysis of plotting positions (percent failure) showed a different set of positions applicable for each distribution and for each shape parameter within these distributions, a recommended procedure is included for the use of the optimal sets of positions which were determined in the interests of economy. A nonparametric procedure is presented and compared with the parametric procedure; and a method is included for the handling of both parametric and nonparametric procedures that contain suspended items. Appendices deal with the derivations for the mathematical formulas for calculating the sensitivity of life quality characteristics estimated from uncensored life test or fleet failure data, assuming the exponential survivorship function when the distribution is truncated normal, log normal, gamma, or Weibull; and it is noted that sensitivity measurements indicate that significant errors can occur with any of the distributions. M.W.R.

Review: The major portion of Volume One is devoted to calculating the estimated time to p% failures and comparing it to the actual time to p% failures. In the calculation it is assumed that the life data came from an exponential distribution, whereas in fact they did not. The theoretical derivations of the formulae are given in appendices; the mathematics was not thoroughly checked, but appears to be competent. In the section on plotting positions for parametric graph paper the emphasis given to plotting position is not uncommon and the results are interesting. However, the assertion can reasonably be made that: "For small samples, the data are so scattered that differences in plotting position have little effect on the overall accuracy in individual cases. For large samples the differences in plotting position are negligible." Thus while this portion of Volume Three certainly has its uses, many experimenters will ignore it and go ahead with their favorite simple method of calculating parametric plotting positions for most of their work. The discussion of non-parametric analysis is interesting and the plotting positions for it may be quite useful. The method is valid for interpolation only; one cannot extrapolate to shorter failure times than the least data point, nor to a smaller probability than about 1/n where n is the number of items on test. The second volume is concerned largely with graphical procedures although some formulas are given for estimating the parameters. Some of the graphical methods are rather complicated (at least they take a long time to explain) and for that reason will seldom be used. The formulas for estimating the parameters are not unique in that other kinds of estimators are equally valid and perhaps as useful. A lot of work has been done on the Weibull distribution especially. The explanations of the graphical procedures appear detailed enough for an engineer to follow. The construction of the graph papers is not explained anywhere. It would have been a help in understanding the graphs instead of relying on cookbook explanations. Due caution should be used on extrapolation, regardless of the distrubution actually chosen. All in all, the effort required to become familiar with these reports may well render them more useful to those who are developing the body of theory than to those who are actively concerned with analyzing failures. For those who are doing the work, the effort to read the abstracts of the reports will be well repaid; the portions of the reports which appear useful should then be studied. While the reports themselves are long, some of the methods are short.

R66-12871 ASQC 822; 552; 553

Computer Applications, Inc., New York.

FAILURE DISTRIBUTION ANALYSES STUDY. VOLUME TWO: GRAPHICAL RELIABILITY ANALYSIS PROCEDURES

Aug. 1964 188 p refs For Review See R66-12870

(Contract NObsr-89126)

(CAI-NY-6052, Vol. 2; AD-631526; N66-84533)

Details are presented for visual determination of the applicability of the exponential, truncated normal, logarithmic normal, gamma, or Weibull distributions as the appropriate survivorship function of life test or fleet failure data. Consideration is also given to the determination of the appropriate function's parameters and life quality characteristics from the data, as well as to a practical nonparametric procedure for estimating such data at various confidence levels. Two graphical reliability analyses of actual failure data are included: (1) fleet failure data, consisting of 35 recorded times to failure; and (2) censored field failure data on tubes from a group of fixed ground station communications receivers, consisting of 48 recorded times to failure and 68 recorded times to suspension. M.W.R.

R66-12872 ASQC 822; 552; 553

Computer Applications, Inc., New York.

FAILURE DISTRIBUTION ANALYSES STUDY. VOLUME THREE: TABLES OF PLOTTING POSITIONS

10 Aug. 1964 107 p refs For Review see R66-12870

(Contract NObsr-89126)

(CAI-NY-6052, Vol. 3; AD-631527; N66-84539)

Linear, median, and percentile ranks are presented in tables of plotting positions (percent failure) for use with the parametric and nonparametric graphical reliability analysis procedures. The linear and median ranks are for use with the parametric procedure; while the tables used with the nonparametric procedure give plotting positions for confidence levels ranging from 5% to 99.5%. Sample sizes from one to 54 are covered in the tables; and an approximation formula is included at the end of each table to compute plotting positions for samples of more than 54. Formulas programmed to generate the tables are given. M.W.R.

R66-12881 ASQC 824

METHOD OF PREDICTION OF THE LIFETIME OF SEMICONDUCTOR DEVICES. [METOD PROGNOZIROVANIIA SPOKA SLUZHBY POLUPROVODNIKOVYKH PRIBOROV].

A. S. Taratuta

(Radiotekhnika i Elektronika, vol. 10, Dec. 1965, p. 2257–2259. In RUSSIAN.) *Radio Engineering and Electronic Physics,* vol. 10, no. 12, 1965, p. 1933–1935.

(A66-17195)

Description of a method of determining the lifetime of an entire batch of semiconductor devices by one brief measurement on a standard apparatus. It is shown that the nature and intensity of the measured noise levels of semiconductor devices can be used to determine the nature and intensity of the transients leading to failures in these devices, and thus to determine the potential unreliability of a given device. A.B.K.

Review: This is a purely theoretical paper, viz., a simple model for transistor behavior and failure is assumed and some analysis is done. The extent of the analysis is to assert that the equations have a unique solution and thus, *in principle,* the problem is solved. There is some physical reasoning mixed up in the analysis and its validity is not at all clear. Noise processes are considered to be at the root of the problem, so noise characteristics at some level are to be measured. The whole thing is so vague and tenuous that at best it should be regarded as a first try at solving the problem. Whether making the second try at this method is worthwhile or not is doubtful.

R66-12891 ASQC 824; 412

ANALYZING RELIABILITY DATA AND DESIGNING ACCEPTANCE TESTS.

Cynthia Kolb Whitney (Massachusetts Institute of Technology, Dept. of Physics, Cambridge, Mass.).

IEEE Transactions on Reliability, vol. R-15, May 1966, p. 42–48.

(A66-30666)

Discussion of the basic theory of reliability in order to enable engineers to make the most of experimental data. It is shown, for three typical test situations, that the observable quantities in the test are firmly related by equations to confidence and confidence intervals. The method of solving the equations for the desired quantities from the given quantities is discussed. Common mathematical models are listed, and a method for obtaining confidence intervals on their parameters from experimental data is given. It is considered that the advantage of the point of view presented is that it allows experimental data to be collected and analyzed without depending on the choice of a mathematical model. F.R.L.

Review: This paper was covered by R65-12287.

83 DESIGN

R66-12842 ASQC 837;844
VOLTAGE FAILURES IN SERIES-CONNECTED DIODES—THEIR CAUSE AND PREVENTION.
E. E. Von Zastrow (General Electric Co., Auburn, N. Y.).
Electronic Design, vol. 13, no. 22, Oct. 25, 1965, p. 62–67. 5 refs.

The damage mechanism in overvoltage failure in simple series-connected diodes is discussed, and an inexpensive remedy is presented for use when compensation is required to prevent overstressing of the diode with the best blocking capability. It is noted that leakage current determines sharing, and factors affecting voltage-sharing are discussed. The R-C network for transient sharing is considered since series-connected diodes must share transient voltage as well as steady-state peak-repetitive reverse voltage. To have reverse-voltage sharing during the reverse-recovery interval, the capacitor must supply the "slower" diodes with a low-impedance source of recovery current by: (1) limiting voltage across the "fastest" diode according to the circuit's commutating conditions, (2) supplying a sufficient charge to permit recovery of the "slower" diodes, and (3) facilitating circuit-imposed transient voltage sharing within the rated capabilities of the diodes. Means of meeting these three requirements are discussed, and a step-by-step design example is given for a two-diode network. M.W.R.

Review: This phenomenon certainly has been a problem and this article does discuss a traditional method for alleviating it. The assumptions are, of course, only an approximation to the actual conditions; when using the formulas, attention should be paid to their derivation. While several transient conditions are mentioned, not all of them are accounted for in the analysis, e.g., corona and capacitance-to-ground. However, the author in a private communication has pointed out that these are of interest only in specialized "high-voltage" applications. The use of avalanche rectifiers is expected to reduce the need for compensation in properly designed systems. The article does point up how much power is wasted in the compensation.

R66-12843 ASQC 831; 770
TEST CONCEPT FOR THE GEMINI ACME PROGRAM.
R. M. Plaisted and L. Riabokin (Honeywell, Inc., Aeronautical Div., Development and Evaluation Laboratory, St. Petersburg, Fla.).
In: Institute of Environmental Sciences, Annual Technical Meeting, San Diego, Calif., April 13–15, 1966, Proceedings. Mt. Prospect, Ill., Institute of Environmental Sciences, 1966. p. 27–31.
(A66-30438) Members, $9.00; Nonmembers, $14.00.

Formulation of a testing concept for the Gemini Attitude Control and Maneuver Electronics (ACME) System. The Gemini ACME System test configuration and the Master Test Plan for the Gemini ACME Program are summarized briefly. A detailed account is given of the qualification test program and of the overstress testing and life testing procedures. A.B.K.

Review: This is a good brief description of the philosophy and other considerations involved in the test program for thee Gemini Attitude Control and Maneuver Electronics (ACME) System. The success of the Gemini flights to date attests to the effectiveness of this test program and to the reliability of the hardware. The paper will be of interest and value to those who are planning and executing similar test programs. While the detailed methods of establishing system performance and reliability are necessarily unique to the individual system, certain principles are of general applicability. Some of these have been highlighted by the authors. They include the need for careful planning of the program and the value of integrated system-level testing as compared to device-level testing. The former is more expensive in time and dollars, but justified by the degree of assurance which it provides regarding the system's satisfactory operation, especially with respect to interactions of devices.

R66-12844 ASQC 831;770;782
THE EFFECTIVENESS OF SYSTEMS TESTS IN ATTAINING RELIABLE EARTH SATELLITE PERFORMANCE.
Albert R. Timmins (NASA, Goddard Space Flight Center, Test and Evaluation Div., Greenbelt, Md.).
In: Institute of Environmental Sciences, Annual Technical Meeting, San Diego, Calif., April 13–15, 1966, Proceedings. Mt. Prospect, Ill., Institute of Environmental Sciences, 1966, p. 123–128. 4 refs.
(A66-30449) Members, $9.00; Nonmembers, $14.00.

Laboratory tests on complete systems have been a vital part of the effect to attain high reliability for earth satellites. The effectiveness of this approach is examined by summarizing the laboratory results on 64 spacecraft. These results are used to compare in-house and out-of-house performance with respect to the number of problems and environments on both prototype and flight spacecraft. The in-house data are further developed to show the effect of time and thermal level in detecting problems under simulated space environment. Comparisons of space problems with simulated space problems are made with respect to number and location. The distribution of space problems with respect to time is presented and discussed. The space performance is used to show the merits of the test philosophy and test program and also to suggest areas of improvement. Author

Review: This paper is a summary of data in the form of histograms and bar charts together with brief descriptions. As such it conveys gross results rather than details. The data show that despite a prototype program in which many problems were detected and resolved, the flight model spacecraft had a significant number of problems. If these problems had occurred in space rather than the laboratory, the satellite performance would have been degraded significantly. Thus the paper provides a validation of the need of environmental systems tests on the flight spacecraft. The data also show (1) how long to run a system test and (2) that one or two days in a cold environment is not an adequate time period. The paper is clearly written and accomplishes the author's purpose of demonstrating the effectiveness of laboratory tests on complete systems as a means of attaining high reliability for spacrcraft. Limitations due to cases in which no relevant systems test is available and the impossibility of detecting certain time-dependent space problems in a short-term simulated space test are mentioned.

R66-12862 ASQC 831; 844
FOUR CASE STUDIES SHOW HOW TO MATCH RELIABILITY METHODS TO REAL SITUATIONS.

Charles E. Bloomquist and George E. Monroe (Planning Research Corp., Washington, D.C.).
Evaluation Engineering, vol. 5, no. 4, Jul./Aug. 1966, p. 6–8, 10.

Four practical examples are cited to show that reliability methods can vary widely, and to emphasize that the most suitable method for any given situation is directly related to the definition of its objective. It is stressed that the desired objective must be clearly defined and the method utilized must be realistic in cost and in terms of the results to be obtained. The first situation deals with the selection between two redundant command subsystems, primarily on the basis of reliability, early in a satellite development program. The second example concerns the freezing of the design of a command subsystem that is on paper; the third discusses a possible modification in a decoding circuit which was conjectured to be more reliable than the existing design. Finally, consideration is given to another weak link in the command subsystem, with the objective being whether and how the design can be significantly improved. The methods presented begin with a simple analysis and proceed to programs which, in general, are more time consuming and costly. M.W.R.

Review: This is a clear and concise presentation which serves to illustrate the point that the most suitable method of analysis in any real situation must be selected on the basis of the question to be answered. This may sound simple, but in practice it is often overlooked by those who look for something more sophisticated than the situation requires. There are cases, too, perhaps of less frequent occurrence, where a real need for greater sophistication goes undetected. The authors' chief message, which comes through clearly, is that before any analysis method can be selected, the problem must be defined. (The figure-of-merit approach, featured in the discussion of three of the four examples, was presented in the paper covered by R63-10979.)

R66-12864 ASQC 832; 612
Aeronutronic, Newport Beach, Calif.
HUMAN FACTORS ASPECTS OF RELIABILITY Final Report, 1 Jul. 1962–30 Sep. 1963
Gilbert E. Miller, Richard A. Maxwell, Linda Ferguson, and Charles J. Galbo Jan. 1964 207 p refs
(Contract DA-36-039-SC-90877)
(U2296; AD-431611; N64-84183)

Procedures for generating task equipment analysis (TEA) data by computer simulation are discussed in terms of applications to a model for predicting man–machine system reliability. Details are presented of the methodological approach and the mathematics used in deriving the predictive model, and for the formulation of the computer program. Appendices outline a measure of effectiveness which combines the principal outputs of the TACDEN (Tactical Data Entry) simulation into a single quantity, and the integration of the outputs of the simulation model with other factors influencing the overall reliability of the TACDEN. One objective of the latter is to obtain a single measure of reliability which will reflect changes in machine and human capabilities. Logic flow diagrams, preparation for the computer program, and input data for the GRAPHDEN TEA are included; and an overview is presented of the literature pertaining to reliability and factors affecting human performance. M.W.R.

Review: This is a quite detailed report on a study of the feasibility of quantifying human factors aspects of reliability and the development of a model for predicting man–machine system operational reliability. The main body of the report contains information of interest and value to those concerned with the general problem; detailed statistical and analytical data are found in appendices. Much of the literature pertaining to reliability and factors affecting human performance is reviewed; and 37 references are cited. The technique described in this report, which is based on computer simulation, would appear to be quite general, and thus applicable to a wide variety of situations in which a man operates a machine. A necessary input which must be available, of course, is appropriate task-equipment analysis data. From the simulation results it should be possible to develop performance equations to describe operator behavior. Thus this study represents an important contribution to the solution of the complex problem of assessing the dependability, consistency, and accuracy of performance of the human component in man–machine systems. This problem has an important bearing on the success of manned space flight programs.

R66-12867 ASQC 838; 615
A DIGITAL COMPUTER-OSCILLOSCOPE SEARCH TECHNIQUE APPLIED TO A RELIABILITY REDUNDANCY PROBLEM.
J. L. Liittschwager (Iowa University, Iowa City, Iowa) and R. K. Hoppe (Department of the Air Force, Washington, D.C.).
The Journal of Industrial Engineering, vol. 17, no. 6, Jun. 1966, p. 335–337. 6 refs.

A reliability redundancy problem is used to indicate the potential of utilizing on-line visual display devices in conjunction with digital computers for solving certain engineering problems. A digital computer-oscilloscope search technique for use in systematic algorithms, is described for which each intermediate iteration can be displayed on the on-line oscilloscope. The technique is based on a systematic search over all possible values of the Lagrange multiplier to locate the region of the better multipliers; and results of the first Lagrange multiplier (zero) are computed as a part of the main computer program. Internal-halving and weighting are described for the procedure, which is considered to have widespread application. M.W.R.

Review: This note describes the use of a digital computer in a direct tie with an on-line oscilloscope in solving a reliability-redundancy problem by a combined dynamic programming-Lagrangian multiplier approach. The essentials of the technique and the advantages of its use are clearly brought out in the paper, and references are cited for those who desire more details. A non-referenced thesis by the second author on this topic was covered by R66-12536. The earlier review should be consulted for discussion of the disadvantages of the method.

R66-12873 ASQC 835; 090
THE LITERATURE OF INTEGRATED CIRCUITS RELIABILITY.
Philip L. Holden (Texas Instruments, Inc., Dallas, Tex.).
Evaluation Engineering, vol. 5, no. 4, Jul./Aug. 1966, p. 36–37.

Titles, authors, and sources are presented in a short bibliography dealing with the various reliability aspects of integrated circuits. Publishers of related abstracts and indices are included. M.W.R.

Review: This brief bibliography of sources of information on the reliability of integrated circuits has been prepared by an author who has made several important contributions to the literature on this topic. While the author makes no claim for the completeness of the listing, it does seem to cover the recent literature quite well. Of the 22 individual papers cited, ten have been covered by RATR; in some of the others reliability does not appear to be a prime consideration.

R66-12874 ASQC 833; 770; 844

COMPARATIVE OPERATING LIFE TESTS ON P-N-P GERMANIUM POWER TRANSISTORS FROM AMERICAN, EUROPEAN AND JAPANESE MANUFACTURERS.

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

Scientia Electrica, vol. 10, fasc. 1, 1964, p. 24–39. 17 refs.

Operating life tests of about 5000 hours were made at a mounting base temperature of 75°C on six germanium P–N–P power transistors from each of four different manufacturers. Junction temperature reached the maximum permissible value indicated by each manufacturer; and dc current gain, collector leakage current, and emitter base voltage were measured during aging. Ranking methods were applied to compare the criteria for degradation behavior, and these results are tabulated. M.W.R.

Review: The tests appear to be well thought out and well executed. There are a few language problems, but they are by no means insurmountable. The practical significance of the tests was apparently to decide upon which make to buy. For that purpose the tests and their analysis are probably adequate, even if somewhat controlversial. Of course many deficiencies could be pointed out; but within given constraints such as shortages of time, money, and facilities, this procedure can easily be justified—as could others. One of the tests is an operating one (for many good reasons—given in the paper) and the other is non-operating (also for many good reasons—given in the paper). In a private communication the authors have indicated that former investigations have shown that for simple comparisons of the quality of different transistor types the storage test is recommended, while for investigations limited to one make only, the loading test may be preferable. Ranking criteria are used to decide on the best make. They have many advantages—simplicity of analysis being a major one—and are probably quite adequate in this situation. These are certainly not large tests from some points of view—only six transistors per manufacturer—but are probably typical of many run in this country.

R66-12875 ASQC 833; 770; 884

COMPARATIVE RELIABILITY TESTS OF SILICON LOW POWER LF TRANSISTORS OF EUROPEAN, JAPANESE AND U. S. MANUFACTURERS.

M. J. O. Strutt (Swiss Federal Institute of Technology, Department of Advanced Electrical Engineering, Zurich, Switzerland).

Scientia Electrica, vol. II, fasc. 1, 1965 p. 1–21. 4 refs. For Review See R66-12874.

Storage tests are described which indicate the aging behavior of six low power silicon transistors from each of five manufacturers; and tables present the relative merits of these devices. Aging behavior is compared at storage temperatures of 75°C and 150°C for periods of about 8000 hr; and parameters measured include collector saturation current, current gain, and breakdown voltage. The dispersion band as well as the median value and its position relative to the dispersion band are considered as the ranking criteria for the various transistors. M.W.R.

R66-12882 ASQC 837

AVOID POWER TRANSISTOR FAILUREI CUT TRANSISTOR-REPLACEMENT COSTS.

Peter P. Balthasar (Bendix Corp., Bendix Semiconductor Div., Holmdel, N. J.).

Electronic Design, vol. 14, no. 18, Aug. 2, 1966, p. 52–56; vol. 14, no. 19, Aug. 16, 1966, p. 192–197.

Application-oriented guidelines to establish safe operating areas (Soar) for transistors are presented, and these Soar principles are considered for the design of power transistor switching circuits. Soar is based on those parameters that best reflect the transistor's role, and a different Soar is developed for each major application category. Soar represents the combined effect of transistor limitations and the individual maximum absolute ratings. The power hyperbola that sets dc operation is discussed, as is the derating needed for temperature changes. It is noted that pulse operation is more arduous than dc, and safety operating areas are given for various pulse widths. Attention is also given to resistive and clamped-inductive switching circuits, unclamped inductive switching networks, and Class-B operating systems; and the Soar is developed for popular power transistors in each of these areas. Current-voltage relationships peculiar to each application are examined, and the step-by-step procedure for the Soar testing of circuits is given. M.W.R.

Review: The principle of safe operating areas for transistors is, of course, a good one. This two-part paper presents the approach in use by the author's company for some time. Unfortunately the paper is not too clear. For example, the meaning of the term "test point" is not obvious nor is the distinction between "actual curve" and "hyperbola" (which certainly does not look like what one expects of this hyperbola). The difference between the safe operating area for an application and the operating curve for that application is not brought out. It appears that the author is trying to show how the user should develop his own safe operating area, but the criteria for safe vs. unsafe for a particular transistor are not given. Finally, it is not clear whether the transistor degrades when improperly operated or whether a catastrophic failure is experienced. In the former case, there would be different safe areas for each allowable degradation rate.

R66-12887 ASQC 830; 873

MAINTAINABILITY DESIGN REQUIREMENTS FOR FUTURE SPACE SYSTEM.

Elmer L. Peterson (North American Aviation, Inc., Space and Information Systems Div., Downey, Calif.).

IEEE Transactions on Reliability, vol. R-15, May 1966, p. 17–21. 7 refs.

(A66-30662)

Examination of the operational requirements for maintainability in future space systems, with a discussion of interface problems, and definition of quantized maintainability objectives for the different applications of spacecraft, space stations, boosters, and support equipment. Maximum urgency is placed on crew safety, mission success, and meeting a launch window. F.R.L.

Review: This is an introductory, general discussion; for example, two-thirds of the paper itself is devoted to its own introduction. As such it fills a need to get the ideas out where they can be developed; but the paper does little of the developing. It will be of little use to designers; perhaps it will be useful to those who are laying the philosophic groundwork for future designs.

R66-12890 ASQC 838; 831; 612
RELIABILITY OF A SYSTEM HAVING QUASI-REDUNDANCY.
L. Tin Htun (Raytheon Co., Wayland Laboratory, Quality Assurance Dept., Reliability Section, Wayland, Mass.).
(Institute of Electrical and Electronics Engineers, Annual Young Engineers Night, 2nd, Bedford, Mass., Mar. 12, 1964, Paper.) IEEE Transactions on Reliability, vol. R-15, May 1966, p. 37–42. 4 refs.
(A66-30665)

Development for the nonrepair environment of reliability mathematical models of a certain type of system with a branching configuration, possessing quasi-redundant properties. A simple system of this type is chosen as a vehicle to illustrate the method of approach when in a repair environment. To solve the simultaneous differential equations for such a system in a repair environment, analog computer simulation is found to be suitable. F.R.L.

Review: This is a theoretical paper which treats a special kind of redundancy. Not all the mathematics was checked but appears to be of high quality. The assumptions are clearly stated so that applications of the model to physical systems can be made readily where appropriate. It is likely that some communications systems, for example, would be fitted adequately by this theory. The equations are simple enough for the non-repair case so that they can be applied easily by engineers.

R66-12893 ASQC 837; 844
PREDICTING PART FAILURES. PART I: FAILURE THEORIES AND DESIGN VALUES; AND PART II: SAFETY FACTORS.
Ray C. Johnson (Worcester Polytechnic Institute, Worcester, Mass.).
Machine Design, vol. 37, Jan. 7, 1965, p. 137–142. 20 refs.; vol. 37, Jan. 21, 1965, p. 157–162. 3 refs.
(A65-14459; A65-15281)

Failure theories and safety factors are considered in terms of predicting failure modes and selecting reasonable values for use in design equations, and an approximate value is given for the safety factor to be included in the original design work. Selection of proper values is simplified by reducing the overall design problem to the individual elements; and since failure from fatigue breakage cannot be tolerated within the useful lifetime of a part, the use of a conservative design criterion is considered appropriate for establishing the safety factor. Guides for selecting the safety factor are tabulated according to the accuracy required, the type of stress analysis, and the material. Criteria for avoiding fatigue breakage and exessive wear are included for ductile and brittle materials, and theories of failure in such materials are discussed. Fatigue strength in reversed bending and in shear are considered, as is fatigue strength for finite life in ferrous and nonferrous materials. A numerical example details the selection of safety factors for use in the design of a helical spring, including the procedure for estimating the part-strength uncertainty components. M.W.R.

Review: This two-part paper documents and discusses very well the use of failure theory and safety factors in new design work. The contents will not be easily understood without some knowledge of maximum-shear-stress theory. The selection of safety factors involves a lot of engineering guessing even by competent engineers. All of the uncertainties mentioned in the paper are often forgotten by those who insist on exact calculation of everything, including the reliability of a design.

R66-12899 ASQC 830; 711; 712; 844
NUT DESIGN FACTORS FOR LONG BOLT LIFE.
Joseph Viglione (U.S. Naval Air Engineering Center, Philadelphia, Pa.).
Machine Design, vol. 37, Aug. 5, 1965, p. 137–141.
(A65-32799)

Evaluation of the effect of nut design factors, such as material strength level and height, on the weighted minimum fatigue life of bolts, based on the results of a series of tests conducted with NAS 1069 steel nuts. Bolt fatigue life as a function of nut material, for nuts of various heights, is graphically illustrated. It is shown that the fatigue life of nut and bolt combinations increases with the strength level of the nut material up to a certain point and that beyond this the fatigue life drops to a minimum value. This relationship holds true for all nut heights. Therefore, maximum fatigue life of the combination is obtained by increasing the nut height and specifying optimum nut material. The beneficial effect of proper lubrication is discussed. The effect of washers, tightening torque, re-use, and unengaged threads on the fatigue life of nut and bolt combinations is described. D.P.F.

Review: The paper presents the material in an excellent way. It definitely points out a need for information concerning optimum bolt and nut design and application. The author has done a good job of evaluating the factors effecting fatigue life of bolts. The paper is highly recommended and well worth reading. The nut is often not considered seriously as part of the bolt problem and this paper illustrates the importance of attention to detail that is required to design reliable products. For any investigator who is further interested in study along these lines, the author in a private communication has suggested reading the full and comprehensive report from which the paper was condensed, "The Effect of Nut Design on the Fatigue Life of Internal Wrenching Bolts," issued 17 June 1964 by the Naval Air Engineering Center. A copy of this report may be obtained upon request from the following: Mr. G. D. Norman (Air 530323), Naval Air Systems Command, Department of the Navy, Washington 25, D. C.

R66-12900 ASQC 830; 782
UNDERSTANDING FATIGUE IN METALS.
R. E. Kling (General Electric Co., Power Generation Div., Schenectady, N. Y.).
Machine Design, vol. 37, Oct. 14, 1965, p. 202–208. 6 refs.

Basic fatigue theory is discussed, as are the phenomena exhibited by metals when acted upon by various types of loading. The Bauschinger effect; prior cold working, hold time, and temperature effects; and cyclic strain induced creep are considered in terms of effect on the design of components. It is noted that while there is considerable data concerning fatigue failures in numerous metals and many nonmetallic materials, only limited conclusions can be drawn from this information. In general, the design procedure to meet specified fatigue requirements consists of analytical investigation, reproduction of design conditions in a test, and analytical correlation between test and design conditions. Analysis is considered adequate by itself provided that, with the intrinsic conservatism, it can be shown that the fatigue life of the component has not been exceeded. Construction and limitations of fatigue curves are considered, and a mechanical analogy of internal restraining forces is detailed. M.W.R.

Review: This paper serves mainly to point out that the material condition, loading environment, and loading pattern all must be considered in successful design. Neglecting, for example, temperature or prior cold working could result in an inadequate design. It also indicates that design based on fatigue can be complicated and a designer must rely a great deal on his judgment. The theory section, concerning, for example, the Baushinger effect, cold working, and cyclic-strain induced creep is good. A mechanical analogy of internal restraining forces presented in the paper is excellent and in itself makes the article well worth reading.

R66-12901 ASQC 830; 711; 712

FRACTURE TOUGHNESS—WHAT IT IS, HOW TO DESIGN FOR IT, HOW TO TEST FOR IT.

R. A. Davis and W. E. Quist (Boeing Co., Seattle, Wash.). *Materials in Design Engineering,* vol. 62, Nov. 1965, p. 91–97.

Theory behind fracture toughness is discussed in order to understand the behavior of solid materials. It is noted that while cleavage strengths of certain metals have been established as one-half of Young's modulus, theoretical cleavage strengths are not applicable to real materials since they are imperfect. Griffith's theory, which says that microcracks are responsible for lower strength values, is applied to a centrally cracked plate. Because of plastic deformation in metals, Orowan modified Griffith's equation by adding a plastic strain energy term; and Irwin evolved the same equation for the residual strength of a cracked panel by linear elastic stress analysis theory. These basic equations are modified in discussions of fracture toughness parameters; and a graphical solution is shown with plastic zone correction. Testing for fracture toughness is considered; and typical values of plane strain fracture toughness are tabulated for aluminum alloys, steels, and a titanium alloy. Consideration is given to the complexities of designing for fracture toughness, and some practical examples are included. M.W.R.

Review: Understanding this paper requires a good knowledge of crack propagation theory as developed by Griffith and Irwin. The paper is well organized and well documented. Its contents will be of interest primarily to those in design work where failure would be catastrophic. The paper does present a treatise on fracture toughness that is well worth reading. This failure mode is becoming more important with the use of "very-high-strength" metals because the term "strength" does not include resistance to all failure modes—usually it just refers to uniaxial tensile strength.

84 METHODS OF RELIABILITY ANALYSIS

R66-12852 ASQC 844

Texas Instruments, Inc., Dallas. Semiconductor-Components Div.

THE STUDY OF THE EPITAXIAL PARAMETERS ON RELIABILITY OF SILICON PLANAR DEVICES Technical Summary Report, 25 Jun. 1964–25 Jun. 1965

W. M. Bullis, W. R. Runyan, and R. L. Petritz 20 Aug. 1965 134 p refs

(Contract NAS8-11330)

(NASA-CR-67158; TI-03-65-81; N65-34463) CFSTI: HC $4.00/MF $1.00

The effect of epitaxial parameters on the reliability of silicon planar devices was investigated. The properties of the silicon substrates, substrate surface preparation, and growth conditions for the epitaxial layers were varied. High reliability, n-p-n, double-diffused, epitaxial planar silicon transistors were fabricated from layers deposited under different conditions. Power step-stress tests, temperature only step-stress tests, high temperature storage tests, and various materials investigations were carried out. It was concluded that present epitaxial deposition processes are quite satisfactory for this type device. C.T.C.

Review: The dependent variables used to measure reliability are never explicitly listed in this report. The measurements made include those of transistor electrical properties (h_{FE}, BV_{CEO}, I_{CBO}, etc.), dislocation density, structural defects as revealed by X-ray topographs, and second breakdown voltage. Reliability seems to be equated with stability of these transistor electrical parameters under various stress conditions. This performance depends on so many processing variables in addition to those being investigated that the failure to observe any correlations in these experiments is not surprising. Surface properties, for example, are known to greatly influence electrical performance. These experiments confirm that influence and suggest that suitable surface-independent monitoring of reliability can be obtained by measuring I_C at fixed V_{EB} with V_{CB} equal to zero. Here again no correlation of bulk diffusion currents (which is what I_C now depends on) with the variables of deposition was apparent. One of the more important results of this research, as pointed out by one of the authors in subsequent correspondence, was the fact that "changes in deposition conditions did not result in observable differences in device behavior as a function of stress and time despite the fact that significant yield differences occurred." The general tendency has been to equate yield and reliability (see, for example, R66-12617). These experiments also confirm that improved surface properties result from vapor etch prior to epitaxy. The use of second breakdown voltages (see R64-11347 and R66-11365) as a dependent variable for evaluating epitaxy (it could be used to evaluate other processes as well) is novel and appears to give meaningful correlations with epitaxial deposition rates.

R66-12853 ASQC 844; 850

Booz-Allen Applied Research, Inc., Bethesda, Md.

RELIABILITY VARIATION ANALYSIS FOR SPACE SYSTEM DEVELOPMENT

R. L. Madison, P. Gottfried, and G. Ronald Herd Nov. 1963 144 p

(Contract NASw-643)

(NASA-CR-60315; N66-15381) CFSTI: HC $4.00/MF $1.00

General considerations and techniques for space systems reliability evaluation are discussed in the following topics: *New Reliability Control Techniques, Reliability Variation Analysis, Potential of RVA Techniques, Nature of the Problem, The Determination of Reliability Risks, and Resources Allocation for Reliability Testing.* Appendixes include: *Mathematical Derivations; An Example: Determining Development Risks and the Allocation of Testing; and Failure Rate Variability Model.* G.G.

Review: The concepts introduced in this report are good and valuable ones, although they have not yet found their way into widespread practice. One of the major contributions is the unabashed suggestion of using existing information about the reliability of a product and then updating it as tests are run. The authors do point out, wisely, that the ideas are still in the conceptual stage and that they should not be blindly applied. Nevertheless they are important enough to be tried and further developed. Even though the Reliability Risk may not always be the best figure-of-merit, the research done in its development is good. Likewise in the Allocation of Testing Effort, the criteria for best allocation in use in a specific instance may vary, but the principles are going to be similar. (Not all the mathematics was checked, but it appears to be of high quality.) Virtually all of the Bayesian approaches have dealt in equivalent failures on a test. It will be worthwhile, though difficult, to try and find other measures of system reliability to which Bayesian methods can be applied.

R66-12856 ASQC 844; 612

Sperry Rand Corp., Blue Bell, Pa. Univac Div.

INVESTIGATION OF FAULT DIAGNOSIS BY COMPUTATION METHODS FOR MICROCIRCUITS Final Report, 20 Oct. 1964–19 Nov. 1965

L. Mah, L. Buchsbaum, and T. J. B. Hannom Wright-Patterson AFB, Ohio, AF Aero Propulsion Lab., Nov. 1965 253 p ref

(Contract AF 33(615)-2094)

(AFAPL-TR-65-111; AD-623957; N66-15901) CFSTI: HC $6.00/MF $1.25

This report describes the computational techniques formulated to extend the methods of automatically isolating faults in electronic circuitry to the level of a micromodule. The micromodule may consist of a single component or it may itself be a microcircuit consisting of several active and passive components. The techniques developed are oriented towards analog circuits. All circuit equations used in the diagnosis are generated by a digital computer from the specification of the circuit schematic in coded form, and from the nominal values and tolerances of all circuit components. Three (3) diagnostic techniques are implemented. Two of the techniques presented utilize a digital computer to implement the diagnosis, whereas the third technique utilizes precomputed network measurement bands and a manual graphic method for fault diagnosis. Author

Review: The approaches to fault diagnosis of micromodules which are discussed in this report are akin to those used in the performance variation analysis area, particularly worst case. There may be some ideas here for those interested in this part of reliability analysis. The report appears to be of high quality, and it concentrates on computational techniques. Flow diagrams and the computer program comprise the bulk of the report, and a previous report which is referenced apparently contains more information on the methodology which is needed to complete the picture. Experimental applications of the fault diagnosis techniques of a rather limited nature are cited and no mention is made of applications to operational situations.

R66-12860 ASQC 844

American Power Jet Co., Ridgefield, N. J.

GUIDE FOR DEVELOPMENT OF STATISTICAL TECHNIQUES FOR DEFINING SIGNIFICANT VARIABLES AFFECTING PRODUCT QUALITY AND RELIABILITY

George Chernowitz, Samuel J. Bailey, and Angelo W. Castellon Jun. 1964 175 p refs

(Contract NObs-88629)

(APJ-376-1; AD-632011; N66-85129)

A combined engineering and statistical analysis is made to determine significant variables which affect product reliability and quality control in metal processing or plastics technology; and sources of product variation during design, manufacturing, and equipment operation are discussed. Main sources of predictor variable determination data are detailed, and engineering screening of these as potentially strong predictors of performance loss are covered along with the statistical aspects of screening. Statistical models which apply multiple regression techniques are described, and the formulation of practical reliability guidelines is considered. It is concluded that the quality improvement depends upon the development of both engineering and statistical techniques; and that engineering procedures must establish the relationship between physical realities and statistical techniques. Statistical techniques are considered to be clearly useable as screening procedures for predictor variables at both the material and operational levels, and the use of failure mechanisms is considered a necessary adjunct to the identification of predictor variables. M.W.R.

Review: This is an extensive and detailed report concerned with a combined engineering and statistical analysis for identifying significant variables affecting quality and reliability in metal processing or plastics technology. Because of restriction to the latter areas, particularly metal processing, it is less general than the title may imply. However, for those interested in this topic area, the report merits careful study. The logic by which predictor variables are determined is described in detail. Statistical methods appropriate for use with these predictor variables are described adequately for those with a background in the fundamentals of statistical methodology. Thirty-seven references are cited and brief discussions of researched techniques are presented. This report should serve the purpose of stimulating more penetrating thinking into the actual causes of inadequacies in design which result in poor product survival.

R66-12865 ASQC 844

RESEARCH ON FAILURE IN ELECTRONIC COMPONENTS.

H. F. Church (Electrical Research Association, Leatherhead, Surrey, England).

British Communications and Electronics, vol. 12, Jun. 1965, p. 357–359. 4 refs.

(A65-25852)

Study of the basic mechanisms of failure of electronic components with the aim of improving reliability. Defects which result in early failure arise most often from mechanical imperfections, poor sealing against moisture, the presence of impurities, or mishandling during use. Resistors and capacitors receive special attention. The defects described are those of most general interest. Serious defects are rare in the best component designs, but, where abnormal failures do occur, the information obtained is communicated to the maker concerned so that manufacturing practice can be improved. Author

Review: This is a summary paper and would be more useful to those who are new in the field; it gives a light once-over. Much of the paper is devoted to descriptions of a half dozen causes of failure, such as "electrochemical effects in the absence of moisture." Each is illustrative of typical failures. Those familiar with the field will find little in it of value.

R66-12866 ASQC 844; 824
PREDICTING RELIABILITY OF HIGH-POWER KYLSTRONS.
Robert I. Reed (ARINC Research Corp., Washington, D.C.). *Electrical Design News,* vol. 10, Sep. 1965, p. 110–116, 119–121. 3 refs.

A mathematical model, described for use in predicting reliability of high power kylstrons, is considered applicable for estimating reliability of any type tube. The model consists of several terms representing failure categories or failure modes, and for each term there are two factors: (1) an amplification factor, derived from operating experience, which represents the expected proportions of tube failures in a given mode; and (2) a reliability-versus-life relationship derived from analysis of field failure reports. To provide the necessary data for using the model, failures were divided into those caused by the operator, equipment design, or tube design; with 60% of the failures attributed to tube design. Graphs depict the tube failures according to (1) emission depletion, which can be used as an indicator of ultimate tube life; and (2) short-term failures due to gas, filament, multipactoring, sublimation, and mechanical difficulties. M.W.R.

Review: This is another in the series of papers which attempt to find a semi-empirical equation for reliability of equipment or parts. They are essentially direct interpolation schemes and can be quite useful. The insight they offer into failure correction is not great, but there are times when prediction is the important thing. The paper appears to summarize the program quite well and [1], cited as a reference, is presumably the report on which it is based.

Reference: [1] Reed, R. I.; "A Study and Investigation of a Predictive Reliability Model for High-Power Klystrons"; ARINC Research Corp. Publication 308-01-1-478.

R66-12869 ASQC 844
THE BASIC CONCEPTS IN THE PHYSICS OF FAILURE.
H. M. Lampert and G. E. Best (General Electric Co., Missile and Space Div., Spacecraft Dept., Valley Forge, Pa.).
American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, Ill., May 11–14, 1964, Paper 64-MD-33. 8 p. 20 refs.
(ASME Paper-64-MD-33; A64-25189)

Introduction of a rigorous definition of failure into problems involving reliability assessment, control, and improvement. A discussion is given of the relationship of product value to performance, performance to operational availability, operational availability to reliability, and reliability to physics of failure. Basically, an object is defined as a material, piece, part, or assembly which has a strength, or a capacity to store energy in an applied stress field. A failure in an object is seen to occur when the energy stored by a given mechanism or series of mechanisms exceeds a critical value. Author

Review: This is a very general paper suitable for giving management a very rough idea of the concepts involved. It should not be used for the details in it. For example: (1) The "derivation" of the Larson–Miller formula from the Arrhenius equation is too procrustean to be correct. (2) The conceptual postulates are largely misleading and incorrect except for the first one. These are reviewed adversely in more detail in R63-10976.

R66-12877 ASQC 844
A REVIEW OF SOME METALLURGICAL FACTORS AFFECTING RELIABILITY OF INTERCONNECTIONS.
M. H. Bester and M. B. Borland (Autonetics, Anaheim, Calif.). *In: National Aerospace Electronics Conference, Dayton, Ohio, May 11–13, 1964, Proceedings.* Conference Sponsored by the Professional Group on Aerospace and Navigational Electronics, Dayton Section of the Institute of Electrical and Electronics Engineers, and American Institute of Aeronautics and Astronautics. Dayton, Institute of Electrical and Electronics Engineers, Dayton Section, 1964, p. 124–139. 29 refs.

Silver migration, metal whisker growth, and crystal growth in beta to alpha transformations of tin-lead solders are discussed in relation to failures and reliability of interconnections. Materials susceptible to silver migration are listed, and parameters and means of inhibiting such migration are discussed. Whisker growth studies are reported, the physical features and growth mechanisms involved are discussed, and the effect of stress on growth rate of tin whiskers is tabulated. Inoculation and nucleation, alloy composition, tensile stress and pressure are discussed in relation to tin-lead transformations. M.W.R.

Review: This is a physics-of-failure type paper and deals with three causes for failure: silver migration, metal whisker growth, and crystal transformation in tin-lead solders. The paper is well organized with a summary, discussion, and references for each part. The discussion is reasonably intensive, but also refrains from using jargon unintelligible to engineers. Each of the summaries is certainly worth reading and those with special problems can profit by reading the discussions.

R66-12878 ASQC 844
HIDDEN WEAKNESSES IN ELECTRONIC TRANSFORMERS AND INDUCTORS.
J. R. Clark (General Electric Co., Defense Electronics Div., Light Military Electronics Dept., Utica, N.Y.).
In: National Aerospace Electronics Conference, Dayton, Ohio, May 11–13, 1964, Proceedings. Conference Sponsored by the Professional Group on Aerospace and Navigational Electronics, Dayton Section of the Institute of Electrical and Electronics Engineers and American Institute of Aeronautics and Astronautics. Dayton, Institute of Electrical and Electronics Engineers, Dayton Section, 1964, p. 140–147. 8 refs.

Analysis of causes and types of failures in electronic aerospace equipment. A total of 347 transformers and inductors which had failed during factory testing or during field service, and for which the mechanism of failure was not apparent, are considered. The "hidden" cause of failure associated with open circuits, short circuits, and performance degradation are analyzed. Most of the "hidden weaknesses" are found to be related to internal construction and material inadequacies. P.K.

Review: This paper lists and illustrates many weaknesses which it is possible and easy to build into small transformers and inductors. In many cases the solution is not altogether obvious, but this merely serves to illustrate the difficulties. This paper also shows that many reliability problems are basically quality control problems. Proper attention to detail during manufacture can eliminate many failure modes. Eternal vigilance is the price of reliability as well as of liberty.

R66-12879 ASQC 840; 775
DETECTION AND PREDICTION OF MALFUNCTIONS OF ELECTRONIC COMPONENTS BY CONTACT THERMOGRAPHY.

James W. Ballard (Systems Research Laboratories, Inc., Dayton, Ohio).
In: National Aerospace Electronics Conference, Dayton, Ohio, May 11–13, 1964, Proceedings. Conference Sponsored by the Professional Group on Aerospace and Navigational Electronics, Dayton Section of the Institute of Electrical and Electronics Engineers, and American Institute of Aeronautics and Astronautics. Dayton, Institute of Electrical and Electronics Engineers, Dayton Section, 1964, p. 154–163. 6 refs.

Description of a thermographic method for determining malfunctions and predicting failures due to thermal stresses in electronic equipment. A thin coating of high-resistivity thermographic phosphor is sprayed onto the top of electronic equipment in a chassis. When irradiated with UV light, the bright yellow fluorescence is quenched (darkened) by the heated components, with the degree of quenching proportional to the temperature. The method provides two-dimensional temperature information and presents thermal gradients visually. Temperatures can be determined through comparison with standards, or through the use of photographic and densitometric techniques, and can be used for determining malfunctions and predicting failures. The method can also be applied to the study of airflow patterns over surfaces, electrical conductivity in thin sheets or surfaces, and mechanical defects. P.K.

Review: This method appears to have received little publicity since it was published. It would certainly seem worthy of much more exploitation to see if in extensive practice it fulfills the author's hopes for it. Quick methods of detecting unusual operation are needed both in production and in the development laboratory. Procedures such as using this phosphor spray should be given a more-than-fair trial. It may be rather technique-dependent so that early discouraging results in a new application should not be cause for immediately dropping it. In a private communication the author has stated that the method has been further developed.

R66-12883 ASQC 844
STRUCTURAL FATIGUE.
Philip Donely (NASA, Langley Research Center, Flight Mechanics and Technology Div., Langley Station, Va.).
Astronautics and Aeronautics, vol. 4, Jun., 1966, p. 11–12.

Critical problems related to fatigue of aircraft structures are concerned with the determination of residual life and the means of obtaining a true measure of damage before crack formation. Despite limitations, life predictions must be made to account for the stress histories in estimating residual life. Methods which are useable range from simple evaluations based on the airplane log to elaborate installations, which provide load or stress histories at selected structural locations. The log-book approach is considered adequate for stable operations of a routine nature. It is concluded that accessible crack-tolerant structures combined with monitoring and inspection provide the greatest protection against fatigue failure. In view of the many detailed elements that affect fatigue properties, a failure scatter of 4 to 1 in the residual life at any stage should be considered excellent; and considerable effort in inspection and monitoring is required to attain this. M.W.R.

Review: This is a good short general state-of-the-art review for designers. It has applications to any system wherein fatigue is one of the critical failure modes. The author wisely stresses the fact that the basic fatigue data, even on structures, has a minimum life uncertainty of a factor of 2, and factors of 4 are certainly not uncommon. It should be emphasized that designing to a given fatigue life is extremely difficult even under the best of circumstances.

R66-12884 ASQC 844; 351; 816
POOR QC YIELDS BAD IC'S.
Joseph B. Brauer (Rome Air Development Center, Griffiss Air Force Base, N.Y.).
The Electronic Engineer, vol. 25, no. 8, Aug. 1966, p. 78–82. 8 refs.

In order to illustrate the role of quality control in producing reliable electronic components, an analysis was made of the failures on an actual input gate. After finding the failures and retesting, the next step was to de-lid the device and to look for the trouble; and this indicated that the equivalent circuit assumed by the user did not agree with the actual circuit. Microscopic investigation revealed misalignment of metallization patterns and of diffusion masks, as well as poor quality of the photoresist. Failure mechanisms were then pinpointed. Results are considered typical of those obtained when sufficient concern is shown for reliability to do a rigorous analysis. It is stressed that better tests will prevent failures; in addition to time-zero screens or quality tests, operating or reverse-bias burn-in and bake tests are very effective in screening defects from semiconductors. It is concluded that there are many tools to analyze and prevent degradation and failure; and success depends upon fitting the tool to the job that must be done. M.W.R.

Review: The key to this problem is a quote, out of context, from the paper: ". . .become sufficiently concerned about reliability to do a rigorous analysis." Until this state comes about, quality and reliability will both be pretty miserable. It is only when someone—usually the customer—decides that "things are too bad" that changes are made. The author's emphasis on "goof-failures" coincides with the serious thinking of many people. Until we get rid of most of them, it is pointless to worry more—at the equipment level—about the other kinds of failure. Again and again one wonders "who can the manufacturer of all these lousy parts have been?" The advertisements show virtual perfection on all fronts. This article is in the nature of a review that reliability engineers should read. In a private communication the author has stated that there were some mistakes in the paper as a result of editorial abbreviation. Errata are anticipated in a subsequent issue of *The Electronic Engineer.*

R66-12892 ASQC 844; 775
Navy Electronics Lab., San Diego, Calif.
MICROCIRCUIT RELIABILITY PREDICTION METHODS
Research Report, Jul. 1965–Feb. 1966
H. F. Dean 11 Mar. 1966 15 p refs
(NEL-1347; AD-631972; N66-29940) CFSTI: HC $1.00/MF $0.50

A survey of possible test methods, and some exploratory work, showed that the most promising methods for the reliability screening of microcircuits are conventional electrical tests; special electrical tests such as ff noise measurement and use of the ring-counter technique; infrared temperature measurement; and visual inspection. Author

Review: This is in the nature of a progress report on what methods might be suitable and what ones are probably not. There are few details and those who would be interested are probably limited to Reliability Engineers who are keeping up on the general field. The reports about an Apollo computer at MIT (see R66-12467) show a somewhat different approach. There, the integrated circuit type for use was selected on the basis of being easy to test.

R66-12894 ASQC 844; 711; 712
FATIGUE TESTS ON SMALL-SIZED SPRINGS.
Yuichi Shimizu, Tosiaki Matino, and Eisaku Matumoto (Electrical Communication Laboratory, Switching Apparatus Section, Tokyo, Japan).
Review of the Electrical Communication Laboratory, vol. 13, no. 1-2, Jan./Feb. 1965, p. 130-147. 6 refs.

Fatigue testing procedures and equations, as well as experimental results for small-sized springs are reported. Repeated bending fatigue tests are described for various types of springs, including those used in electrical communications systems; and a fatigue testing machine for cantilever springs is considered. Expressing the maximum fiber stress of the cantilever spring, its mounting on the testing device, and the effect of oscillation frequency are reported. M.W.R.

Review: This paper is translated from Japanese and is difficult to read and comprehend. The excessive use of equations and lack of good organization also contribute to difficulty in interpreting what the authors are trying to relate. The useful information comes mainly from the results of the fatigue tests which are understood primarily because of the graphs and curves, although even the latter are not presented adequately. Fatigue is an important failure mode in springs which are an important part of many mechanical devices. It is a necessary part of the physics-of-failure approach to understand the behavior of these devices as well as possible.

R66-12895 ASQC 844; 711; 712
PRACTICAL ASPECTS OF FATIGUE.
Jack E. La Belle (General Motors Corp., Detroit Diesel Engine Div., Detroit, Mich.).
Metal Progress, vol. 87, May 1965, p. 68-73.

Fatigue phenomena are used to explain problems in crankshaft, spring, piston pin, and engine cylinder head failures. Fatigue is defined as fracture due to repeated stresses which are so low that a single stress apparently does nothing to the structure; and endurance limit, based on decreasing load at a certain stress is considered to be fairly distinct in the ferrous metals. Benefits of compressive stresses, from processes such as shot peening, are discussed in the case of a driveshaft. Several cases are given to illustrate how fractures reveal origin of failures. It is noted that "spring surge" can cause failure in compression springs, and a typical spring fracture indicates that failure usually starts just below the surface. During the five years since the cold extrusion process was put into effect, the failure rate in piston pins dropped from one in 50,000 to less than one in a million. Thermal fatigue of cylinder heads of diesels and special cylinder head gaskets to prevent gas leakage in high compression engines are other problems considered. M.W.R.

Review: This paper is for those who are not too well acquainted with fatigue. While one cannot expect to become an expert in fatigue on the basis of this paper, the ideas and principles outlined are a good starting point. The paper is well written and well documented. Fatigue is an important failure mode, even in electronic parts. Many designers are not sufficiently aware of it and their products suffer because of it. The case histories are interesting, illustrative and informative.

R66-12896 ASQC 844; 711; 712
FATIGUE IN CONSTRUCTIONAL STEELS. PART I: BASIC CONSIDERATIONS; AND PART 2: APPLICATIONS OF FATIGUE DATA.
Charles A. Martin (United States Steel Corp., Pittsburgh, Pa.).
Machine Design, vol. 37, Aug. 5, 1965, p. 130-136. 7 refs.; vol. 37, Aug. 19, 1965, p. 161-165. 3 refs.

Fatigue tests are reported for samples of various types and strengths of construction steels, and procedures are suggested for using the resultant data as a basis for designing structures and equipment subjected to fluctuating loads. Special attention is given to fatigue limit and tensile strength relationships and fatigue in structural joints, including effects of stress ratio and fillet welds. Basic fatigue data are presented in the form of charts for representative high-strength, low-alloy steels. The second part of the article gives equations to determine the fatigue characteristics of a structure. Allowable stresses in base metal and weld metal are tabulated for various construction steels; and numerous practical suggestions are offered in terms of geometric effects and design considerations, and metallurgical and fabrication considerations. The linear accumulation theory for determining cumulative fatigue damage is detailed. M.W.R.

Review: The first part is a fairly basic treatment of fatigue in constructional steels. For those familiar with fatigue, it will be of interest because of the results obtained and the conclusions reached. The development may not be sufficient for those not already in the fatigue field. The second part clearly illustrates procedures for establishing the allowable design stress under a constant alternating load and for spectrum type loading. Examples are given which aid considerably in explaining the use of the equations. No test data are presented to confirm the life estimated with respect to any of the design examples. In general, the paper is well organized and easy to read. There is still some controversy on the best method for estimating cumulative damage; the Miner's method shown here is widely used. Welded steel structures are commonly used and designers need all the information they can get on this important failure mode.

R66-12897 ASQC 844; 712
NEW FASTENER TESTS STRENGTHEN JOINT RELIABILITY.
H. B. Sorensen, J. E. La Belle (General Motors Corp.), W. G. Waltermire (Lamson and Sessions Co.), and S. K. Clark (Michigan, University, Engineering Mechanics Dept.).
SAE Journal, vol. 73, no. 7, Jul. 1965, p. 50-56. 4 refs.

Physical testing of nuts and bolts to evaluate their capabilities, and new test equipment and techniques to improve product reliability are described. A torque-tension load machine that measures torque and tension developed in fasteners under a wide range of loading conditions, as well as the ultimate strength of nuts and bolts, is considered which contains three separate hydraulic systems: torque, tension, and load-apply. Charts developed from this type testing can be used to determine optimum bolt specifications on the basis of weight, cost, safety, factor, and function. A bolt-load analyzer that measures and records preload, ultimate load and torque, and other pertinent joint factors; and produces torque-tension curves in strip chart form is also considered. Other means to improve joint reliability include a cyclic load tester that indicates the effect of repetitive loading on loosening of nuts and bolts, a test fixture that determines torque breakaway behavior of self-locking nuts, and a technique that evaluates effect of hardness on brittle-failure of bolts. M.W.R.

Review: The paper clearly describes and illustrates the use of several types of bolt testing apparatus and also serves to demonstrate how recent technology is used in improving the reliability of fasteners. Perhaps through the use of equipment such as that described, standards can be set up for fastener designs based on the load requirement of the use. Fasteners are ubiquitous in electrical, electronic and mechanical equipment. Knowledge of their failure modes is important to the design of reliable equipment. The factual information, for example on self locking bolts, is helpful.

R66-12898 ASQC 844; 711; 712; 864

FATIGUE FAILURE ANALYSIS AND "PREVENTION".

F. B. Stulen and W. C. Schulte (Curtiss-Wright Corp., Curtiss Div., Caldwell, N.J.).

(Gulf Coast Metals Conference, Houston, Tex., Mar. 31, 1964). Metals Engineering Quarterly, vol. 5, Aug. 1965. p 30-39. 12 refs.

Major factors to be considered in the analysis of fatigue failure that occurs during service operation are discussed, and a general approach and specific means for minimizing fatigue failures of machine or structural parts are described. Causes for fatigue failure and their recognition during analysis are reviewed; and it is noted that most fatigue failures can be traced to inadequate knowledge of either the (1) environmental conditions under which the component operates or (2) response of the material to these conditions. Requirements for successful design of structures for fatigue service are tabulated, as are the conditions which cause reduction in fatigue strength. Design techniques for improving fatigue strength are illustrated; and graphs are included to show fatigue loads and strengths of a structural component, critical dynamic and static crack lengths, and behavior of some steels and wrought aluminum alloys. It is concluded that the only general solution for preventing fatigue failures lies in the education of personnel to understand the nature of fatigue in materials. M.W.R.

Review: This paper is a very general and elementary discussion of fatigue problems and methods for preventing them. Very little prior knowledge is needed for a good understanding of the contents. It does an excellent job of providing practical and useful knowledge for the reader and refrains from a discussion of crystallographic concepts of failure. Papers such as this serve a useful purpose both by providing some factual information and by reinforcing the importance of this failure mechanism in the minds of designers. The feedback of failure information to enable redesign is well emphasized here.

85 DEMONSTRATION/MEASUREMENT

R66-12845 ASQC 850;770;782

VACUUM-THERMAL ENVIRONMENTAL TESTING OF THE NIMBUS I CONTROL SYSTEM.

Alexander London (General Electric Co., Missiles and Space Div., Valley Forge, Pa.).

In: Institute of Environmental Sciences, Annual Technical Meeting, San Diego, Calif., April 13-15, 1966, Proceedings. Mt. Prospect, Ill., Institute of Environmental Sciences, 1966, p. 583-592. 7 refs.

(Contract NAS5-1347)

(A66-30504) Members, $9.00; Nonmembers, $14.00.

Review of the testing of the Nimbus 1 control system, which was meant to demonstrate reliable performance in the vacuum-thermal environment. The structural elements, control system, and orbit of the satellite are described. The test facility and its instrumentation and procedure are discussed. The thermal design and its constraints are examined, and the external thermal and pressure environments are briefly discussed. B.B.

Review: This paper gives a good description of the environmental testing program for the attitude control system of the Nimbus I weather satellite. It emphasizes the fact that the vacuum-thermal testing program was an integral part of the overall reliability and quality assurance programs conducted for the spacecraft. The environmental test described identified potential problem areas which resulted in improvement in the design and quality of the system. The material is clearly presented in a commendable amount of detail. Supporting photographs and charts enhance the presentation. Seven references which are cited will be helpful to those who desire more detail. Testing programs of the type described in this paper are vital in providing desired confidence in the reliability of non-maintainable spacecraft systems. Descriptions of programs which have proven their effectiveness are very valuable to those who are planning and/or carrying out similar programs for future spacecraft.

86 FIELD/CONSUMER ACTIVITY

R66-12847 ASQC 864; 815; 844

SIDELIGHTS ON THE "FEEDBACK" PROBLEM BY A HARASSED VENDOR.

L. G. Rado (ITT Cannon Electric, Inc., Los Angeles, Calif.).

Institute of Electrical and Electronics Engineers Professional Group on Reliability, Los Angeles, Calif., April 20, 1964. 7 p.

Use of feedback from customers in the failure analysis of aerospace components is discussed in terms of improving product reliability. It is noted that poor returns were obtained when questionnaires were sent to 90 aerospace plants; and it is concluded that if questionnaires are to be useful, they must be well-planned, fit the specific situation, and reach the proper individual. The need for closer relationships between customers and vendors is stressed for full utilization of feedback and for adequate failure analysis. M.W.R.

Review: Feedback and failure analysis have an important part to play in the improvement of the reliability of many components for aerospace use. Closer correlation of specifications with customer needs can result in greater efficiency reflected through reductions in total cost and test time. This paper is concerned with the feedback problem as it pertains to connectors—components of very high usage in missile/satellite systems. It highlights an effort by one company to improve the feedback situation, and cites some conclusions which should be helpful to others concerned with a similar problem.

R66-12868 ASQC 864; 841; 843
HOW TO CAPITALIZE ON FIELD FAILURE REPORTS.
Stanley T. Zawacki (Potter Instrument Co., Inc., Engineering Dept., Plainview, N.Y.).
Machine Design, vol. 38, 23 Jun. 1966, p. 136–140.

A system for failure reporting and analysis is detailed which can aid in implementing design improvements as well as increasing product reliability. Trend analyses, based on field service reports of failures, are particularly important for product improvements and decreasing necessary repair times; and such improvements result in better customer relations. Attention is given to the acquisition of data, coding, and analysis of results; and economy in instituting and using the program is noted, as are the immediate results in product design and increased reliability that are achieved. M.W.R.

Review: This paper does a very good job of fulfilling the purpose implied by the title. It describes the essential features of a system for failure reporting and analysis which can be very effective in producing design improvements and increased product reliability. The value of failure trend analysis is clearly indicated. The need for electronic data-processing when the volume of field reports is large is emphasized. This need will, of course, be less acute in situations where the volume is low; in fact there may be cases in which manual methods have advantages. The key consideration in a system of this kind, also discussed in the paper, is that of having a truly effective means of reporting failures, conveying all of the pertinent information needed for a meaningful analysis. A large part of the problem lies in getting people to follow instructions carefully in filling out the report forms. This historically has been the biggest problem with reporting systems; many would be excellent if only people would bother. The author in a private communication has pointed out that the transformation of the data from the report to the input card should be handled by someone familiar with the equipment and technically oriented.

R66-12886 ASQC 863; 871; 881
RELIABILITY CONTRIBUTION TO MINUTEMAN LOGISTICS.
Leonard L. Schneider (Thompson Ramo Wooldridge, Inc., TRW Systems Group, Redondo Beach, Calif.).
(Annuals of Reliability and Maintainability; Annual Reliability and Maintainability Conference, 4th, Los Angeles, Calif., Jul. 28–30, 1965. Volume 4—Practical Techniques and Applications, p. 105–110.) *IEEE Transactions on Reliability*, vol. R-15, May 1966, p. 6–10.
(A66-30661)

Description of the contribution made by reliability to the logistics planning operation of the Minuteman weapon system. The weapon system, its operational concepts, and its maintenance philosophy are briefly described. The average number of failures/month/wing predicted for Wings I through V are plotted for a period of more than 3 yr. The two refinements effected in the Minuteman operational support planning failure rates documents for the advanced Minuteman system are described. It is pointed out that the unusually high in-commission rate of the Minuteman system is evidence of what proper planning early in a program can accomplish. Many factors influence the system in-commission rate, but the publication and consistent use of operational support failure rates by all of the principal agencies are a major determinant. The experience gained on Minuteman proves that it is possible to generate predictions of operational failure rates long before operating data are available. M.M.

Review: This paper was covered by R66-12807.

87 MAINTAINABILITY

R66-12848 ASQC 873; 711
Minneapolis-Honeywell Regulator Co., Boston, Mass. Aeronautical Div.
DEVELOPMENT OF SELF-REPAIR PROCEDURES Final Report, Mar. 1962–Mar. 1963
William S. Jarnagin, John Flynn, Douglas Pitman, and Kevin Fitzgerald Griffiss AFB, N. Y., Applied Res. Lab., Nov. 1963 80 p refs For Review See R66-12857
(Contract AF 30(602)-2727)
(TADC-TDR-63-175; AD-425002; N65-12207)

The purpose of the program is to develop non-redundant self-repairing electronic circuitry which utilizes the natural behavior of the material constituting the circuitry. The approaches investigated included several metallic-whisker-growing mechanisms (the idea being to grow metallic whiskers across breaks in electronic circuitry and thus restore electrical continuity), and several post-solder coatings, such as silver epoxy, indium-gallium, conductive rubber, etc., (the idea being to add mechanical flexibility to a given circuit and to make possible a redistribution of material for spanning damaged regions). Author (TAB)

R66-12857 ASQC 873; 711
Minneapolis-Honeywell Regulator Co., Boston, Mass. Aeronautical Div.
DEVELOPMENT ON SELF-REPAIR PROCEDURES Final Report, Mar. 1963–Mar. 1964
Griffiss AFB, N. Y., RADC, Sep. 1964 87 p refs
(Contract AF 30(602)-3027)
(RADC-TDR-64-183; AD-608140; N65-11887)

The automatic in-place repair of conductors, resistors, and inductors by the application of special purpose whisker growing and post coating alloys was investigated. Alloy compositions, and processing and application techniques were optimized for maximizing repair rates. Problems of practical application to operation systems were identified and evaluated. It was concluded that while the techniques investigated have only limited potential feasibility for general practical application, feasibility may exist for specialized applications. The repair of faulty semiconductor devices (diodes) by in-place remelting and rate growing using passive thermal gradients was investigated and found to be unfeasible for practical application. A literature search on capacitors revealed extensive prior work on the development of capacitors with the inherent capability for self-repair of certain types of failures. Author (TAB)

Review: These reports deal largely with the self-repair of conductors in which there is a very fine break. While some of the methods appeared encouraging, by and large the results are negative. This does not imply that the results are worthless since the subject is an important one and one for which the Edisonian approach of testing everything in sight is probably quite applicable. The reports seem to be rather frank in discussing the failures and the experimental problems—a good approach which is none-too-frequently used. The results on self-repair for semiconductors, inductors, and resistors are essentially negative. This kind of research, while discouraging much of the time, is worthwhile since we do not yet know what avenues will be the ways for achieving highest reliability.

R66-12858 ASQC 871; 873; 875

Army Missile Command, Huntsville, Ala. Engineering Requirements Office.

MAINTAINABILITY ENGINEERING GUIDE

Charles D. Cox, ed. 1 Oct. 1965 145 p refs

(RC-S-65-2)

Mathematical and other concepts for specifying, quantifying, and testing for a specific level of maintainability are presented in this manual, which has particular application to Army missile weapons and equipment. A practical method is formulated for applying the fundamental engineering and statistical techniques associated with the technology of maintainability. In addition to discussions of time, cost, and capability indexes, this manual includes chapters on maintenance theory and classification, a maintainability engineering program, designing for maintainability, demonstration testing, and various technical development requirements. Appendices deal with maintainability design features and support factors, a sample maintainability checklist, and a portion of a technical development plan. M.W.R.

Review: An Army orientation toward maintainability is presented in everyday, readable language by this guide. It is primarily qualitative discussion, with a small amount of quantitative content. Much of the contents are introductory, and anyone curious about the real "meat" will have to look further. For example, about all that is said on inherent availability is that it is MTBF divided by MTBF plus mean active corrective maintenance time. While this is certainly a good introduction to the notion, the formula is limited to non-redundant items and is applicable only to steady-state conditions. Typically no cautions of this sort are mentioned in the guide. Thus some reliability concepts enter the guide in the quantitative discussions, and also in those about program planning. The guide is potentially most useful to the novice in maintainability, but is not restricted to this audience, as others seeking an Army maintainability orientation will also find it helpful. There is some itemized material, such as maintainability documents and definitions, which may be helpful to those seeking detail. This guide is similar in content to the document with the same title and author dated 1 May 64, which was covered by R65-12346. The present document, dated 1 Oct. 65, does not refer to the earlier one.

88 AVAILABILITY

R66-12889 ASQC 882; 412; 413

LOWER CONFIDENCE LIMITS AND A TEST OF HYPOTHESES FOR SYSTEM AVAILABILITY.

Mary Thompson (Hughes Aircraft Co., Aerospace Group., Space Systems Div., Los Angeles, Calif.).

IEEE Transactions on Reliability, vol. R-15, May 1966, p. 32–36. 4 refs.

(A66-30664)

Derivation of techniques for placing a lower confidence limit on system availability, and for deciding if the true system availability differs significantly from a specified value when MTTF and MTTR are estimated from test data. These techniques could be used to analyze existing test data or to design a test program to demonstrate system availability and/or detecting significant deviations from specified values of system availability. To facilitate utilization of these techniques, curves of the lower 0.90 and 0.95 confidence limits and power curves for the testing of hypotheses at the 0.05 and 0.10 levels of significance are presented. Illustrative examples are given. F.R.L.

Review: This is a theoretical paper; the assumptions are clearly set forth and the derivations are carried out in a straightforward manner. Care should be used in applying the results, of course, to see that the assumptions reasonably apply to the physical system. The theory and curves may be of help to those responsible for system testing against specifications.

R66-12888 ASQC 882

EFFECTS OF FAILURE ON PHASED-ARRAY RADAR SYSTEMS.

A. H. Hevesh and D. J. Harrahy (Raytheon Co., Wayland, Mass.).

IEEE Transactions on Reliability, vol. R-15, May 1966, p. 22–32. 12 refs.

(A66-30663)

Examination of the effects of outages on phased-array radar performance, with some preliminary views on the availability of such radars to perform when required. The usual definitions of system failure or success are given in terms of a discrete threshold of acceptability for a minimum number of operable elements out of the total simultaneously available. The availability, or readiness, of the phased-array system is examined so as to account for (1) the treatment of the outage threshold on probabilistic grounds in order to include the effects of various physical geometries of operable elements in the antenna array for given levels of outage, and (2) the branched dependency of a part of the system on other parts, creating a "tree" relationship between failures at different functional echelons. A definition of availability in terms of performance as well as outage is sought. Analytic treatment of these factors is employed wherever possible in modeling a general phased-array radar with reasonable constraints. F.R.L.

Review: This is a theoretical paper. The relationships to the physical system are well explained and approximations are justified. The brief examples help to illustrate the theory. (Not all the mathematics was checked, but it appears to be good.) The theory deals with the availability of systems when portions of the array go bad and is rather general. (This is not of physics-of-failure paper as might be inferred from the title.)

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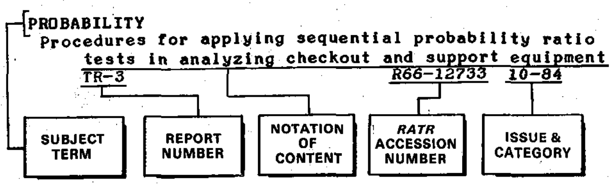

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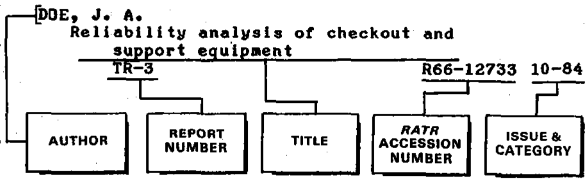

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REPORT AND CODE INDEX

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NOTE: Abstract-reviews numbered R66-12378 through R66-12732 appeared without the preceding R66-1 (i.e., as 2378 through 2732) in consecutive order in Issues 1 through 8 of this volume of *RATR*. Therefore, this list is primarily for use in locating abstract-reviews numbered R66-12733 through R66-12901 arranged in categories in Issues 9 through 12 of this volume of *RATR*.

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