RELIABILITY ABSTRACTS and TECHNICAL REVIEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Office of Reliability and Quality Assurance
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Abstracts 776-1305

PREFACE

In order to help scientists concerned with the reliability of parts, assemblies, components, and systems to stay abreast of the latest developments in the literature in this field, the National Aeronautics and Space Administration in April, 1961 contracted with the Research Triangle Institute for the conduct of an abstracting and review service for technical literature on reliability. The first annual volume of Reliability Abstracts and Technical Reviews produced under this contract contained Serial Numbers 1-275, which were issued during the period between April, 1961 and May, 1962. The second annual volume contained Serial Numbers 276-775, produced during the period between June, 1962 and May, 1963. This, the third annual volume contains Serial Numbers 776-1305, issued between June, 1963 and May, 1964.

The work on this project is performed by the Research Triangle Institute, Durham, North Carolina under the sponsorship and supervision of the Office of Reliability and Quality Assurance of NASA. Current papers on reliability and closely related subjects are sought from all available sources, including technical journals, trade magazines, and proceedings of conferences and meetings. Authors of papers and technical reports in the field are invited to submit their material for inclusion in the service. Abstracts and reviews of the papers are prepared and submitted in monthly installments to NASA for distribution to a NASA mailing list. Prior to its submittal to NASA, each abstract and review is sent in draft form to the author (or first author) of the paper to enable him to make comments. The comments received are considered in preparing the final form of the abstract and review.

Each item in this volume has been classified as to subject according to the American Society for Quality Control Literature Classification System, Methodology or Techniques Classification, as revised in January, 1963. A listing of the code numbers of this system, together with the subject-matter categories for which they stand, appears on page three. The codes assigned to the individual paper appear below the serial number on the corresponding abstract and review sheet, and are intended to represent not only the principal subject matter of the paper, but also areas in which the contents may be expected to be useful.

To facilitate the search for material in given subject-matter categories, a listing has been prepared of the serial numbers of the papers to which the various codes have been assigned. This listing appears as the INDEX OF SERIAL NUMBERS BY CODES, on pages four, five, six, seven, and eight. The user may find it worthwhile to transfer this list to a card file, using a separate card for each code number. The card file may then be kept up to date by appropriately entering on the cards the serial numbers of subsequent articles, as the abstracts and reviews appear.

000 GENERAL
- 010 QUALITY CONTROL DEFINITIONS / SYMBOLS
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100 STATISTICAL PROCESS CONTROL
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  - 425 FITTING DISTRIBUTION FUNCTIONS
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  - 432 QUEUING THEORY
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500 EXPERIMENTATION AND CORRELATION
- 510 TESTS OF SIGNIFICANCE AND CONFIDENCE INTERVALS
  - 511 SIGNIFICANCE TESTS
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  - 523 SPECIAL METHODS FOR ANALYSIS OF DATA
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- 540 CURVE FITTING
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  - 543 MULTIPLE REGRESSION
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  - 546 GOODNESS OF FIT TESTS
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INDEX OF SERIAL NUMBERS BY CODES

Serial Number 776 -1
Codes 720;770;833
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Final Report: Reliability study of silicon VHF power transistor developed under Contract No. DA-36-039 SC-85255, 27 July 1961 to 31 March 1962

AUTHORS: H. A. Lauffenburger, R. R. Henderson, and M. Mann, Pacific Semiconductors, Inc., Reliability and Quality Control Department, 14525 Aviation Blvd., Lawndale, California

SOURCE: PSI Report No. 8000:2-F, 116 pp. (ASTIA Document No. 276925)

PURPOSE: To present and evaluate the results of a reliability study conducted on a 3 watt, 70 mc silicon power transistor developed by Pacific Semiconductors, Inc.

ABSTRACT: This report by Pacific Semiconductors, Inc. concerns a reliability study of a 3 watt, 70 mc. VHF silicon power transistor previously developed by Pacific Semiconductors, Inc. for the U.S. Army Signal Supply Agency. This study was performed in two parts; one part involving the use of step-stress techniques and a second part consisting of conventional high temperature storage and operational life tests. Units used for the reliability study were representative of actual production techniques. However, only those units which exhibited a high stability throughout a series of initial tests including temperature, moisture, vibration, and a 50 hour operational test at 25°C and 2.5 watts power dissipation were accepted for use in the reliability study. The four electrical characteristics I_{CBO}, I_{EBO}, V_{CER} and h_{FE} were measured periodically during the linear life tests and at the conclusion of each stress level during the step-stress tests.

Linear life tests were conducted for 2500 hours on four separate groups of 92 specimens. One group was stored at a temperature of 200°C, with the other three groups, respectively, being operated at dissipation levels of 0.675 watts, 2.5 watts, and 4.375 watts in an ambient temperature of 25°C. Results of these linear life tests indicate that the simple Weibull distribution provides an excellent model for these life test conditions. It was found that the reliability of the transistor at 25% rated load is very nearly equal to that obtained in the 200°C storage life test.

Step stress tests were conducted in both the time-temperature and time-power domains. Separate groups of 25 specimens were each tested for intervals of 1, 24, 72, or 168 hours with the temperature stress being increased in 8 increments from 200°C to 488°C and the power stress being increased in 7 increments from 2.5 watts to 10.0 watts of power dissipation. Almost 100% of the test units failed at the 10.0 watt level.

Among the overall conclusions of this study was the fact that the

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

reliability level of the 3 watt 70 mc transistor is significantly lower than the reliabilities obtained with low-level and switching transistors. The difficulties appear to be the large device areas and the critical geometric considerations involved in the production of such high power, high frequency devices. This study also indicates that at high power levels no reliability advantage is gained from broadening circuit tolerances as failures were generally catastrophic and failure rates are essentially the same for all definitions of failure. However, at low operating levels, equipment reliability can be improved through wider circuit tolerances as there are significant differences in failure rates for different definitions of failure.

In regard to the design of future step-stress test programs with similar devices the persons conducting this study suggest (a) the use of a larger number of stress steps with smaller stress-level increments, (b) the employment of shorter test time intervals, (c) establishing a starting stress level high enough to insure meaningful data, and (d) the use of larger sampling sizes, preferably 50 specimens for each test time interval.

REVIEW: The reliability study conducted under this contract represents one of the first comprehensive life evaluations of a high power VHF silicon transistor. The transistors tested did not exhibit the same high level of reliability usually associated with low power or switching transistors. Thus, this study is of particular significance insofar as focusing attention on deficiencies in materials and techniques and establishing guidelines by which the reliability of these large-area devices may be improved. Considerable thought has been devoted to the organization and conduct of the tests and to the evaluation of the results. The final report is well written and serves not only to indicate the reliability of the transistor, but also to provide considerable insight into the various failure mechanisms observed, and to suggest means whereby the device reliability may be upgraded as well as ways in which future reliability studies of similar devices may be facilitated and made more meaningful. ##

Serial Number 777
Codes 713;762;775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How valid are requirements for nondestructive testing of welds?

AUTHOR: Jay Bland, Knolls Atomic Power Laboratory, General Electric Company, Schenectady, New York

SOURCE: Metal Progress, vol. 83, April, 1963, pp. 65-66

PURPOSE: To suggest what is wrong with nondestructive weld testing and how to improve it.

ABSTRACT: The nondestructive testing of welds is widely used as a means for predicting whether or not a weld will hold up in service. The present methods need qualified inspectors just as welders are qualified. Unfortunately, few codes in this country make provision for qualifying the inspectors. The number and kind of defects which are shown by a test depend on the test; there is no absolute measure. Data should be developed to provide an engineering basis for acceptance standards for welds. The welding codes should be modified to reflect improvements in welding quality and more realistic acceptance standards for welds.

REVIEW: This article points up a general problem in nondestructive testing--how does one know that the test he is using will actually measure the right things? The author's point is well taken, but the problem will continue to be with us, especially as performance standards become higher and exact data are difficult to get because of the time/money involved. Naturally the tests should take full advantage of the state-of-the-art; but someone will always want a prediction beyond that state. ##

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Serial Number 778
Code 773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Testing for reliability

AUTHOR: Gordon L. Ness, Fairchild Semiconductor

SOURCE: solid/state/design, vol. 4, March, 1963, pp. 63-64

PURPOSE: To point out the requirements of measuring apparatus for reliability tests.

ABSTRACT: The testing of component parameters in reliability tests requires high accuracy and rapid instrumentation. These instruments have been developed so that 24 parameters each on 240,000 devices can be tested per month with high accuracy, utilizing digital pulse techniques.

REVIEW: This is a short general article containing some interesting facts. It will be of more interest to management and quality control/quality assurance personnel involved in high-reliability testing, than to the design engineer. ##

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Serial Number 779
Codes 782;835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Heat shield effects on tube life

AUTHOR: John C. McAdam, IERC Division, International Electronic Research Corporation, Burbank, California

SOURCE: Electrical Design News, vol. 8, March, 1963, pp. 32-36

PURPOSE: To give data on tube life vs type of heat shield.

ABSTRACT: Most military and commercial electronic equipment failures are caused by tube failure. High bulb temperatures greatly reduce tube life. The old JAN shield, now prohibited by the DOD, causes the bulb temperature to be higher than without the shield. Forced air cooling helps some, but a well designed shield can reduce the temperature much more. An increase in life from 2:1 up to 12:1 can be obtained by using the proper shield. Substantiating data are given.

REVIEW: Even if these facts are already known by designers, it is well to emphasize them again here. The subject is an important one. ##

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Serial Number 780
Codes 837;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable circuits through redundancy
Part 1: Redundant circuit philosophy
Part 2: Redundant circuit design

AUTHOR: Theodore Goldstein, Kollsman Instrument Corporation, Elmhurst, New York

SOURCE: Electronic Equipment Engineering, vol. 11, March, 1963, pp. 56-59 and April, 1963, pp. 78-82

PURPOSE: To present redundant circuit philosophy and worst case design.

ABSTRACT: The philosophy and principles are shown using an inverter as an example. A quadded and a logically redundant type are both shown. The failure probability of a quad is shown to be 3(failure probability of element)^2/2 for low failure probabilities. Failure modes and their effects are discussed.

Worst case design is shown step by step for an inverter (both quad and logically redundant). A flip-flop and single-shot are briefly discussed.

REVIEW: This is a fairly standard treatment of quad redundancy (the full title "quadruple" would seem more appropriate than"quadrature" which has other meanings). It is important to realize all the assumptions involved in calculating the reliability in this way. The most important of these are (1) only catastrophic failures are considered, (2) a diode or transistor is generally assumed to be a perfect switch, (3) the improved reliability (as the author mentions) applies only to the particular circuit--the system may require many more such circuits to perform the same function, and (4) failures are assumed to be independent.

In the compromise single-shot diagram, the capacitors seem to be missing.

Articles such as this can be very helpful to the designer if he does not blindly apply the results--all the assumptions (implicit ones are dangerous) must be taken into account. For a further discussion of some of these points see Abstracts and Reviews Serial Numbers 199, 277, 396, 488, and 560. ##

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Serial Number 781
Codes 770;844;853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relationships of corona to life and reliability of polyethylene insulated cable (new test methods for cable)

AUTHORS: W. T. Starr, General Electric Company, Schenectady, New York and J. P. Agrios, USASRDL, Fort Monmouth, New Jersey

SOURCE: 21 pp., presented at the IEEE Winter General Meeting, New York, New York, January 27 to February 1, 1963, IEEE Transactions Paper No. 63-180

PURPOSE: To present results of life tests on radio frequency and pulse cables.

ABSTRACT: Life data indicating the effects of materials and processing are presented for available polyethylene insulated radio frequency and pulse cable. Two points selected for illustration purposes are:

1. A life in excess of 1×10^{11} cycles of applied voltage may be obtained with a cable with a stranded central conductor and with a stress at the central conductor as high as 0.38 megavolts peak per cm. This is below the stress required for corona.

2. A life of the order of 5×10^{8} cycles of applied voltage to failure is found for cables with a braided shield. Corona occurs at the braid at 0.4 to 0.5 times the voltage required for corona at the central conductor. Material and processing changes can improve the life by up to ten to one, or can lower the life by a factor of one thousand to one.

The effect of applied voltage upon life can be predicted for cables with a braided shield from measurements of the way that the number of corona discharges per cycle varies with voltage. It is found that the number of discharges to failure is constant over a voltage range. The effect of temperature upon life has been shown to follow the Arrhenius law. The expression which fits the measured effect is given. The effect of cable length on life is given. Weibull probability is used for this because the data fit it. The use of prestressed specimens for life testing results in an excellent determination of the minimum expected life. A high voltage 60 cycle life test is suggested for purposes of processing development or engineering evaluation of cables. This test is far superior to the short time rising voltage electric strength tests because it finds faults which the electric strength tests do not. These faults result in poor service behavior. Frequency acceleration of life testing is useful because the number of cycles to failure does not change with frequency. The limits within which this statement is true have been determined, and have been shown to be related to corona loss. (Authors)

REVIEW: This series of experiments was apparently well thought out and well executed. The assumptions involved in the analysis are clearly stated. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Switchgear insulation systems for improved reliability with expanding loads

AUTHORS: J. D. Finley and Russell Frink, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania

SOURCE: 14 pp., presented at the IEEE Winter General Meeting, New York, New York, January 27 to February 1, 1963, IEEE Conference Paper No. CP 63-425

PURPOSE: To present new approaches to solutions of switchgear insulation problems.

ABSTRACT: Rapid load growth and the importance of continuity of service have established the need for new levels of reliability and endurance of switchgear insulation. This paper presents new approaches to solutions of these problems in which the insulation is considered as an integrated system and in which the system is built by new applications of existing materials and the development of new materials where required. (Authors)

A major problem with bushing insulation is the temperature rise due to dielectric losses and the consequent increase in these losses at higher temperatures. In some materials, this condition can produce thermal runaway at modest overvoltages. An epoxy-paper and a porcelain bushing are described which have been developed to solve this problem.

REVIEW: The major portion of the paper is devoted to the bushing material design as regards thermal runaway. Apparently differences between bushings are quite small compared to the safety margins involved since these differences are not mentioned. Likewise the problem of deterioration with time is not explicitly mentioned and again this effect presumably was small. Although voltage stresses are given considerable attention, no mention is made of any magnetic field or internal heating effects as a result of high conductor currents. (The term reliability is not used here in a quantitative sense.) ##

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Serial Number 783
Codes 512;552;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Lower confidence limits for mean life when life times are exponentially distributed

AUTHOR: Arnold H. Cronshagen, Corporate Reliability Control Staff, Aerojet-General Corporation, Azusa, California

SOURCE: Aerojet-General Corporation Technical Report RCS60-4, 8 pp. (ASTIA Document No. 287360)

PURPOSE: To present charts for determining lower confidence limits for mean life when the life times are exponentially distributed.

ABSTRACT: This report presents charts giving lower confidence limits for estimates of mean life as a function of total observed life and the number of failures observed. The assumption made is that the life times are exponentially distributed. Two situations are considered, (1) termination of test observation after the first k failures have occurred, and (2) truncation of the test after a specified time interval has elapsed. Replacement and non-replacement cases are given for each situation. Lower estimates of mean life for .50, .80, .90, .95, .99 and .995 confidence levels respectively are presented in charts 1-6 inclusive as functions of total observed life and k = 1 (1) 10 (5) 40 (10) 100 failures for the "first k failures" case and k = 0 (1) 9 (5) 39 (10) 99 failures for the "specified time interval" case. Examples illustrating the use of the charts are also presented. (Author)

REVIEW: In the case for "specified time interval" the confidence statement should be "the confidence $\geq 1 - \alpha$". An upper limit to the confidence, $1 - \alpha'$, can be obtained from the relationship $\chi^2_{\alpha'}(2k) = \chi^2_{\alpha}(2k + 2)$. Otherwise the theory is correct.

Other comments on this topic may be found in Reviews Serial Numbers 679 and 713. ##

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Serial Number 784
Codes 831;853;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How failure indicators can improve reliability

AUTHOR: W. B. Bishop, Air Force Cambridge Research Laboratories, Bedford, Massachusetts

SOURCE: 12 pp., Electronic Material Sciences Laboratory Project 4608, Air Force Cambridge Research Laboratories, Office of Aerospace Research, United States Air Force, AFCRL-62-361, June, 1962 (ASTIA Document No. 285793)

PURPOSE: To show the relationship between the statistical theory of failure indicators and other parts of the reliability literature.

ABSTRACT: The fact that a failure has occurred usually can be detected without a specifically-designed failure indicator. In a complex device, however, many types of failure indicators can be helpful in determining the source of trouble. If reliability is defined to be a measure of the percentage of time a device is operable, then proper design and use of failure indicators can improve reliability. This paper shows the relationship between the statistical theory of failure indicators and other parts of the reliability literature and develops some of the principles which should be followed in the design and use of failure indicators. As might be expected, a number of these principles have been followed by good maintenance men for many years.

Rapid location of troubles permits rapid repair with resultant minimized "down time". The design of failure indicators involves the same theory as the design of any reliable equipment. However, in general, failure indicators are less complex than the devices they monitor. Properly designed failure indicators can be used to provide important information to the maintenance man or to program automatic replacement of defective modules. (Author)

REVIEW: The entire article could be summarized by the sentence: failure indicators which point to the failed part are very desirable; they should have high probability of showing the correct state and low probability of showing an incorrect state. However, the author takes eleven pages to say some fairly obvious things, and contributes little that is new on the subject. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design for a failure

AUTHOR: W. B. Bishop, Air Force Cambridge Research Laboratories, Bedford, Massachusetts

SOURCE: 21 pp., Electronic Material Sciences Laboratory Project 4608, Air Force Cambridge Research Laboratories, Office of Aerospace Research, United States Air Force, AFCRL-62-578, August, 1962 (ASTIA Document No. 285021)

PURPOSE: To develop the theory of designing for failure.

ABSTRACT: There is a distinct need for specifying when it is acceptable for a piece of equipment to fail. Not necessarily all at once like Holmes' "One-Hoss Shay," but when the weakest part may fail. Although there is a close relationship between specifying when parts may fail and specifying when they should not fail, there is an important difference. Designing for a specific time of failure tends to increase efficiency and does not necessarily reduce reliability. Also, more information about actual failure mechanisms is required in order to achieve failure reasonably close to a specified time.

The earlier concept of a "Failure-Indicating Module" is extended to include a "Failure Module." Paradoxically, reliable equipment can be built of "Failure Modules" if either: (1) module failure has a high probability of falling within a known time interval; or (2) provision is made for failure detection and automatic replacement.

Reliability specifications should include clauses stating when it is acceptable for equipment to fail. These clauses should not be "open ended" (i.e., any time after t_2) but should state for example, "failure shall occur within the interval $2\Delta t$ centered around the time T with a probability of say 90 percent." The present requirement that the probability of failure between t_1 and t_2 must be below say one percent need not be removed. The two requirements are completely compatible.

This new requirement does not simplify the design of reliable equipment. It is not easy to meet. However, efforts toward satisfying it could provide an improved attitude toward failures, and a more efficient means of designing reliable equipment. (Author)

REVIEW: It is difficult to tell what the author's thesis is, especially because of the sentence in his conclusions (also shown above) "The present requirement that the probability of failure between t_1 and t_2 must be below, say, one percent need not be removed."

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

If during a period of desired use, the failure probability is sufficiently small, one does not care what it is after that period. The author is not too clear on what he is trying to hold constant (the constraints in his analysis) and what he wants to change. It may be that the author wishes to say that for a given mean life, the reliability during a period somewhat shorter than the mean life can be much greater if the failure probability distribution is Gaussian and quite narrow, rather than a negative exponential. In that event he would be quite right. It would also seem that if the author were to use the cumulative (from the left) failure distribution, he could make his point in a very few pages. Regardless of what practical merit some of the ideas may have, the paper is not a good contribution to the literature on reliability theory. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and confidence criteria in structural design

AUTHOR: H. Serbin, Hughes Aircraft Company, Aerospace Group, Space Systems Division, El Segundo, California

SOURCE: Aerospace Engineering, vol. 21, December, 1962, pp. 37-40

PURPOSE: To present an alternate evaluation of finite sampling with regard to tolerance estimates.

ABSTRACT: Concepts of reliability as dependent on sample size are reviewed in their application to structural design. The use of the confidence level as a qualification attached to the measure of reliability is examined. An alternate formulation of reliability is proposed to avoid the double valued description usually associated with confidence levels. (Author)

The problem is solved by considering a new distribution with modified standard deviation. This modification includes the effect of small sample sizes (for size ≥ 5).

REVIEW: The author's complaints about the interjection of a confidence level into the problem are reasonable. All of his algebra was not checked since there is a reasonably simple, exact answer to his problem.

If a sample of size n from a normal (Gaussian) population results in unbiased estimates $\bar{x}$ of the true average and s^2 of the true variance of a random variable x, then the quantity $t = (x-\bar{x})/[s\sqrt{1+(1/n)}]$ has the student's t distribution. Thus the fraction of the population which has a value greater than $\bar{x} - ts\sqrt{1+(1/n)}$ is obtained from the t tables. (The author calls this fraction the "reliability".) The reference [1] below will assist in deriving this equation. It should be noted that the result gives only the average probability (over many samples). The probability for any particular sample is likely to be somewhat inaccurate. The reference [2] is an important fundamental paper on confidence and tolerance intervals for the normal distribution.

REFERENCES: [1] Freund, John E., Mathematical Statistics, Prentice-Hall, Inc. Englewood Cliffs, New Jersey, 1962, p. 202

[2] Proschan, Frank, "Confidence and tolerance intervals for the normal distribution," Journal of the American Statistical Association, vol. 48, pp. 550-564, September, 1953 ##

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Serial Number 787
Code 782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Components in space

AUTHOR: Leonard B. Gardner, Northrop Space Laboratories, Hawthorne, California (current affiliation: Consulting Scientists, P. O. Box 103, Toluca Lake Station, North Hollywood, California)

SOURCE: Electromechanical Design, vol. 7, February, 1963, pp. 28-29

PURPOSE: To review contemporary effort on the effects of the space environment on components.

ABSTRACT AND REVIEW: This is an informal column, apparently to be a regular feature. Dr. Gardner has published extensively in this area and the column should be very worthwhile to those interested in the subject. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable stepping switch circuit design

AUTHOR: J. D. Ashby, Automatic Electric Sales Corporation, Northlake, Illinois

SOURCE: Electromechanical Design, vol. 7, February, 1963, pp. 52-55

PURPOSE: To emphasize the characteristics of stepping switches that are most often overlooked in circuit design.

ABSTRACT: The article is limited to indirect drive (the rotor advances on coil break, rather than coil make) rotary stepping switches. The following subjects are treated: power supplies, contact protection, contact load, coil considerations, drive mechanism adjustment, hunting and halting, homing, scanning and sequencing. To achieve a reliable system at lowest design cost, consultation with the prospective vendor is the first logical step.

REVIEW: The article appears to be a good one for designers, although one gets the feeling that something has been left out--otherwise why the competition from solid state devices and the sealing in oil done by some digital voltmeter manufacturers? Consulting the vendor is, in principle, good advice but can so often be a frustrating experience (depending, of course, on the vendor).

In a private communication the author has made the following comments. "Actually, the basic intention of the article was to attempt to make a few people realize that although stepping switches have been widely condemned, and often replaced with solid state devices, they are inherently long lived, reliable devices. We have felt a strong trend in the industry to replace electro-mechanical switch gear that was not functioning properly due to improper circuit design with a solid state circuit at higher cost. One of our friends has condemned this as a disease and dubbed it solidstatitis...The subject of sealing stepping switches in oil was not treated in our article because this is a "fad" that is going out of style in most circles...It has been our experience that sealing switches in oil drastically reduces their capabilities."
##

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Serial Number 789
Codes 770;823;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A second progress report on TV-receiver reliability

AUTHOR: E. H. Boden, Sylvania Electric Products, Inc., Emporium, Pennsylvania

SOURCE: IRE Transactions on Broadcast and Television Receivers, vol. BTR-7, July, 1961, pp. 11-13

This paper was covered by Abstract and Review Serial Number 256.
##

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Serial Number 790
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor failure modes in high power switching operation

AUTHOR: Joseph W. Mathews, Advanced Development Laboratory, Consumer Products Division, Philco Corporation, Philadelphia, Pennsylvania

SOURCE: IRE Transactions on Broadcast and Television Receivers, vol. BTR-8, July, 1962, pp. 35-39

This paper was covered by Abstract and Review Serial Number 585.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability considerations in the application of power transistors to consumer products

AUTHORS: C. F. Wheatley and J. W. Englund, Radio Corporation of America, Semiconductor and Materials Division, Somerville, New Jersey

SOURCE: IRE Transactions on Broadcast and Television Receivers, vol. BTR-8, July, 1962, pp. 65-73

PURPOSE: To describe considerations in design of power amplifiers that will affect the failure possibilities of the transistors.

ABSTRACT: The reliability normally associated with transistors results not only from the inherent characteristics of transistors, but also from careful effort in their design and application. To obtain the required degree of reliability in consumer products, it is necessary to analyze many considerations, both in the design of transistors and their application to circuits. This paper describes these considerations, and offers practical solutions to some of the existing problems. The discussion is limited to power stages such as audio output, vertical deflection, horizontal deflection, video output, and power-supply regulation. (Authors)

REVIEW: This is a very worthwhile paper for anyone who designs power transistor circuits. The models which are analyzed take into account many of the peculiarities of practical circuits. Several of the equations are derived in a rather lengthy appendix. (None of the equations in the paper were checked for accuracy.) ##

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Serial Number 792
Codes 817;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A self-protecting transistor power amplifier

AUTHORS: Gerald Randolph, Norman Kramer, and Richard Kerwin, Knight Electronics Corporation, 2200 Maywood Drive, Maywood, Illinois

SOURCE: IRE Transactions on Broadcast and Television Receivers, vol. BTR-8, July, 1962, pp. 91-95

PURPOSE: To show how audio power transistors can be protected by a barretter.

ABSTRACT: The efficient use of transistors in audio power stages results in their operation in a state close to thermal runaway. The addition of a barretter in the emitter circuit is discussed, showing the self-protecting features of this nonlinear feedback system for germanium alloy transistors. In addition to the protection feature, this type of circuit results in a quasi-constant power amplifier regardless of load (loud speaker) impedance.

The first part of this paper discusses circuits in common use, and some of the parameters defining them, in order to make a clearer comparison with the protected circuit discussed in part two.

The cold resistance of the bulb affects the stage current gain, in the worst case, i.e. 4 ohms, by only 5%. The thermal time constant of the barretter is in the neighborhood of 500 msec, causing practically no effect on program material. In the event of an output transistor failure, the barretter acts as a fast fuse, protecting the loud speaker load from damage. In normal use as an emitter resistor, however, the applied voltage would be less than one volt, assuring a life in excess of the sum of the lives of all other components in the equipment, thus assuring no degradation in reliability. (Authors)

REVIEW: This paper concerns design to prevent failure--always a worthwhile cause. The equations have not been checked but there appear to be several implicit assumptions: class A operation, average (not peak) power is calculated, and the frequency range is such that the thermal resistance can be used to calculate junction temperatures. The limitations caused by these assumptions have not been estimated. The principle adopted for the solution appears to be a good one and may have application elsewhere. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Computer reliability--what's that?

AUTHORS: G. C. Hendrie and R. W. Sonnenfeldt, The Foxboro Company, Natick, Massachusetts

SOURCE: ISA Journal, vol. 10, January, 1963, pp. 51-56

PURPOSE: To give a general discussion which provides exact (where possible) yet simple methods for determining a computer's worth and provides guidelines for judgment in other areas.

ABSTRACT: Computer uptime is not a good measure of reliability; mean time between failures (MTBF) is; and the longer it is, the better. Control computers should have an MTBF of 1000 hrs at least. MTBF is difficult to measure precisely and statistical statements are usually made about it. Further, actual times between failures will vary widely from the mean.

In general, a computer is more reliable if it has fewer parts (is less complicated) and runs at a lower temperature. A computer should be easily maintained by reasonably available service personnel. In evaluating this requirement (in the absence of specific, written, verifiable data) attention should be paid to the existence of adequate drawings and manuals at the computer site, the type of construction of the equipment (modular units that can be replaced and then repaired elsewhere are best), the availability of test points and indicators, the possibility of marginal tests, the ability to keep the ambient temperature well below the recommended limit, and the availability of maintenance and test programs. The effect of every failure in the computer on the process line should be investigated. A satisfactory response should be achieved for every one. The computer operation should be reasonably fool-proof; this is a more demanding and necessary precaution than many people realize. In the event of a computer failure the system should be easy to get back on the air, and the system should not be shut down unnecessarily. Do not be misled by inaccurate statements about computer reliability, however innocently they are made.

REVIEW: As a general article to introduce the layman to the subject, this is good and well written. Extreme care should be used in reading the section on MTBF. Not enough distinction is made between the true MTBF and estimates of the same. The estimation procedures are not accompanied by references where they can be checked. The proper estimation methods differ depending on (1) whether the test is stopped at a given time or after a given number of failures, (2) whether a decision is made only once, or several times--criteria for the one cannot be used for the other, and (3) the type of estimate that is desired. It is probably best to get information on this process of MTBF estimation from books or good consultants,

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since too many magazine articles give too much misinformation. (See, for example, Abstract and Review Serial Number 713.) A good reference on this subject is cited below [1]. The explanations concerning complexity and temperature are likewise true in a general way -- the reader applies them to exact situations at his own risk.

In a private communication the first author has stated that the mean-time-between-failure testing schedule given under the heading "Evaluating Manufacturer's MTBF Number on the Basis of Limited Testing" was derived from the test schedule given in "Reliability of Military Electronic Equipment," published by the AGREE Committee, June 1957, page 89. Figure 2 in the paper entitled "Curves of 90% Confidence for MTBF Values Based on Limited Testing" is a graphical plot of the formula developed by Epstein in "Truncated Life Tests in the Exponential Case," Annals of Mathematical Statistics, volume 25, pp. 555-564. The author has also indicated that there was no intention to provide the tools necessary for a customer to accurately evaluate the reliability of the machine on his own from the data included in the paper.

REFERENCE: [1] Reliability: Management, Methods, and Mathematics, David K. Lloyd and Myron Lipow, Prentice-Hall, Inc., 1962 ##

Serial Number 794
Codes 810;817;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aircraft safety and missile reliability

AUTHOR: Air Vice-Marshal H. B. Wrigley, C.B., C.B.E., R.A.F., Senior Technical Staff Officer, Headquarters, Fighter Command, Royal Air Force, Bentley Priory, Stanmore, Middlesex, England

SOURCE: Journal of the Royal Aeronautical Society, vol. 66, pp. 314-319, May, 1962 (4 Hamilton Place, London, England)

PURPOSE: To show the need for and problems involved in high reliability.

ABSTRACT: Reliability is important to the RAF because it enables the meeting of operational tasks at minimum cost. The reliability and maintainability needs of commercial operators are different from those of the services and the commands within the service have different needs. The responsibility for reliability begins with the specifications and covers the whole field of design, manufacture, servicing and use. Many specification/design factors must be considered and compromises made; delivery time, cost and performance are also important. To convert sound specifications into sound design and then to make the item well are not easy tasks. Not all the engineering information is available to the people who need it (if it is available at all). But even so, many design faults are in areas where the proper way has been known for years. Adequate quality control and testing of the designs are very important. To emphasize the economic need for reliability, the maintenance cost for a sample of electronic equipments, during their life, was about ten times the purchase cost. (Examples are given of the type of malfunctions, the areas where they occur and maintenance men who cause servicing faults.) Field reporting of failures is important, but difficult to have done well.

REVIEW: This is a good general paper on reliability. It contains nothing that is new to those who have been in the field, but is well written for its intended audience. It should be contrasted with a somewhat different point of view in the paper covered by Abstract and Review Serial Number 795. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of electrical systems

AUTHORS: (An extract from the paper "An Airline Operator's Examination of Reliability in Principle and Practice" by R. D. Jones, F. D. Hoyle and F. J. Sullings (British Overseas Airways Corporation) which was read at a Joint Conference on The Importance of Electricity in the Control of Aircraft.)

SOURCE: Shell Aviation News, no. 286, 1962, pp. 8-10 (Shell Centre, London, S.E.1, England)

PURPOSE: To examine reliability in principle and practice.

ABSTRACT: The Certifying Authority (Aircraft), the maintenance planner, and the airline engineer each have a different approach to reliability although they are not incompatible. Redundancy is of particular concern here. In some cases, exact replication is the optimum method. If the original system is large/expensive/complex, then sometimes a simple, not so "classy" alternate may be a better solution to the redundancy problem. In electrical generators, several identical units are often used, each of which can supply more than its minimum share of the load. Decisions in this regard in civil aircraft are not always made purely on a technical basis.

Two axioms for designers are: (1) avoid the use of moving parts and (2) assume that your equipment will be operating frequently at or above the maximum temperature used for type tests. The reliability of mechanisms with moving parts is usually, but not necessarily always, less than that of static ones. The effect of errors in the latter case is also easier to fix. The 55°C limit for certification is often exceeded and the designer will do well to aim toward the operating conditions rather than type tests when the former are more severe.

Preventive maintenance has been a major source of high reliability in aircraft. But now some electronic equipment seems to follow the statistics of random failures rather than wearout. In these cases little is to be gained by replacement before failure. Rules have been established for placing components in an "on condition" or giving them a definitive life. Special considerations apply to equipment using thermionic valves (tubes) and/or forced air cooling.

REVIEW: This summary of civil aircraft experience with electrical systems is good, especially since most papers deal with military problems. The contrast between this paper and that covered by Abstract and Review Serial Number 794 is interesting. In the discussion of maintenance, the question of failures caused by servicing is omitted, although in the paper covered by Serial Number 794 this failure cause is regarded as quite important and is considered good reason

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RELIABILITY ABSTRACTS
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to avoid preventive servicing where possible. The points made about designing for actual conditions are good, but could probably have been made even stronger. The question of eliminating moving parts is open to some debate, especially by relay makers. Only random failures following the Poisson distribution have a time independence. There are other random distributions in which service time is important.

In general, the points in this paper are well made. ##

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Serial Number 796
Codes 770;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability testing of semiconductors

AUTHOR: R. M. McRobb, Texas Instruments Ltd., Manton Lane, Bedford, England

SOURCE: British Communications & Electronics, vol. 9, pp. 842-846, November, 1962

PURPOSE: To describe various kinds of tests used to ensure reliability.

ABSTRACT: Most of the reliability and environmental tests performed these days are required by the specifications of the British or U.S. military authorities. The tests for both groups are similar and fall into three categories-- environmental, physical, and electrical. These tests include salt spray; moisture resistance; low air pressure electrical tests; shock, random drop, and bumping; centrifuge tests; lead fragility and solderability; leak testing; life tests. The life tests are by far the most expensive; automation helps to reduce their cost and improve their accuracy. Much of the cost of rectifier tests is in the wasted rectified power. The reliability requirements are becoming more severe as time goes on. One example is the preference for specifying a consumer's risk rather than a producer's risk.

REVIEW: This summary of British experience is interesting and worthwhile. It is in a rather general vein; few detailed figures are given. ##

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Serial Number 797
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relying on reliability

AUTHOR: (Editorial Matter)

SOURCE: British Communications & Electronics, vol. 9, p. 891, December, 1962

PURPOSE: To philosophize about the IEE (British) Conference on Electronic Equipment Reliability (London, England, October, 1962).

ABSTRACT: If one extrapolates the results of a reliability test very far, he may be misled. Defining reliability ideas is still a matter of opinion. The delegates solemnly debated the subject--to improve reliability, designers must make equipment more reliable--for three days. Some delegates felt that the outcome of the conference was negative, that too few positive suggestions were put forth. In the majority of cases the reason for a breakdown lies in a false prediction of expected operating conditions. Many of the papers gave an interesting insight into the experience of users of electronic equipment.

REVIEW: The editorial, if taken in a general and light hearted vein, is fun to read. However, if it is analyzed part by part, it is misleading.

When several tests have been run with consistent outcomes, something more than test results have been obtained. Our whole engineering practice is built on the fact that the future can be adequately predicted from the past in many fields. The problems are in how to do it wisely--bridges are built that are reliable.

People can and do make positive suggestions about improving reliability. An adequate design review is a good example.

All in all, as fun, the editorial is good; as a serious commentary, it is poor. See also Abstracts and Reviews Serial Numbers 798 and 799. ##

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Serial Number 798
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic equipment reliability (discussion at the second IEE Symposium)

AUTHOR: (Editorial Matter)

SOURCE: Wireless World, vol. 68, pp. 572-573, November, 1962

PURPOSE: To discuss the IEE (British) Conference on Electronic Equipment Reliability (London, England, October, 1962).

ABSTRACT: This is a general review of the conference plus brief commentaries on some of the papers. Complexity, proper mechanical design, redundancy, availability, 10 sec. vs 25 year life, repairability, and cost of unreliability are mentioned.

REVIEW: This is a straightforward accounting of the conference, although no details are given about the papers. This editorial can be contrasted with those covered by Abstracts and Reviews Serial Numbers 797 and 799. ##

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Serial Number 799
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Commentary

AUTHOR: (Editorial Matter)

SOURCE: Electronic Engineering, vol. 34, p. 797, December, 1962

PURPOSE: To comment on the IEE (British) Conference on Electronic Equipment Reliability (London, England, October, 1962).

ABSTRACT AND REVIEW: This is a brief and reasonable commentary on the types of papers and the problems which were discussed at the Conference. See also Abstracts and Reviews Serial Numbers 797 and 798. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The life expectancy of cold-cathode tubes

AUTHOR: M. E. Bond, Mullard Ltd.

SOURCE: Electronic Engineering, vol. 34, pp. 798-803, December, 1962

PURPOSE: To present life test data on some cold-cathode tubes and to show a pattern in them.

ABSTRACT: This work shows that cold-cathode stabilizers, reference tubes and trigger tubes can give very long lives. Life test results show that for periods from 100 hours (four days) up to 36,000 hours (c. four years) there is an inverse power relationship between the length of life obtained and the peak current passed. It seems highly probable, therefore, that as these results have been shown to be true for periods up to four years they will hold for times appreciably in excess of this. Thus it can be seen that if the working conditions are correctly chosen lives of tens of years can be confidently expected. (Author)

The test data are presented in some detail and the arguments for the hypothesis of an inverse power relationship between tube current and tube life are given. These tests are continuing and more results will be reported later.

REVIEW: This is a good presentation of data so far available on these tubes and should be very worthwhile to designers. So far, the quantities of tubes tested are small and most of the results apply either to an average or to 80% of the tubes. This still leaves many unanswered questions for critical applications. The author should be encouraged to continue this work. ##

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Serial Number 801 -1
Codes 822;824;840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weibull distribution in reliability analysis of certain electronic components

AUTHOR: James E. Bell, Reliability and Quality Control, U.S. Semcor, Solid State Division, Nuclear Corporation of America, Phoenix, Arizona

SOURCE: Semiconductor Products, vol. 6, March, 1963, pp. 33-36

PURPOSE: To present to the engineer a concise and practical description of the most widely employed methods in Weibull analysis.

ABSTRACT: The three-parameter Weibull distribution is shown. It involves a scale parameter, a location parameter, and a shape parameter. When the shape parameter (β) is one, the equation is that for a device having a constant (conditional) failure rate (represented by the exponential distribution). When $\beta < 1$, the device is said to have a decreasing failure rate; when $\beta > 1$, the device is said to have an increasing failure rate. The Weibull parameters can be estimated graphically except for the location parameter, for which an equation is given. With special coordinates, the cumulative Weibull distribution plots as a straight line. A "least squares" solution is also given for the scale and shape parameters. An example shows how the calculation is used. Seven general references are cited.

REVIEW: This is a "cook book" type of presentation and has the good and bad points of that method. There are no specific references on the theory in which an engineer can check any points in which he is interested. He must blindly follow the rules and hope that neither the author nor the printer made any errors.

Except for the location parameter, the treatment is fairly standard. There are some controversial points and/or misprints in the paper. Examples follow.

1. The location parameter, γ, is definitely not the time to first failure although it may be estimated by that statistic. It is rather the time at which the hazard function (conditional failure rate) ceases to be zero. (In most applications this parameter is estimated at zero.) The value given for estimating γ (equation (1) in the paper) may be satisfactory although the reason for it is not at all obvious.

2. Grouped data are used here, i.e., the time for specific failures is not recorded. The only data are the number of existing failures at predetermined time intervals. A formula is given for estimating the "exact" time of failure within any particular interval. It does not appear to be consistent with that given for γ, which is interpreted by the author to be the exact time of the first failure. It is also not stated whether or not the "exact" failure time estimate is referenced to the original time origin or to the time γ. From the way it is used, it should be the latter

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

except that this is never mentioned to the reader.

3. Two other problems arise with respect to the formula for "exact" failure time. First, it is possible to calculate the "exact" failure time of no failure during a period, and the author does it in the example. Second, the concept of exact failure time is a poor one since it is presumed that all failures are independent and that the probability of more than one failure at a given time is zero. Therefore one should either have an "effective" failure time for all the failures in one interval, or some way of estimating the effective time for each.

4. Equation (3) appears to be incomplete.

5. The "percent failure" assigned to the j th failure (and also to the previous ones happening in the same interval) is j/n where n is the total number of devices. There is more than one method for assigning this number; $(j - 1/2)/n$ is given in the literature and $j/(n + 1)$ is the "expected" value and thus has some special theoretical justification.

6. One can calculate a "least squares" line, but about all one can "eye-ball" graphically is some sort of best line.

7. K and k are used in the same equation for apparently the same thing (total number of time intervals).

8. The equations for obtaining the least squares estimates are incorrect in two ways. First, the equations are written incorrectly, as reference to the section on linear regression in any good elementary statistics textbook will show. Second the equations which the author intended to use are incorrect since the least squares analysis requires that the points be equally weighted and independent; in a cumulative distribution of this type the points cannot have these properties. A correct solution of the problem is, for example, the probit method when the distribution is Gaussian. This is a striking example of the hazard mentioned in the first paragraph of this review.

All in all, the engineer who wishes to use the Weibull distribution for reliability analysis would do well to get his introduction to it from a better source. It is also not universally agreed that the extra parameter (over the exponential distribution) really contributes anything valuable; in a large number of cases, the experimental methods and data deserve nothing more complicated than an exponential distribution, even though it may be a gross approximation.

Other papers on the Weibull distribution and its applications have been covered by Abstracts and Reviews Serial Numbers 320, 437, 499, 749, and 751. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluation and reliability

AUTHOR: S. W. Herwald, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania

SOURCE: Electrical Engineering, vol. 81, pp. 614-617, August, 1962 (presented at the AIEE Winter General Meeting, New York, New York, January 28-February 2, 1962)

PURPOSE: To show the importance of evaluation in achieving the greatest possible degree of reliability.

ABSTRACT: The increasing complexity of modern devices, together with the increasing proportion of vital components in each, creates a very difficult reliability problem. Keeping up to date on the conventional components can be a severe problem, not to mention evaluating the new ones. Reliability must be considered a necessary systems parameter. During the conceptual phase, the effect of other parameters on reliability must always be kept in mind. Cost, delivery time, and performance level are other competing factors and a severity increase in one may have a potent effect on the others. Large systems that are developed in parts can be especially difficult; other portions besides the one being worked on must be simulated--always a risky job. The final and true test of reliability is always that the entire system should work well in the field. Availability and maintainability are also important.

The reliability program must have management support; the proper climate must exist at every level--especially down to the worker who actually does the job. All are necessary, and any one can ruin the efforts of the rest.

REVIEW: This is a good general paper on reliability philosophy. It contains nothing that will be new to the experienced worker in the field, but serves as a good introductory paper. ##

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Serial Number 803
Codes 833;837;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Basic rules for designing reliability into semiconductor circuits

AUTHOR: K. L. Hall, Radiation Incorporated, Melbourne, Florida

SOURCE: Electronics, vol. 36, April 12, 1963, pp. 62-66

PURPOSE: To show how the quad system can be applied to digital semiconductor circuits.

ABSTRACT: Redundancy can be applied at the component or circuit level. At the component level, the quad concept is useful. The quad has two parallel branches with two components in series in each branch. If failure by shorting is more likely than failure by opening, the tie should not be placed across the middle; if shorting is less common, it should be included. It is necessary that under worst case conditions of one failure and maximum adverse drift of other parameters, the circuit still work. Circuits (no numerical values) for buffers, flip-flops, and a multivibrator are shown and discussed. Eight rules are given for general reliability improvement.

REVIEW: While quadding will improve the reliability of a particular circuit under particular conditions, it may cause other problems. The power gain is usually lower and the fan in/out will usually be appreciably reduced; thus more circuits may be required. One should be particularly careful that the final system reliability has been appropriately improved since the system will usually be bigger, heavier, have a larger power supply, dissipate more heat, etc.

The eight rules for better reliability are good, but derating (point 8) should always be checked with the manufacturer to be sure that it will actually improve the reliability; aluminum electrolytic capacitors and relays are two devices that may not follow the general rules.

This is a good article on the general philosophy of quad circuits--within the limitations described. Other articles on quadding have been covered by Abstracts and Reviews Serial Numbers 277, 396, 488, 560, and 780. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability maturity index (RMI)--an extension of PERT into reliability management

AUTHOR: D. G. Malcolm, President, Management Technology Incorporated

SOURCE: The Journal of Industrial Engineering, vol. 14, pp. 3-12, January-February, 1963

PURPOSE: To describe a method of reliability management which utilizes some of the features of PERT and which is compatible with it from a systems point of view.

ABSTRACT: A description is given of a PERT-oriented procedure for treating one aspect of the technical performance variable--the reliability plan. The background of the program and a description of Reliability Maturity Index (RMI) as an operating information system are included. The application of information sampling of management reports to reduce the volume of input information is described. The output reports and their uses are indicated and the use of RMI procedures in the area of integrated management systems and as a documentation control approach is discussed. (Author)

REVIEW: The PERT, PRISM, and RMI programs all have one basic purpose--the programming of information for managers. Reliability data as well as other information can be and is being charted, plotted and evaluated for management decision-making processes. The major benefit of RMI is that it provides a running measure of the compliance with planned reliability activities by collecting, analyzing, and displaying information on the progress of the reliability documentation program and the quality and significance of the documents produced.

This article is excellent in explaining the uses, the needs, and the benefits of RMI. It falls short, however, in pointing out how the technique helps in improving, controlling, or evaluating the reliability of the product. This may have been omitted purposely, since the article describes only the aspects of PRISM similar to PERT. It must be assumed that the listed 23 reliability events which are scheduled, plotted, costed and followed are performed correctly and affect the equipment in a positive manner. They are the start and completion of:

1. Design Specifications
2. Design Review Reports (Conceptional, Preliminary, Interim, Final)
3. Engineering Evaluation Test Report
4. Acceptance Test Specification
5. Acceptance Test Procedure
6. Quality Assurance Test Specification
7. Quality Assurance Test Procedure

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8. Quality Assurance Test Report
9. Reliability Assurance Test Specification
10. Reliability Assurance Test Procedure
11. Reliability Assurance Test Report
12. Flight Test Plan
13. Flight Test Report
14. Factory Test Plan
15. Factory Test Report
16. Parameter Document
17. Reliability Training Plan
18. Reliability Reporting Plan
19. Repair and Maintenance Manual
20. Logistic Requirements Report
21. Failure Reporting and Corrective Action Plan
22. Qualification Test Plan
23. Qualification Test Report
24. Production Test Plan

The records and paper work described in this article will cost a considerable amount of money, and a very careful study of potential costs should be made before committing an organization to the use of RMI (unless the records and paper work are required by the contract anyway). Management could use a graphical method of determining the critical operations in reliability functions. This requirement for a quick look by top management must be evaluated in terms of the possibility of making an incorrect decision if the RMI presentation is not available. The value of the decision process with RMI must be compared to the cost of keeping the charts, records, and reports. In large complex system operations where the amount of data is relatively large RMI is especially valuable. In small systems the data may be readily visible without the RMI technique.

In a private communication the author has made the following comments. "If a management is interested in positive assignment of responsibility for specific tasks and wishes to ensure that they have indeed been discharged, it must have a method of visually displaying the assignment and reviewing the performance. Otherwise, due to the large number of such assignments, responsibility can be avoided by the simple act of changing definitions by the responsible party. In this context, the cost of the information is incidental to the operations of management." ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Self-verification--needs and methods

AUTHORS: J. Cohen, H. J. Kishi, and M. P. Rosenthal, Radio Corporation of America, Surface Communications Laboratories, 76 Varick Street, New York 13, New York

SOURCE: Electronic Industries, vol. 22, February, 1963, pp. 92-96

PURPOSE: To point out how self verification can be applied, and to alert planners to its advantages in reducing "no-go's."

ABSTRACT AND REVIEW: Some of the essential concepts in this paper are difficult to interpret, perhaps due to the brevity of the paper. The audience to whom this periodical is normally circulated probably will not be able to understand the article without having other source material to draw on.

From the title, one would expect that the ideas do have merit, and this may well be so. ##

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851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving semiconductor reliability

AUTHOR: Hauw T. Go, Diode Division, Transitron Electronic Corporation, 168 Albion Street, Wakefield, Massachusetts

SOURCE: Electronic Industries, vol. 22, February, 1963, pp. 110-113

PURPOSE: To present a basic approach toward improved reliability in semiconductors.

ABSTRACT: A reliability program must have a well defined objective, the proper organizational implementation, and a control and monitoring system. The program must cover all phases of design, development, etc., through field evaluation. A lot control system must be used. The defects in each lot can be traced to faulty processing and these faults can then be cured.

A "burn-in" is a quick reliability test and can have beneficial effects on product quality under the proper conditions. Leakage current is a good indicator of product stability. A matrix test can be used to set up derating curves. High stress and step stress life tests are quick, but have some inherent disadvantages.

A description is given of the basic reliability feed-back loop, which covers the areas of process development, production specification, manufacturing, in process quality control, failure analysis, and reliability testing; the application of lot control to derive correlation between failure rate and escape of discrepant devices found at IPQC Station, based on the random balance principle; burn-in as a screening tool and its limitation; the use of leakage current as an indication of device stability; matrix testing for generating derating curves; and objective and limitation of accelerated testing.

REVIEW: This is a rather general paper and suffers somewhat from the effort to make it so. The use of specific examples rather than generalities would have made it more readable. (Exhibit II is missing.) The points made are good, but the paper cannot be recommended for the beginner because of the above effect. It almost falls in the class "if you can understand it, you know it already," perhaps because the paper has been heavily cut by the editors. In a private communication the author has indicated that the paper is actually intended as an introduction to an extensive description of accelerated testing, which is to be published this fall. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of remote control systems

AUTHOR: V. A. Lutskii (Kiev)

SOURCE: Automation and Remote Control (A translation of Avtomatika i Telemekhanika, a publication of the Academy of Sciences of the USSR), vol. 23, pp. 104-108, June, 1962 (Russian original dated January, 1962) (Instrument Society of America, 530 William Penn Place, Pittsburgh 19, Pennsylvania)

PURPOSE: To introduce a measure of reliability which allows partial performance.

ABSTRACT: If the failure probabilities, p_i, of the parts of a remote signaling system are independent, then the reliability, R, is the product of the $1 - p_i$. However, any part will not cause total failure, but only partial failure. Let η_i be the fraction of blocks which fail due to failure of the i th part. Define an $R(\eta)$ which is the product of $1 - p_i\eta_i$; $R(\eta) > R$. The systems can have a parallel frequency code, a series time code, or a parallel-series code. Define $L = (1-R)/[1-R(\eta)]$ as the vitality factor. If L is high, the system is better than if L is low. Assume that all the p_i are equal. Then the L can be evaluated for each coding system. Graphs of the results are shown.

REVIEW: This is a theoretical analysis of a special problem. The restrictions are rather clearly stated, except that it should be emphasized that it is assumed that a part failure cannot cause any other parts to fail. (Thus, for example, a short circuit which kills the power supply is not allowed for.) The case of equal p_i is rather restricted, but makes for easy calculation. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of reliability of systems with fault signalling

AUTHORS: V. A. Zhozhikashvili and A. L. Raikin (Moscow)

SOURCE: Automation and Remote Control (A translation of Avtomatika i Telemekhanika, a publication of the Academy of Sciences of the USSR), vol. 23, pp. 352-357, September, 1962 (Russian original dated March, 1962) (Instrument Society of America, 530 William Penn Place, Pittsburgh 19, Pennsylvania)

PURPOSE: To present a mathematical model for the analysis of the reliability of a system with automatic checking and signalling of faults.

ABSTRACT: One way of raising the reliability of a system is to introduce either fixed-in or independent devices enabling the checking of the performance of its components. In this paper indices of reliability of systems are given when the probability of the system being in use at any instant of time and the fact that the occurrence of some faults is signalled are taken into account. Various kinds of operational servicing of the system are examined. An example is given to illustrate the proposed procedure. (Author in part)

REVIEW: This is a mathematical paper which essentially extends the usual meaning of reliability of a continually operating system to obtain a reliability index for a system not continually in use and for which checking and signalling of faults takes place. The mathematics appears to be reasonably straightforward, and the assumptions are stated, although some of them are not very clearly worded. The idea of an index such as this has potential value in determining methods of increasing the reliability of a system or its operation policy, provided the underlying constraints and assumptions are satisfied. ##

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Serial Number 809
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The average loss criterion for estimating the reliability of control systems

AUTHOR: G. A. Shastova (Moscow)

SOURCE: Automation and Remote Control (A translation of Avtomatika i Telemekhanika, a publication of the Academy of Sciences of the USSR), vol. 23, pp. 704-712, December, 1962 (Russian original dated June, 1962) (Instrument Society of America, 530 William Penn Place, Pittsburgh 19, Pennsylvania)

PURPOSE: To derive a general expression for the average losses in cases of rare failures.

ABSTRACT: The usual criteria of reliability are not always adequate. A measure of the average loss is proposed here. Two types of systems are treated, viz. those in which partial failure stops the process (central significance) and those in which partial failure stops only part of the process. Several specific cases are considered and examples are worked out.

REVIEW: This is a theoretical paper and the subject seems adequately treated. The loss criterion may be useful in many cases. ##

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Serial Number 810
Code 090

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A list of papers devoted to reliability questions for the year 1961

AUTHOR: A. L. Raikin

SOURCE: Automation and Remote Control (A translation of Avtomatika i Telemekhanika, a publication of the Academy of Sciences of the USSR), vol. 23, pp. 1194-1199, March, 1963 (Russian original dated September, 1962) (Instrument Society of America, 530 William Penn Place, Pittsburgh 19, Pennsylvania)

PURPOSE: To list a bibliography on reliability.

ABSTRACT AND REVIEW: There are about 120 references of which approximately one third are in Russian. The remainder are largely in English, although there are a few in German and Japanese, and some which were translated to Russian from the English. The coverage of English language journals is far from complete, the principal ones included being IRE publications. It is interesting to note that the Russians seem to have an annual symposium on Reliability and Quality Control of Radioelectronic Apparatus; it began in about 1955. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of a system in which spare parts deteriorate in storage

AUTHOR: George H. Weiss (University of Maryland and National Bureau of Standards)

SOURCE: Journal of Research of the National Bureau of Standards--B. Mathematics and Mathematical Physics, vol. 66B, pp. 157-160, October-December, 1962

PURPOSE: To determine the failure statistics for a system consisting of a single part and n spares, in which it is assumed that failure occurs at different rates in use and in storage.

ABSTRACT: The problem considered is the calculation of the lifetime statistics of a component with n spares when it is assumed that redundant elements can fail in storage, and that elements which fail in service are instantaneously replaced. Similar models have been considered before in the literature [1, 2], in the determination of the optimal spare parts kit for a system of components in series, given a fixed amount of capital to provide the spare parts. If it is assumed that components do not deteriorate in storage, then the time to failure of the system as described is just the sum of the individual failure times. In the situation considered, the calculations are somewhat more complicated, and a solution is given only for the case in which the reliability functions for on-line failures and for in-storage failures are exponential. In other cases algorithms for the solution are prescribed. (Author in part)

REFERENCES: [1] F. Proschan, Optimal system supply, Naval Res. Logistics Quart., 7, 609 (1960).

[2] G. Black and F. Proschan, Spare parts at minimum cost, Proc. Fifth Natl. Symp. Reliability and Quality Control (1959).

REVIEW: This is a mathematical paper, involving mainly a Markov process, with state equations solved by the use of Laplace transforms. The work is presented clearly and the underlying assumptions, restrictions, and limitations are carefully stated. The two references which are cited serve to indicate the orientation of the work relative to other published material on the topic. ##

Serial Number 812
Codes 512;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A method for determining a confidence bound on unreliability when time-to-failure is normally distributed (U)

AUTHORS: Vanamamalai Seshadri and Patrick L. Odell, Applied Mechanics Department, U.S. Naval Nuclear Ordnance Evaluation Unit, Albuquerque, New Mexico

SOURCE: NAVORD Report 6623, 26 pp., U.S. Naval Nuclear Ordnance Evaluation Unit, Albuquerque, New Mexico, 31 August, 1959 (ASTIA Document No. 286302)

PURPOSE: To present a method for predicting an upper confidence bound on the unreliability of a component when the time-to-failure is normally distributed.

ABSTRACT: Methods to set up an upper, one-sided $100(1 - \alpha)$ percent confidence limit ($1 - \alpha$ is a preassigned confidence coefficient) on the unreliability of certain weapon components are developed. The time-to-failure is assumed to be distributed normally. The method is based upon life tests in which every member of a randomly selected sample is tested to failure in an environment which simulates the actual operational environment. (Authors)

REVIEW: This is a mathematical paper, and the material is clearly and concisely presented. Five relevant references are cited and a numerical example is given. Over one half of the over-all length of the paper is devoted to the tables necessary for the application of the method. These tables are modifications and extensions of tables originally presented in one of the references cited by the authors.

The applicability of this method in reliability analyses will be in situations in which the wear-out phase in the life of the component is being considered, since it is in this phase that the normal distribution is often appropriately assumed as the underlying distribution of time-to-failure. A corresponding method for situations in which the Pearson Type III or Weibull distribution is appropriate has been presented by the same authors in one of the references cited in this paper. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thermal environmental control techniques applied to electronic equipment

AUTHOR: Charles F. Sepsy, Mechanical Engineering Department, Ohio State University

SOURCE: The Journal of Environmental Sciences, vol. 6, April, 1963, pp. 15-19

PURPOSE: To discuss techniques of thermal environmental control for electronic equipment.

ABSTRACT: The rapid advance of technology and application in the electronic field has far outdistanced the improvement of equipment reliability for high performance aircraft and missiles. Efforts to increase reliability by miniaturization, plug-in subassemblies, isolation of sensitive components from environmental effects, improved mechanical design, and reduction of operating temperatures are discussed in this paper. Methods of effective heat removal are classified as direct and indirect systems and refer to the supply of the ultimate coolant to equipment items directly or to an intermediate heat exchange system. The improvement in component reliability by proper control of the thermal environment is illustrated by using redesigned airborne electronic equipment as models.

Examples of good cooling techniques are shown by the redesign of a forced-air cooled radar jamming set for indirect liquid cooling of all component parts, by the redesign of a search and fire control radar modulator utilizing a compact air-to-air heat exchanger, and by a forced-air crossflow cooling power supply unit. (Author)

REVIEW: This paper discusses an important problem in the design of modern electronic equipment. Eight pertinent references are cited, which, in addition to the present work, may be quite helpful to the designer concerned with problems related to adequate heat removal.

Other papers dealing with topics related to thermal environmental control have been covered by Abstracts and Reviews Serial Numbers 49, 75, 77, 78, 280, 304, 427, 489, 533, 534, 660, 701, and 779. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Titanium oxide and silicon oxide capacitors for microminiature functional circuits

AUTHORS: H. G. Rudenberg*, J. R. Johnson**, and L. C. White*** (*Arthur D. Little, Inc., Cambridge, Massachusetts, **Hewlett-Packard Company, Palo Alto, California, ***Transitron Electronic Corp., Wakefield, Massachusetts)

SOURCE: solid/state/design, vol. 3, August, 1962, pp. 27-34

This paper is essentially the same as the one covered by Abstract and Review Serial Number 729. ##

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Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Total reliability in research and development

AUTHOR: Richard M. Jacobs, Sylvania Electronic Systems, Division of Sylvania Electric Products Inc., Waltham, Massachusetts

SOURCE: Industrial Quality Control, vol. 19, March, 1963, pp. 17-21

PURPOSE: To show the responsibilities of the quality control and reliability functions during all phases of a research and development project.

ABSTRACT: Much has been said and written recently about Reliability and Total Quality Control, and in many instances animosities have built up regarding the responsibilities of these functions. These animosities have been eliminated in many cases by the setting up of integrated activities in departments called "Product Assurance." In these departments the two schools of thought together attempt to provide the customer with a high-quality, long-life product with a specified degree of assurance. This paper discusses the way in which the job is accomplished.

The tasks of Product Assurance are described under the following headings, which represent project phases: pre-bid, bid and proposal, contract negotiation, project planning, study, research and development, fabrication (prototype and deliverable units), test and evaluation, delivery and installation, and field or customer usage.

REVIEW: This paper accomplishes its purpose and accordingly will be useful to those concerned with the setting up and/or reorganizing of Product Assurance functions. To those with experience in the successful management of such a function, there is little if anything in the paper that will be new. ##

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Serial Number 816
Codes 512;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability demonstration

AUTHOR: Frank M. Gryna, Jr., Associate Professor of Industrial Engineering, Bradley University, Peoria, Illinois

SOURCE: Industrial Quality Control, vol. 19, April, 1963, pp. 19-25

This paper is identical to the one covered by Abstract and Review Serial Number 753. ##

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Serial Number 817
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability

AUTHOR: K. S. Packard, Airborne Instrument Laboratory, Division of Cutler-Hammer, Inc.

SOURCE: Industrial Quality Control, vol. 19, May, 1963, pp. 10-14

PURPOSE: To present a broad and heuristic discussion on the subject of reliability.

ABSTRACT: This paper contains discussions of the reasons for reliability problems, the approaches used to solve them, and the special language used to describe them. (This material originally appeared in the Proceedings of the IRE, vol. 47 in a series of four advertisements in April, May, June, and July, 1959.)

REVIEW: This paper accomplishes its purpose; it should provide interesting and potentially useful reading for newcomers to the field of reliability, and is suitable for use in elementary courses. However, to those with experience in the field there is little if anything in the paper that will be new. The author has expressed the hope that more engineers will become interested in using and understanding the techniques mentioned and will explore them further through reference to available literature. A paper of this type will assist in arousing interest, but for details on the technical aspects of the subject, the uninitiated are urged to consult appropriate technical references. It often happens that over-simplified discussions of technical subjects inadvertently convey misleading impressions. ##

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Serial Number 818 -1
Codes 800;810;853;
860

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effective reliability programs reduce costs and complaints

AUTHOR: Harmon S. Bayer, Bayer, Kobert and Associates, Inc., Management Consultants, 1154 Book Building, Detroit 26, Michigan

SOURCE: Industrial Quality Control, vol. 19, May, 1963, pp. 19-23

PURPOSE: To discuss ways to set up and operate an effective reliability program so as to reduce costs and complaints.

ABSTRACT: Most of the current reliability programs in industry have been set up as a result of reliability assurance requirements in government procurement contracts, particularly in the missile and space field. Specified assurance must be provided that equipment will function properly throughout the time of its intended use, since repair stations in outer space are not yet a reality. However, the need for reliability in manufactured products is not confined to the military and space fields. With increasing business competition, the lack of an assurance for a reasonable life of a product and a reasonable time between repairs will certainly be detrimental to any manufacturer.

The problem of setting up an effective reliability program for the non-military producer is discussed under the following headings:

Warranty costs as an indicator of reliability effectiveness,
Priorities for reliability improvement,
The "bathtub" curve and its relation to warranty costs,
"Debugging" or early failure,
The constant failure rate portion,
Organizing the reliability program,
Where is the reliability problem,
Definition of reliability,
Reliability programs for the design engineer,
Design review,
Contract vendor and consumer relationships,
Product development,
Reliability and manufacturing,
Relationship of reliability and quality control,
How the QC department supports a reliability effort,
Some inspection problems encountered with reliability, and
Quality control engineering and reliability.

It is concluded that reliability requires the organized approach and support of management, that it must be established in the design and adequately protected throughout the process of manufacture, handling and use. The ultimate result of high reliability is reduced warranty costs and increased customer satisfaction.

REVIEW: This is a fairly comprehensive discussion of the topic covered, and

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

should be quite helpful to those concerned with organizing a reliability program for a commercial product line. A paper which reviews briefly certain techniques which have potential applications in commercial reliability programs was covered by Abstract and Review Serial Number 382. The reader interested in this topic may find that both of these papers contribute useful background information. ##

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Serial Number 819
Codes 825;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design considerations for reliable electronic equipment

AUTHORS: W. J. West and H. S. Scheffler, Autonetics, A Division of North American Aviation, Inc., Downey, California

SOURCE: Autonetics Pub. No. 558-A-2, 38 pp., October, 1962 (NASA accession number N62-17586)

This paper was covered by Abstract and Review Serial Number 244. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A method for the statistical evaluation of small sub-system performance

AUTHORS: Fred R. Decker and Augustine J. Welling, Computer Reliability Section, Minneapolis-Honeywell Regulator Company, Electronic Data Processing Division, 151 Needham Street, Newton Highlands, Massachusetts

SOURCE: 18 pp., presented at the Fall Radio Meeting, Institute of Radio Engineers and Electronic Industries Association, Toronto, Canada, November 12, 1962

PURPOSE: To propose a method for the statistical evaluation of the performance of small sub-systems.

ABSTRACT: In general it is difficult to describe the output of a sub-system as a function of the components making up the sub-system. Conventional engineering techniques frequently lead to cumbersome mathematical expressions which in turn are generally based on a number of assumptions. It is possible, however, to analyze sub-system experimental data by extension of the technique of simple fitting of a least squares line. In turn this solution may be experimented with, varying the inputs, in order to gain some knowledge of the sub-system output including its most likely value and its probable range. Since computations are extensive a computer is required for analysis of the experimental data.

This paper proposes a method for the statistical evaluation of small sub-systems performance. The method requires that performance data from a small sub-system be analyzed using a multiple linear regression method; this has been programmed for a digital computer making use of a step-wise solution. The result along with predetermined component variation is then used in a computer-programmed Monte Carlo simulation to develop both the output distribution and descriptive statistics. Experimental results from a small, one core, impulse switched memory system are presented. Other applications include the analysis of high speed computer circuits; one application, integrated circuitry, offers great promise. (Authors)

REVIEW: The problem of describing the output of a system as a function of the performance of its components is very important in the field of reliability. The degree of difficulty which it presents depends, of course, on the nature and complexity of the system. This paper proposes an approach for use on small sub-systems. The authors have presented their material in a reasonable amount of detail and have cited references to relevant background information which readers may require. The experimental results which are cited have good illustrative value.

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RELIABILITY ABSTRACTS
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Presumably the authors were satisfied that, for the sub-system considered, the output variable Y (switching time) could be represented reasonably adequately by a linear function of write amplitude (X_1), write width (X_2), and read amplitude (X_3). The reader who may wish to apply these ideas to another system or sub-system should first consider the appropriateness of that model for the system he has in mind. This will in general require a careful engineering analysis of the system. It may also be worth emphasizing (as the authors have) that, since the regression coefficients used in the Monte Carlo simulation are estimates, the error term in the regression analysis has an important bearing on the precision of the final results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Computer components and the nuclear space radiation environment

AUTHOR: Leonard B. Gardner, Radiation Effects Group, Litton Systems, Inc. (current affiliation: Consulting Scientists, P. O. Box 103, Toluca Lake Station, North Hollywood, California)

SOURCE: Proceedings of the Institute of Environmental Sciences 1962 Annual Technical Meeting, Chicago, Illinois, April, 1962, pp. 33-46 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To relate observed damage sustained by computer components in reactor environments to that which would be observed in a space environment.

ABSTRACT: This paper furnishes a tool which can be used to extend the radiation damage to computer components resulting from neutrons, of either pulse or steady-state reactors, to the damage produced by the heavier charged particles existing in space. Such correlation techniques are necessary because of the great difficulty in comparing space radiation to reactor irradiation.

The space radiation environment and the mechanisms of radiation damage are summarized. Damage from this environment is considered as it appertains to materials and also as it affects the performance of computer systems in which the materials might be used. It is shown that the probability of damage is roughly proportional to the product of the energy spectrum of each type of particle making up the space radiation environment and the isotropic elastic scattering cross section (reaction probability) of the materials comprising the components. It is also shown that the secondary radiations, resulting from the interaction of the environment with the components or vehicle, are responsible along with low energy radiation for most of the observable damage.

Some of the data from recent operational tests of components in pulse and steady-state reactor environments (combination of gamma rays and neutrons), cobalt-60 gamma-ray environment, and cyclotron environment (20 Mev protons) are presented. Only the data appertaining to transistors are considered, inasmuch as transistors are the most susceptible of all electronic devices to any type of nuclear radiation.

The behavior of other types of components is summarized, based upon the concepts of transmutations and energy absorption. These results are compared and used to predict the components' performance in a space radiation environment. Performance degradation resulting from total radiation exposure and exposure rate is considered respecting the nuclear radiation in the Van Allen Belts (relatively constant

exposure) and in space during the occurrence of solar flares (varying intensity of exposure). Along with the proton flux, the relatively smaller fluxes of nucleons, gamma and soft X rays, and electrons are also considered, all of which are present either as primary radiation impinging on a space vehicle or as secondary radiation from the vehicle impinging on its payload. (Author in part)

REVIEW: This is a rather extensive summary of known information on the space radiation environment and its expected effects on electronic components. As such, it will be of interest and value to designers concerned with electronic systems for use in the space environment. Ten pertinent references are cited.

Other reviews of the space environment and its effects on materials are found in the reports covered by Abstracts and Reviews Serial Numbers 525 and 630. Less extensive treatments of the topic have been covered by Abstracts and Reviews Serial Numbers 145, 181, 242, 255, 361, 384, 413, 429, 514, 515, 531, 644, 693, 747, and 764. The papers covered by Abstracts and Reviews Serial Numbers 548 through 556, 588, 622, 636, 653, 702, and 703 have been concerned mainly with radiation effects. ##

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Serial Number 822
Codes 815 ;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Accelerated life testing of electronic parts

AUTHOR: Jack E. Aalseth, United Testing Laboratories

SOURCE: Proceedings of the Institute of Environmental Sciences 1962 Annual Technical Meeting, Chicago, Illinois, April, 1962, pp. 89-95 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To discuss the need for valid life acceleration factors for the demonstration of the reliability of electronic parts.

ABSTRACT: The demonstration of part reliability is established as a requirement in most procurement contracts for military equipment. The Darnell Report published in June 1960 established the basis for specifying part reliability requirements and a means of demonstration through sequential test plans. The report alluded to the need for life acceleration factors in the example specification. In general, accelerated life test techniques to enable demonstration within reasonable constraints on cost and time do not exist today.

The dependence of system reliability on part reliability is discussed and illustrated. The problems of specification and control of part failure rates are indicated. The classical approach to accelerated life testing and its limitations are described. The selection of accelerated life test variables is discussed. The following are indicated as some of the factors which must be considered in the study and development of accelerated life tests: materials and processes, manufacturing and production testing, environmental test methods, definition of failure and operating region, and engineering statistics.

REVIEW: This is a brief and rather general discussion centering around the theme that valid means must be found to correlate the results of accelerated life tests with those which may be expected under normal operation in real time. This is the key problem in any situation in which accelerated life testing is applied, and the solution in a particular case will depend heavily on the specifics of that case. The principles discussed in this paper should be helpful in a general way to those concerned with this problem. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Pulsed-radiation effect on some electronic components

AUTHOR: D. C. Jones, Battelle Memorial Institute

SOURCE: Proceedings of the Institute of Environmental Sciences 1962 Annual Technical Meeting, Chicago, Illinois, April, 1962, pp. 153-159 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To familiarize engineers with the pulsed-radiation environment, the effects observed in selected electronic components when exposed to a pulse of radiation, and the experimental procedures used in determining the effects of pulsed radiation on electronic components.

ABSTRACT: This paper is concerned with the measurement and effects of radiation on electronic components in a pulsed-radiation environment. That environment is described briefly, and the nuclear characteristics of several pulse reactors are indicated. The experimental procedures and the problems encountered in conducting a radiation-effects experiment are considered. The effects of pulsed radiation on resistors, capacitors, electron tubes, light-sensitive tubes, and gas tubes are discussed. It is concluded that with increased knowledge of the pulsed-radiation environment the manufacturer and the design engineer will be able to more consistently produce components and incorporate them into a design that will tolerate the radiation effects. Presently it is difficult to design a system that will withstand a high-intensity radiation pulse. With future research and effort on the part of the design engineer to understand the effects of pulsed radiation, this problem should be surmounted. (Author in part)

REVIEW: The information presented in this paper should be useful to the design engineer concerned with equipment to be used in a pulsed-radiation environment. Twelve references to additional information are cited.

Another paper concerned with the effects of pulsed radiation on electronic components was covered by Abstract and Review Serial Number 108. A listing of Abstracts and Reviews covering other papers on the effects of radiation and other environments is found in Review Serial Number 821. ##

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Serial Number 824
Codes 300;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quality assurance (reliability) in environmental testing

AUTHOR: Ellsworth F. Seaman, Bureau of Ships, Department of the Navy, Washington 25, D. C. (Current address: Ellsworth F. Seaman, Engineering and Management Consultant, 3113 Westover Drive, S.E., Washington 20, D. C.)

SOURCE: Proceedings of the Institute of Environmental Sciences 1962 Annual Technical Meeting, Chicago, Illinois, April, 1962, pp. 285-287 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To discuss the planning, management, and technical operation of an effective environmental testing program.

ABSTRACT: The purpose of environmental testing is to assure both the initial quality and the long-range reliability of the product. The accomplishment of this purpose depends on the technical validity of the test data and their usage in an over-all coordinated engineering and management program. Each phase must be meticulously examined in order to establish the confidence level that may be attributed to the work. Three main categories which may be specified for the analysis are: (1) the external direction of the laboratory, (2) the work conducted within the laboratory, and (3) the use that is made of the laboratory results. In each category the methods, procedures, decisions, and other actions must be adequate for design guidance and operational reliability.

The principal considerations and points of potential breakdown in each of the above categories are discussed. Specific reference is made to measurement accuracy, calibration, controlled laboratory atmospheres, test method interpretation, test equipment suitability, cleanliness in the laboratory, competence of laboratory personnel, and reproducibility of test results.

REVIEW: This is a brief but worthwhile discussion of a number of points which can have a considerable effect on the reliability of equipment subjected to environmental testing. It will be of most interest to those concerned with the management of an effective laboratory testing program. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Behavior of electronic materials and components under space radiation environment

AUTHORS: W. E. Price and J. C. Lee, Lockheed Missiles and Space Company, Palo Alto, California

SOURCE: Proceedings of the Institute of Environmental Sciences 1962 Annual Technical Meeting, Chicago, Illinois, April, 1962, pp. 379-384 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To describe the radiation sources that space vehicles will encounter, and to discuss the results of some experiments aimed at predicting the behavior of electronic components in a space radiation environment.

ABSTRACT: Designers of electronic equipment for space vehicles must have knowledge of how electronic components will behave in a space radiation environment, defined as consisting of high energy particles and penetrating electromagnetic radiation. This involves first a fairly complete knowledge of the radiation sources in space, both artificial and natural, and of the mechanisms of interaction of radiation with matter. Secondly, it involves a knowledge of the general effects of radiation on material types, and thirdly a knowledge of the materials used in making electronic components. To attack the problem adequately, a team of experts is required, specializing in space radiation sources; radiation effects on materials, components, and systems; and vehicle equipment design. Lockheed Research Laboratories, as well as many others, have been working on these problems for some time. This paper describes space radiation sources and discusses some of the experiments which have been carried out.

The principal conclusions drawn are the following. The largest yearly dose expected is the surface dose from auroral electrons and is 5×10^6 r/year. Radiation data exists on most material types and much of it is directly applicable for choosing space vehicle materials and components. The major area where data is lacking is in natural space radiation effects on materials and components. Specifically, proton and electron irradiations on many of the commonly used semiconductor materials and devices need to be carried out. Other sensitive materials such as optical materials must eventually be investigated with protons and electrons. Until this is done, reliance must be placed on calculations and the data which have been determined with other nuclear radiations. The study of simultaneous environments is an area which is still virtually untouched. (Authors in part)

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REVIEW: This is essentially a relatively brief discussion based on the authors' studies of radiation effects on materials and related research (no references are cited). As such, it constitutes an addition to the knowledge in this field which should be useful tø the designers of electronic equipment for use in spacecraft. The reader interested in this topic may wish to see also the listing of Abstracts and Reviews covering other relevant papers which is given in Review Serial Number 821. The study of the effects of simultaneous environments is an important area in which there is a need for research. ##

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Serial Number 826
Codes 715;770;782;
833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Pulsed nuclear radiation effects on electronic components and materials

AUTHORS: W. Schlosser, C. P. Lascaro, and J. Key, U.S. Army Electronics Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Electro-Technology, vol. 71, May, 1963, pp. 106-112

PURPOSE: To summarize and interpret the results of pulsed-radiation effects on coaxial cables, resistors, and inductors.

ABSTRACT: There are pronounced effects in cables as a result of exposure to pulses of nuclear radiation. These effects can be responsible for an appreciable portion of the changes observed when cables are used in measuring other electronic parts. Solid dielectric cables are less affected by such pulses than the composite, air-plus-dielectric types, and the cable effect can be reduced by keeping to a minimum the cable length exposed with the part.

The mechanisms by which the cable effects occur in this environment are not clear, but the factors that govern the cable behavior have recently been the subject of intensive studies. Unless the cable behavior characteristics are specifically known and can be predicted, an attempt to subtract or compensate for the cable contribution in electronic part measurement would be unreliable and misleading. (Authors)

The effects on 100- and 500-ohm resistors were negligible; those on the one- and 10-kilohm resistors were erratic and presumably due to random combinations of cable and resistor effects; the results on the 100-kilohm resistors were completely disturbed by cable effects. All resistors were carbon film, except some of the 100-ohm which were wirewound. There were no apparent effects on the ferrite cores; again cable effects confused the results somewhat.

The circuits and experimental set-up are described at length.

REVIEW: This is a good and well presented summary of the experimental work and results. As such, it should be of interest to designers, even though more work needs to be done.

Other papers on the topic of pulsed-radiation effects have been covered by Abstracts and Reviews Serial Numbers 108 and 823. A listing of Abstracts and Reviews covering other papers on the effects of radiation and other environments is found in Review Serial Number 821. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability program planning approaches

AUTHOR: E. A. Reeve, International Business Machines Corporation, Space Guidance Center, Owego, New York

SOURCE: IBM Technical Report No. 62-825-479, 33 pp., International Business Machines Corporation, Space Guidance Center, Owego, New York, October, 1962 (presented at the Fall Radio Meeting, Institute of Radio Engineers and Electronic Industries Association, Toronto, Canada, November, 1962)

PURPOSE: To show the key steps in a reliability program and how the approach and program activities must be tailored to meet the needs of the specific system.

ABSTRACT: The approach to achieving reliability should not be the same for every system, but should be designed to meet the particular needs of the specific system. This paper develops a conceptual approach to reliability program planning, based upon the types of failures that occur in usage of electronic equipment. The anticipated difficulty of achieving the required reliability is used as a guide in planning the program. Design, procurement, manufacturing and evaluation activities are all considered in the total reliability program plan. This paper uses three reliability programs--for a bombing navigation missile guidance system, a missile guidance computer, and spaceborne primary processor and data storage--as illustrative examples of the different approaches resulting from different performance and operational requirements. The results of the programs, to date, are compared to what was anticipated when the programs were planned. The over-all considerations and examples expressed here have application for non-military as well as military programs. (Author)

REVIEW: This is a well written description of segments of a typical Total Reliability/Quality Control program. Although the author has indicated that both commercial and military applications of the elements of the program are discussed, there is only a small amount of material on the commercial aspects. The section on Failure Causes has been well prepared and is very worthwhile. The section on Living with Failures contains a good general discussion of redundancy, its advantages and disadvantages, supported with examples and illustrations.

In the formula for R in the quad redundancy part of Figure 2 on page 17 there appears to be a misprint: the sign preceding (1-q) in front of the braces should be minus instead of plus. It might be noted in passing that the quad is sometimes used with a shorting bar across the center, in which case the formula for R will, of course, be different. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: Let's look at the mission profile

AUTHOR: Lucille R. Diamond, Sylvania Electronic Systems, Buffalo, New York

SOURCE: Electronic Design, vol. 11, April 26, 1963, pp. 50-54

The material in this article is very similar to that in the paper covered by Abstract and Review Serial Number 705. ##

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Serial Number 829
Codes 712;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to predict gear life

AUTHOR: E. J. Wellauer, The Falk Corporation, Milwaukee, Wisconsin

SOURCE: The Iron Age, vol. 191, May 9, 1963, pp. 139-141 (also Reprint No. 392)

PURPOSE: To show how gear life is predicted statistically.

ABSTRACT: Both pitting and tooth failures in gears are due to fatigue and fatigue curves can be used to show the life vs load characteristics. The fatigue curves have an endurance limit; below this load, the fatigue failures do not occur regardless of time. Scatter of data points is an important trait of fatigue. If load is plotted in terms of allowable/actual load, it is more convenient. A cumulative distribution is shown of failures as a function of load; it shows that at rated load there are 2% failures. Gear life estimates should be made by persons skilled in the art.

REVIEW: As a general introduction to the subject, this is a good article. Care should be used in applying any of the statistical concepts since they are incomplete--probably due to lack of space. First, the endurance limit is an ambiguous term, but traditionally has meant the median limit (i.e., half will fail and half will not); it should be qualified with a probability statement. In this paper the limit is apparently for 98% probability of survival. Not all materials have a non-zero endurance limit and in some cases this may cause difficulty. The cumulative failure graph shows random behavior regardless of the curvature of the line. On this particular scale, a straight line would appear to be a normal (Gaussian) distribution. A lognormal distribution is not uncommon in such situations.

It should be emphasized that except for the use of scaling factors on similar designs it is likely that a set of curves must be developed for each new gear set. Also the curves apply to constant loading, a circumstance which is often not found in practice. ##

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Serial Number 830
Code 812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The teaching of reliability

AUTHOR: R. C. Winton, Mullard, Ltd.

SOURCE: Radio & Electronic Components, vol. 4, pp. 290-291, April, 1963

PURPOSE: To describe the basic needs a reliability course must satisfy.

ABSTRACT: There are few, if any, courses that teach the fundamentals of reliability. These basic concepts are (1) definitions of terms, and how reliability is measured; (2) sources of reliability information and how to interpret the data; and (3) means of reliability improvement including circuit design and mechanical reliability. The important thing is to instill proper habits of thought. The showing of examples is very helpful. The student should be shown that reliability is an art, not a science.

These courses should be taught in college at the graduate and higher technician level. Short courses for existing engineers would be helpful. The future of the electronics industry depends on engineers becoming "reliability oriented."

REVIEW: Presumably this is a discussion of British rather than United States problems, although the situations may not be too dissimilar. Engineers have traditionally been concerned with the life of equipment and the present problem is more one of having to emphasize the importance of life as a design parameter than to introduce the subject from scratch. The statistical methods themselves may be overemphasized in some cases, but it is virtually impossible to stress enough the extreme variability of the lives of parts and of systems. ##

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Serial Number 831
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determining maximum reliable load lines for power transistors

AUTHOR: Ralph Greenburg, Semiconductor Products Division, Motorola, Inc., Phoenix, Arizona

SOURCE: Electronic Products Magazine, vol. 5, May, 1963, pp. 46-49

PURPOSE: To show how to get the maximum performance inherent in a power transistor and still maintain reliability.

ABSTRACT: Second breakdown in power transistors occurs as follows: for a given I_B, as collector voltage is increased slowly, the collector current increases slowly up to a point where an avalanche condition sets in. If the current is not limited, the transistor will fail. The breakdown point is determined by the bias condition. The circuits and tests for determining the locus of second breakdown for each transistor type are described. For very short pulses, this locus is extended somewhat. These criteria for operation were tested successfully in several common circuits.

REVIEW: This article will be of interest to designers who work with power transistors. Second breakdown is a design limitation and should be included on all transistor rating sheets where it is applicable. Designers should insist on this rating if it is not initially furnished.

Figure 1 is not too clear and the circuit diagram in Figure 3 has at least one error. The use of only ten or so failures in some cases might be considered insufficient to establish an adequate safety margin. Otherwise the article seems to be very informative and well written. ##

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Serial Number 832
Codes 712;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Selective preloading for fasteners

AUTHOR: W. T. Appleberry, Design Engineer, Douglas Aircraft Company, Santa Monica, California

SOURCE: Design News, vol. 18, May 15, 1963, pp. 14-21

PURPOSE: To discuss the effect of preloading on the fatigue life of fasteners and to show that a reduction in preload can actually increase the fatigue resistance of fasteners for certain types of joints (thin or slender).

ABSTRACT: The effect of preload on fastener fatigue life is discussed. It is shown that:

1. The preload should not be based on fastener strength alone, but rather on the relative elasticity of the tension and compression members of the joint.

2. Theoretically (within the stated assumptions), the preload should be such that under maximum service load, the compression load in the joints just reaches zero and tension in the fastener just reaches the yield point.

3.(a) Where the spring rate of the compression members is constant (approximately the case for a thin or slender joint) reduction of the preload extends the fatigue life of the fastener.

(b) Where the compression member is a thick flat plate fatigue life increases with increasing preload because the thick flat plate has a non-linear elastic response.

4. Where preloaded structures are involved, under certain conditions, some existing methods of determining the safety factor permit the yield point of the material to be exceeded upon application of the service load. An improved method of determining factors of safety, consistent with the principles stated above, is presented.

REVIEW: The author does a good job of presenting the effect of preload on fastener fatigue life. He points out several questionable assumptions made in present preload design techniques and proposes some improved techniques.

The author should have noted that his theoretical equations for bolt, joint and critical service load contain the assumption that the effective strain length of the fastener is equal to the grip length for the joint. This assumption enters the equations through the definition of the elasticity factors for the fastener and joint, K_1 and K_2. It should be noted also that the statement in parentheses "(K_3 greater than 1)" in paragraph 4, page 19, should read "(K_3 less than 1)." ##

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Serial Number 833
Codes 413;802

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Naval Weapons Data: Reliability Engineering, Reliability Testing

AUTHOR: --

SOURCE: WD-25477, Volume 5, 15 December, 1962, 40 pp., Code Ident 1001, Bureau of Naval Weapons, Department of the Navy, Washington 25, D. C., U. S. Government Printing Office, 1963

PURPOSE: To supplement the instruction in Film MN8770e, which introduces some of the fundamentals of the design of reliability tests.

ABSTRACT: The fifth in a series of films on reliability introduces some of the fundamentals of the design of reliability tests. The topics considered include the choice of test objectives, and the practical limitations of cost, time, and sample size in designing tests. Statistical concepts associated with estimation problems and for tests of hypotheses are discussed. The use of sequential test techniques is demonstrated for cases where sample sizes for reliability testing are limited.

The reliability tests considered in the brochure are primarily tests of reliability hypotheses. The basic steps in test design including (1) problem definition, (2) determination of objectives, (3) establishment of requirements, and (4) test planning based on statistical methods are demonstrated using a relatively simple reliability test design based on the binomial distribution. An example of a controlled test is described. The most extensive discussion is devoted to sequential testing, centering about an example involving demonstration of the reliability of a Fire Control Radar equipment.

REVIEW: The material in this brochure is clearly presented, and should be helpful to those who do not have a previous background in statistics. However, those who do have such a background, even at a rather elementary level, will find here little, if anything, that is new to them. Previous brochures in this series were covered by Abstracts and Reviews Serial Numbers 284, 285, and 479. ##

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Serial Number 834
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the operational reliability of telemechanics devices

AUTHOR: N. S. Shabalin

SOURCE: Elektrichestvo, Issue Nr. 6, 1960, pp. 91-93 (ASTIA Document No. 266757)

PURPOSE: To present a general, qualitative discussion on the problem of estimating and improving the reliability of telemechanics devices.

ABSTRACT: The author gives his views on the nature of the telemechanics devices reliability problem and lists factors that influence this reliability. A portion of the discussion is devoted to the possibility of using new and improved components in the construction of telemechanics devices to improve their reliability.

REVIEW: This is a very basic and very qualitative discussion. Perhaps it would be useful as introductory material. (The translation is "unedited rough draft" and reads accordingly. It is not obvious whether "telemechanics" means "telemetering" or "electro-mechanical" or something else.) ##

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Serial Number 835
Codes 824;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Calculating the dependability of complex automatic systems

AUTHOR: A. M. Polovko

SOURCE: Izvestiya An SSSR, Otn, Energetika i Avtomatika, Issue Nr. 5, 1960, pp. 174-178 (ASTIA Document No. 267736)

PURPOSE: To give a method of estimating the reliability of complex automatic systems.

ABSTRACT: This paper develops a method of estimating the reliability of complex automatic systems by assuming certain characteristics of the failure of individual elements and then using standard mathematical methods combined with statistical estimates of the reliability of a number of common circuit elements to provide an overall reliability estimate. The assumed characteristics are: failures are "Poisson" occurrences, elements are (logically) in series, and the hazard functions of the elements of the system have the same dependence on operating conditions. Some discussion is given to the problem of the non-simultaneity of the operation of different parts of a complex automatic system.

REVIEW: This is a very straightforward treatment of system reliability. The assumption of a constant hazard function limits the usefulness of the discussion. (The translation is "unedited rough draft" and reads accordingly.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Investigation of the life of capacitors

AUTHOR: W. Ackerman

SOURCE: N. T. Z., 13 (11), 513-518, Nov., 1960, Germany (ASTIA Document No. 268535)

PURPOSE: To present and discuss the results of statistical studies on the life of capacitors.

ABSTRACT: The determination of the life or mean time-to-failure of paper, metallized paper, and tantalum capacitors is approached by first carefully defining what constitutes failure in each type of capacitor. In the case of paper capacitors, failure is defined as the failure of the dielectric. Using the results of breakdown tests on a control group of capacitors, data obtained from the experimental group are found to be amenable to an analytic description, wherein the mean time to failure is a function of the ratio of the working voltage to the mean breakdown voltage of the control group and the operating temperature.

In the case of metallized paper and tantalum capacitors, failure is defined as "tolerance failure", i.e. the value of capacitance decreases until it moves outside a specified tolerance around the nominal value of the capacitor. No analytical relationships are determined for these two cases but a wealth of graphical data is obtained that shows some very interesting characteristics. All plots of tolerance failure as a function of time (with temperature and working voltage fixed) show a "saturation" effect in that the curve falls off rapidly at first and then reaches a nearly constant level.

In the case of tantalum capacitors, further analysis is also performed using the leakage current as the criterion of failure. It is assumed that a value of leakage current twice the value of manufacturer's specifications produces failure. The same saturation effect as before is observed using this criterion.

REVIEW: This paper deserves careful study by reliability engineers. Although the discussion is not analytically conclusive, the experimental results derived could be a significant aid in estimating the reliability of systems containing a sizeable number of capacitors.

The major weakness of the paper is that the author provides no information as to the standard deviation of the discussed values about their statistical average. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Novel design technique for transistor digital circuits

AUTHOR: R. W. Hockenberger, Avco Corporation, Electronics and Ordnance Division, Cincinnati, Ohio

SOURCE: Electronics, vol. 35, August 24, 1962, pp. 42-46

PURPOSE: To present a new design technique for transistor digital circuits.

ABSTRACT: This paper presents a technique that permits the designer to derive equations for the cutoff and saturation conditions of a transistor logic circuit. These equations provide circuit values for worst-case variations of parameters and optimization of the design is achieved by plotting the equations and displaying the permissible values of circuit parameters. Used in conjunction with the permissible fractional tolerances of the circuit parameters, these equations also provide limiting inequalities for the values of the parameters.

REVIEW: The author's exposition of his design technique is correct and concise. A further sophistication of the method could be achieved by applying statistical methods to evaluate the effects of aging on the Beta of the transistors and to determine the relative criticality of the parameter variations with respect to the specifications imposed on circuit performance.

In the concluding section of the paper (subtitled "Design Example") a tolerance for the "or gate" resistor of ± 10% is used rather than the ± 5% shown in Figure 5(A). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How important are resistor tolerances?

AUTHOR: J. G. Curtis, Senior Applications Engineer, Corning Electronic Components, Corning Glass Works, Bradford, Pennsylvania

SOURCE: Electronic Design, vol. 11, March 29, 1963, pp. 44-49

PURPOSE: To demonstrate the desirability of using low tolerance resistors and voltages in transistor logic circuit design.

ABSTRACT: Circuit designers should be aware of the compromises they make by using loose-tolerance components and voltages. Unintentionally, they may be trading simplicity, reliability, size, heat dissipation, and possibly greater over-all economy for the initial economy of loose tolerances. This paper demonstrates this point by a worst case analysis of a transistor-resistor logic system. The results show a significant gain in simplicity and a large reduction in heat dissipation. (Author in part)

REVIEW: This paper is an excellent demonstration of the advantages of using low tolerance resistors and voltages in logic circuit design. The continuity of the paper would be better if more of the necessary algebraic manipulations were developed, but this is not essential as they are very straightforward albeit somewhat involved. A limitation on the paper is the author's failure to consider statistically the time degradation of the system parameters.

In a private communication the author has indicated that the "design tolerance" figures are those expected in worst case at equipment "end of life", and therefore the system can be expected to perform within specifications statistically until this "end of life" point.

The author has available a brochure, from which the material in the article was taken, which gives a more complete story on the topic. ##

Serial Number 839
Codes 770;824;831;
853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Review of a reliability demonstration program for a large solid propellant rocket motor

AUTHORS: D. K. Lloyd and M. Lipow, Mechanics Division Reliability Staff, Space Technology Laboratories, Inc., Redondo Beach, California

SOURCE: Proceedings of the Case Study Conference on Reliability, Maintainability, Human Factors--Prediction and Demonstration Techniques, sponsored by Professional Technical Group on Reliability, Boston Section, Institute of Electrical and Electronics Engineers, Framingham, Massachusetts, April 25, 1963, pp. 3-22

PURPOSE: To discuss the variations which affect a reliability demonstration program when the effort is still in the development phase and available data are limited.

ABSTRACT: A reliability evaluation and demonstration program for solid rocket motors which was first presented in 1959 at the Ballistic Missile Space Technology Symposium sponsored by AFBMD/STL is reviewed. This program has now been in use for the last three years. First a recapitulation of the original paper is given. It is shown that reliability estimates can be obtained even though the configuration of the motor is undergoing change and the objectives of test firings vary. Each motor is apportioned into Principal Subsystems which are screened for their degree of representation of the operational configuration. The intention of each test firing is determined and each Principal Subsystem is declared to be applicable or inapplicable prior to the test. The behavior of the Principal Subsystem when tested within the motor environment is then classified according to pre-specified ground rules as a success, failure, or exclusion. These results are then statistically combined to give an estimate of motor reliability. The major consideration was that because of economic reasons there would be no rocket motor test firings specifically and solely for the purpose of reliability evaluation. All the reliability estimates would have to be derived from development test results as the program progressed and both the intent of the tests as well as the configurations of the motors varied. In review, a discussion is given of the modifications which have evolved during the period of the program's application. Finally, the important aspects and experiences of such programs are discussed. (Authors)

REVIEW: This paper should be very worthwhile reading for project reliability engineers. It will serve as a guide in the implementation and logical justification of the methods of analysis suggested by the authors. It would have been interesting for the authors to have presented a reliability growth curve showing the progress made in the three-year program, but regrettably such data are classified. An earlier paper on this topic was covered by Abstract and Review Serial Number 526. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Human factors in reliability-maintainability trade-offs

AUTHOR: M. A. Tolcott, Director, Human Factors Engineering Division, Dunlap and Associates, Inc., Stamford, Connecticut

SOURCE: Proceedings of the Case Study Conference on Reliability, Maintainability, Human Factors--Prediction and Demonstration Techniques, sponsored by Professional Technical Group on Reliability, Boston Section, Institute of Electrical and Electronics Engineers, Framingham, Massachusetts, April 25, 1963, pp. 23-38

PURPOSE: To identify the types of human factors which affect equipment maintainability, to describe recent research results which begin to permit quantification of these factors, and to show how they can and should be considered in reliability-maintainability trade-off studies.

ABSTRACT: The fundamental techniques employed in conducting intelligent trade-offs can be characterized as operations research. They are based on the development of mathematical system descriptions, or models, which permit one to determine the effects of several variables upon important system parameters. (Author)

A set of definitions and symbols is proposed for use in equating maintenance/human factors elements. Some of these are: failure detection time, verification time, localization time, correction time, and check-out time. A discussion of these times and their quantification by results of studies and experiments is presented. A set of graphs relating the time for these tasks to the probability of performing them is given. Trade-off equations and a numerical example involving relative costs for varying situations are also presented.

REVIEW: This is a well written and concise fundamental work which should be worthwhile reading for reliability managers and engineers. Other studies on human factors as they affect reliability and maintainability should be examined by the reader who wishes to get a picture of the total scope of the accomplishments in this field. Some of these are covered by Abstracts and Reviews Serial Numbers 188, 196, 240, 248, 267, 480, 502, 565, 567, 712, 841, 842, and 843. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Apparatus and procedures for human factors research

AUTHOR: R. B. Sleight, Applied Psychology Corporation, 4113 Lee Highway, Arlington 7, Virginia

SOURCE: Proceedings of the Case Study Conference on Reliability, Maintainability, Human Factors--Prediction and Demonstration Techniques, sponsored by Professional Technical Group on Reliability, Boston Section, Institute of Electrical and Electronics Engineers, Framingham, Massachusetts, April 25, 1963, pp. 39-55

PURPOSE: To describe the apparatus and procedures used in a program to study the ability of the human to operate an airplane so as to reduce the likelihood of mid-air collisions.

ABSTRACT: A broad program of human factors research to determine aids to pilot vision that offers promise of reducing aircraft collisions has been carried out under Federal sponsorship. Some principles of research, and apparatus and procedures which have been developed in this program may have general utility and are described. Among headings under which these developments are presented are: state-of-the-art review, laboratory research, field tests, and use evaluations. The devices and techniques which are described in most cases will contribute to precise experimental control and to efficient data collection. (Author)

REVIEW: The author has done an admirable job of describing a complex experiment with potentially far-reaching results. The problem involves many variables, with potentially many significant interaction effects, the identification and assessment of which will have an important bearing on the degree of confidence to be placed in the results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability and maintenance training

AUTHORS: J. M. McKendry and T. P. Enderwick, HRB-Singer, Inc, State College, Pennsylvania

SOURCE: Proceedings of the Case Study Conference on Reliability, Maintainability, Human Factors--Prediction and Demonstration Techniques, sponsored by Professional Technical Group on Reliability, Boston Section, Institute of Electrical and Electronics Engineers, Framingham, Massachusetts, April 25, 1963, pp. 57-69

PURPOSE: To report on the progress being made in a study to determine the optimum method of training maintenance personnel.

ABSTRACT: There are six general ways in which maintenance technicians may gain experience. They are: (1) the use of operational equipment; (2) the use of complex simulators which attempt to duplicate the major aspects of that equipment, and involve the use of actual test equipment; (3) procedural trainers which utilize abstract representations of the equipment in block or circuit diagram form and which provide feedback to the students in the form of illuminated lights, meter deflections, wave-forms, etc.; (4) programmed manuals which provide printed feedback as to what certain hypothetical checks revealed; (5) audio-visual aids such as films, diagrams, etc.; and (6) apprenticeship training. To complicate the problem further, these techniques can be used in combinations of twos, threes, and fours. These basic techniques and their various possible combinations form one dimension of the problem, "the techniques of accumulating experience."

The second aspect of the problem is how much of the maintenance task should be covered at one time while the technician gains experience. Do all elements of the maintenance task have to be practiced at one time or can they be separated into simpler, easier to grasp, segments? In short, the familiar whole-part learning controversy is intricately involved in the problem as a second dimension.

A third possible dimension is introduced by the presence of different types of maintenance tasks. For example, maintenance tasks might differ significantly depending upon the type of equipment being serviced and the nature of the servicing environment. If this speculation is true, the "best" solution may change from case to case.

This paper discusses in some detail the various problems and their solutions, and reports on some experimental results. (Authors in part)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This paper should be quite helpful to the engineer who has not been exposed to training problems. However, it is less helpful than it might have been, had the material covered by the slides and tables been given. The first author, in a private communication, has indicated that a limited number of the slides and tables are available, and that copies may be obtained by writing to him.

It should be pointed out that much of the information presented may be found also in many industrial engineering texts dealing with personnel administration, and in a number of texts on group psychology. The conclusions are not original or unexpected. The paper does not, in fact, provide a good summary of all of the available techniques. It would have been desirable to have cited references to the more important techniques which were not specifically mentioned in the paper, in order to provide a more complete picture. ##

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Serial Number 843
Codes 832;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A maintainability prediction technique

AUTHOR: Harald R. Leuba, ARINC Research Corporation, Washington 6, D. C.

SOURCE: Proceedings of the Case Study Conference on Reliability, Maintainability, Human Factors--Prediction and Demonstration Techniques, sponsored by Professional Technical Group on Reliability, Boston Section, Institute of Electrical and Electronics Engineers, Framingham, Massachusetts, April 25, 1963, pp. 71-84

PURPOSE: To describe a method of maintainability prediction which encompasses human reaction times as a part of the man-machine concept.

ABSTRACT: This paper describes a new approach to the prediction of maintenance time. Developed under Air Force contract, the technique involves three significant departures from standard methods of predicting maintainability:

(1) It considers parameters of the personnel, of the use situation, and of the integration of these two dimensions with the equipment -- instead of basing prediction solely upon equipment characteristics.

(2) It relies on determining the probabilities of occurrence of certain fundamental activities, and the distributions of times required to perform these activities.

(3) It attempts to predict all system down time -- not merely active repair time.

The approach is considered generally applicable to all systems. The specific prediction procedures developed thus far, however, apply only to those electronic systems which are used under the operational and maintenance programs of the Air Force, and for which maintenance at the system level is accomplished primarily by "black box" replacement. (Author)

The selected approach is described by discussing the various restraints placed upon the team by the customer, the analysis of maintenance elements, and the times for performing such tasks as preparation, verification, location, procurement, repair, and check-out. Models are developed, based primarily on observed data from a "typical" system. Verification of the method is carried out by predicting maintenance times for two other systems.

REVIEW: As the author indicates, more work must be performed in order to prove that this method really works. However, the logical presentation and the numerics given tend to indicate that it has significant value. The references cited will provide the reader with the mathematical derivations and background for the equations in the paper. It is recommended reading for reliability and maintainability personnel. The paper covered by Abstract and Review Serial Number 840 is another (more general) discussion on this subject. ##

Serial Number 844 -1
Codes 815;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability testing of a tactical ground radar

AUTHOR: Gordon H. Beckhart, Manager, Engineering Product Assurance, Radio Corporation of America, Moorestown, New Jersey

SOURCE: Proceedings of the Case Study Conference on Reliability, Maintainability, Human Factors--Prediction and Demonstration Techniques, sponsored by Professional Technical Group on Reliability, Boston Section, Institute of Electrical and Electronics Engineers, Framingham, Massachusetts, April 25, 1963, pp. 85-90

PURPOSE: To discuss the value of reliability testing in the improvement of equipment reliability.

ABSTRACT: The key to successful reliability testing is careful analysis of failures and corrective action for all discrepancies, whether or not they affect mean time between failures. Time and the statistics of failure are actually secondary factors. The biggest payoff for the dollars invested in test facilities and time comes not from demonstrating MTBF but from the product improvement made possible by the knowledge gained of part and system behavior. Thus the life test makes it possible to identify assignable causes and eliminate them from the equipment and control them to prevent reoccurrence in future equipments. The example cited is a light-weight, tactical radar for air search, surveillance or traffic control applications. The test, problems, results, and lessons are discussed. (Author)

The paper is a case study of the reliability effort applied to a particular system. Criteria related to the equipment, test facilities, and personnel training are presented. A major portion of the paper is devoted to a corrective action report on various types of problems encountered.

REVIEW: This paper is worthwhile reading for reliability functions concerned with producing and testing equipment. It is an account of what was done to prove that the equipment performed as required for the specified mean-time-between-failures after it was released for manufacturing. However, it does not indicate the steps which were taken during the design process to develop a reliable equipment. No attempt is made to compare predicted values with laboratory/field test results. Such comparisons would have enhanced the value of the paper as a reliability case history. The data presented are somewhat confusing since many MTBF values are shown, but no reasons are suggested for the differences which exist among them.

In a private communication the author has commented that it should be emphasized that Quality Control Engineering and the use of

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

control charts or other means of identifying assignable causes will greatly assist the reliability engineer in his quest for more reliable equipment. His statement on this follows. "The major lesson of the reliability demonstration test was that we need to apply good Quality Control Engineering if we are going to diagnose failure mechanisms. It is unfortunate that one of the blind spots of the reliability profession has been the application of Quality Control Charts and the principles of Quality Control Engineering to diagnosing or identifying failure mechanisms early in a life test. At the present time, equipments only count as failures if they go outside of specification or performance limits. These performance limits may be in no way related to indication of incipient failure. For this reason it appears quite imperative that we have a means of identifying the presence of assignable causes and calling in the Design Engineers to identify these causes when they are present. In this way, the failure mechanism may be designed out of the system." ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some practical considerations for reliability demonstration tests

AUTHOR: William H. von Alven, ARINC Research Corporation, Washington 6, D. C.

SOURCE: Proceedings of the Case Study Conference on Reliability, Maintainability, Human Factors--Prediction and Demonstration Techniques, sponsored by Professional Technical Group on Reliability, Boston Section, Institute of Electrical and Electronics Engineers, Framingham, Massachusetts, April 25, 1963, pp. 91-107

PURPOSE: To discuss various considerations in the selecting of an optimum test plan for reliability demonstration.

ABSTRACT: The civilian consumer and the industrial customer rarely need to specify reliability requirements. In today's competitive market, no commercial manufacturer could survive for long without providing product reliability. The military services, however, because of their size and the stringent procurement laws under which they operate, must look upon reliability as a contractual matter. Consequently, reliability demonstration tests are receiving increasing emphasis in military electronic systems procurement.

This emphasis creates the practical problems of determining realistic reliability requirements, selecting suitable test plans, and choosing appropriate environmental conditions. It also demands a careful assessment of the advantages and the limitations of reliability demonstration testing. (Author)

This paper discusses some of the very cogent and realistic problems associated with the selection of test plans. A review of significant work in this area in the form of an annotated bibliography is also presented.

REVIEW: It is gratifying to see that the experts in reliability can agree, refer to each other's work, and recommend it as good theory which can be applied to practical situations. This is a very frank, concise, and general (yet adequate) dissertation on the subject of demonstration testing, and is recommended as worthwhile reading for all reliability personnel. ##

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Serial Number 846
Codes 552;821

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A note on the reliability of communication networks

AUTHORS: Y. Fu, Electrical Engineering Department, University of Kansas, Lawrence, Kansas and S. S. Yau, Department of Electrical Engineering, Northwestern University, Evanston, Illinois

SOURCE: Journal of the Society for Industrial and Applied Mathematics, vol. 10, pp. 469-474, September, 1962

PURPOSE: To investigate the probability of maintaining communication between a pair of stations when there is only traffic between the same pair of stations in the network.

ABSTRACT: Reliability is one of the most important problems in communication networks. A probability of success to perform normal operations or simply a reliability is associated with each element (a station or a link between stations) in a communication network. The reliability of the network is formulated in terms of the reliabilities of the individual links and stations. This is done by using a linear graph with both vertices and branches being weighted as the probabilistic model. The path approach is adopted. All possible paths between any two vertices in a linear graph are obtained by simplifying the linear graph. Statistical independence of the random variables is assumed. (Authors in part)

REVIEW: This is a mathematical paper, in which the material is clearly and concisely presented. The underlying assumptions are carefully stated, and six pertinent references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimum redundancy when components are subject to two kinds of failure

AUTHORS: Richard E. Barlow*, Larry C. Hunter*, and Frank Proschan** (*General Telephone and Electronics Laboratories, Inc., Menlo Park, California, **Boeing Scientific Research Laboratories, Seattle, Washington)

SOURCE: Journal of the Society for Industrial and Applied Mathematics, vol. 11, pp. 64-73, March, 1963

PURPOSE: To consider the problem of achieving optimum redundancy for certain types of systems assuming that failure may take either one of two forms.

ABSTRACT: The system considered consists of m subsystems, each subsystem containing n components. A component may fail in either of two mutually exclusive ways. A type 1 failure of a single component causes the subsystem containing it to fail. A type 2 failure of all the components in a subsystem causes the subsystem to fail. These subsystem failures are referred to respectively as type 1 and type 2 failures. Failure of type 1 of all the subsystems causes system failure, while failure of type 2 of a single subsystem causes system failure. Illustrative examples are cited, and it is noted that adding components will make failure of one type more likely at the same time as it reduces the chance of failure of the other type. A valid problem exists in determining the optimum number of components to use.

Each component independently has a certain probability of experiencing type 1 failure and a certain probability of experiencing type 2 failure. Solutions are obtained for the problems of (a) finding the value of m maximizing system reliability for given n and (b) finding the value of m maximizing expected life for n=1. It is shown how the value of m maximizing system reliability varies with n, the failure probabilities, and the time t. The values of m maximizing expected system life for the cases in which component life is exponentially distributed and uniformly distributed are tabulated. (Authors in part)

REVIEW: This paper is a contribution to the mathematical theory related to systems employing redundancy. The underlying assumptions are clearly stated and the mathematical development is concisely presented. The orientation of this study relative to other work in the field is indicated, and twelve pertinent references are cited. ##

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Serial Number 848
Codes 822;824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimation of the shape and scale parameters of the Weibull distribution

AUTHOR: M. V. Menon, IBM Research Laboratory, San Jose, California

SOURCE: Technometrics, vol. 5, pp. 175-182, May, 1963

PURPOSE: To propose estimates for the shape and scale parameters of the Weibull distribution.

ABSTRACT: Estimates $\hat{c}$ and $\hat{b}$ are proposed for the shape parameter c and the scale parameter b of the Weibull distribution on the assumption that the location parameter is known: $\hat{c}$ obtained by first finding an estimate $\hat{d}$ of $1/c$, and then setting $\hat{c} = 1/\hat{d}$. When b is unknown, $\hat{d}$ is a consistent and non-negative estimate of d, with a bias which tends to vanish as the sample size increases and with an asymptotic efficiency of about 55%. When b is known, $\hat{d}$ is an unbiased, non-negative and consistent estimate of d, and its efficiency is approximately 84%. An estimate ln^b of ln b is found. Its asymptotic efficiency is 95%. It is proposed that exp(ln^b) be used to estimate b. (Author)

REVIEW: This is a mathematical paper which will be of interest to the theorist rather than to the engineer. The remark made by the author to the effect that "the maximum likelihood equations for c are not solvable..." may be somewhat misleading, since Lloyd and Lipow [1] discuss an iterative technique for solving this problem. The "lack of an alternative" mentioned as one justification of the estimates $\hat{b}$ and $\hat{c}$ is subject to the same comment. It would be interesting to see a consideration of the relative merits, in practical situations, of the method proposed in this paper and the iterative technique presented in [1].

REFERENCE: [1] Reliability: Management, Methods, and Mathematics, David K. Lloyd and Myron Lipow, Prentice-Hall, Inc., 1962, Section 7.5.5 ##

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Serial Number 849
Code 823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relationship between system failure rate and component failure rates

AUTHORS: James D. Esary and Frank Proschan, Boeing Scientific Research Laboratories, Seattle, Washington

SOURCE: Technometrics, vol. 5, pp. 183-189, May, 1963

PURPOSE: To give a simple sufficient condition for a system to have an increasing failure rate when the identical components comprising it have an increasing failure rate.

ABSTRACT: A number of interesting and important consequences follow when it is known that a system has an increasing failure rate (conditional probability of failure given system age). For example, moment inequalities and bounds for system life can be obtained. It can be inferred that under certain assumptions successive intervals between system checks should form a decreasing sequence. An optimum policy in a certain planned replacement model can be computed more readily. It would be valuable to have simple sufficient conditions under which a system of components each having increasing failure rate itself has an increasing failure rate. In this paper, such a condition is obtained for systems of like components; for systems of components having differing reliabilities, upper and lower bounds which are increasing functions are obtained. Systems which function if and only if at least k of the n components function ("k out of n" systems) are of the type considered; the bounds are increasing functions of time for "k out of n" structures having components with increasing failure rates. Certain more general relationships between system failure rate and component failure rates are also obtained.

REVIEW: This paper is a contribution to the mathematical theory of reliability. The underlying assumptions are clearly stated, and the results are concisely presented. The orientation of the work relative to other material in the field is indicated; seven references are cited. ##

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Serial Number 850
Codes 430;821;825

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Coherent structures of non-identical components

AUTHORS: J. D. Esary and F. Proschan, Boeing Scientific Research Laboratories, Seattle, Washington

SOURCE: Technometrics, vol. 5, pp. 191-209, May, 1963

PURPOSE To explore some general aspects of the reliability of coherent systems whose components are independent, but not necessarily of the same reliability.

ABSTRACT: In [2] Moore and Shannon obtain some basic results concerning the reliability of two-terminal networks composed of independent components of equal reliability. In particular, they show that the reliability of the network plotted as a function of the component reliability is S-shaped, i.e. crosses the diagonal at most once and always from below. In [1] Birnbaum, Esary, and Saunders generalize the results of Moore and Shannon to what they call coherent structures; a coherent structure being, roughly, one whose performance does not deteriorate when failed components are replaced by functioning ones. Coherent structures include two-terminal networks, "k out of n" structures (structures which function if and only if at least k out of n components function), and many others. In [1] it is assumed, just as in [2] that components are independent and of identical reliability.

In the present paper, a basic theorem on the covariance of increasing functions of random variables is used in discussing the case of coherent structures whose components are independent, but of differing reliabilities. Upper and lower bounds, which can be computed directly from the minimal paths and minimal cuts of a system, are found for system reliability. The Moore-Shannon inequality is extended to the case of unequal component reliabilities, permitting a simple demonstration of the S-shapedness properties of system reliability functions. (Authors in part)

REFERENCES: [1] Z. W. Birnbaum, J. D. Esary, and S. C. Saunders, "Multi-Component Systems and Structures and Their Reliability," Technometrics, vol. 3, no. 1, February, 1961, pp. 55-77

[2] E. F. Moore and C. E. Shannon, "Reliable Circuits Using Less Reliable Relays," Journal of the Franklin Institute, vol. 262 (1956), pp. 191-208, and pp. 281-297

REVIEW: This paper is a contribution to the mathematical theory of reliability. In effect, it is an extension of some of the results obtained in the two references cited above. (The paper [1] was covered by Abstract and Review Serial Number 32.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Random hazard in reliability problems

AUTHOR: D. P. Gaver Jr., Westinghouse Research Laboratories

SOURCE: Technometrics, vol. 5, pp. 211-226, May, 1963

PURPOSE: To introduce the concept of a randomly varying environment as a means of relaxing the assumptions of independence and exponentiality which are customarily made in predicting system reliability properties from those of components.

ABSTRACT: A class of models for system reliability is presented which (a) introduces the notion of random variability of environment, and hence of instantaneous failure rate or "hazard," (b) leads to exponentially distributed system time to failure, and to exponentially distributed component time to failure when components are exposed to the environment in isolation, but (c) does not lead to a prediction of series system failure rate based on the usual procedure of adding component failure rates. If the usual procedure is followed, it is shown that underestimates of system reliability are obtained. A simple spares provisioning problem is investigated when such a model is assumed to hold. (Author)

REVIEW: This discussion of a random hazard model is a worthwhile contribution to the literature on mathematical models for reliability estimation. The paper is essentially a mathematical presentation; as such it will be of more interest to the theorist than to the reliability engineer. The material is clearly presented and the underlying assumptions are carefully stated. Ten relevant references are cited. ##

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Serial Number 852
Codes 351;613;633;
816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relating product design and warranties to customer expectations... its importance and method

AUTHOR: W. A. Kinnaman, Director, Marketing Projects, International Telephone and Telegraph Corporation, New York, New York

SOURCE: Mechanical Engineering, vol. 84, December, 1962, pp. 42-45 (ASME Paper No. 62-MD-31)

PURPOSE: To show the need for correlation between product design and warranties and the customer's expectations and to discuss a method for achieving this correlation.

ABSTRACT: This paper discusses the ways in which product failures in the post-warranty period may affect the public image of the brand name. The inevitability of product failures is pointed out, and the discussion centers on the correlation of the efforts of the engineering, marketing, and manufacturing branches of the corporation that is necessary to minimize dissatisfaction. The program for product planning should consist of

(1) Determination of customer expectations,
(2) Design to meet customer requirements, and
(3) The continuing conformance to design specifications.

Great emphasis is placed on the increased exchange by all three branches of the production process of data relevant to the product's development.

REVIEW: This discussion presents some of the basic facts that must be considered by all industries. Although the emphasis is on the major appliance industry, the author correctly points out that the same ideas apply in almost any industrial operation. The emphasis on designing to meet customer needs and expectations while considering such factors as ease of repair in case of failure and designing for minimum complexity is very applicable to the production of all types of aerospace equipment and is highly desirable in view of the need for increased reliability. ##

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Serial Number 853
Codes 810;811;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability requirements of industrial equipment

AUTHOR: R. L. Strauss, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: 10 pp., presented at the Fall Radio Meeting, Institute of Radio Engineers and Electronic Industries Association, Toronto, Canada, November 12, 1962

PURPOSE: To emphasize the need for reliability in industrial equipment and to suggest methods whereby it may be obtained.

ABSTRACT: Manufacturers of industrial equipment must embark upon a course of action in the reliability engineering field that will produce knowledge of just how good their equipment is. This knowledge must be based upon use histories in the case of existing equipment and upon sound analysis in the case of new equipment. Furthermore, this knowledge must be such that the manufacturer will stake his reputation on it.

REVIEW: This is a thoughtful consideration of the nature of the reliability demands on industrial equipment and an assignment of the responsibility for meeting these demands. The suggestions for obtaining reliability are standard and will be effective if diligently applied. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Military computer maintenance (Project Headstart Final Report)

AUTHOR: H. W. Adams, The MITRE Corporation, Bedford, Massachusetts

SOURCE: Special Report SR-66, 37 pp., The MITRE Corporation, Bedford, Massachusetts, Contract AF-33(600)39852, Project 416.0.3, August, 1962

PURPOSE: To determine the relative effectiveness of military maintenance of SAGE computers as compared to maintenance standards established by civilian contractor personnel.

ABSTRACT: Project Headstart is a study of the feasibility of military computer maintenance based on the maintenance of a pilot site, the Washington Air Defense Sector of SAGE. A comparison was made of the IBM experience and of the Air Defense Command experience in maintaining this site. The comparison indicated that military maintenance of SAGE computers was as effective as contractor maintenance. The number of required maintenance men decreased as experience (by both IBM and ADC) was gained on the system. There is a bibliography of 22 related articles. (Author in part)

REVIEW: This study has taken into account all the discernibly relevant inputs (i.e. personnel qualifications, up-to-date maintenance requirements, and several factors unique to the pilot site) in analyzing the collected data. Therefore, within the scope of the factors considered, the conclusions reached appear to be quite sound. However, the original problem was the presence of civilian maintenance personnel over which the military would have no control in war and such personnel were necessarily supposed unreliable under war conditions. It is clear that the present maintenance program of the Air Defense Command still requires the services of a considerable number of civilian personnel at each site. Apparently this is necessitated by the lack of qualified air force personnel in the area of advanced systems technology. Since the data show an increase in civilian assistance to ADC personnel during the period of the study, it appears that the presence of this civilian contingent may be essential to the operation of the SAGE computers. If this were to be true, then the problem of unreliable personnel has not been completely solved. In reply to this the author, in a private communication, has commented as follows: "I would emphasize the capability of the Air Force to replace most of the contractors. Further, the question of continued need for contractor on-site assistance is still open; no data is in on the effect of the airmen who were sent back to IBM for advanced training. During the course of our study, no airmen with advanced training were available for use at the pilot site." (The paper covered by Abstract and Review Serial Number 502 was a preliminary report on this project.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundant semiconductor switching circuits

AUTHOR: K. L. Hall, Radiation Incorporated, Melbourne, Florida

SOURCE: 10 pp., presented at the Mid-America Electronic Conference, Kansas City, Missouri, November 19-20, 1962

PURPOSE: To demonstrate the feasibility of improving the reliability of semiconductor switching circuits by the use of redundancy techniques.

ABSTRACT: The author considers the standard switching circuits (i.e. inverters, buffers, and multivibrators) and shows how component redundancy may be used to improve their reliability. A number of such designs are given.

A brief, qualitative treatment of system redundancy is also presented.

REVIEW: This paper presents a very clear discussion of the techniques of designing redundant semiconductor switching circuitry. The analytic content is sparse but the qualitative discussion and the design examples are quite valuable. Most of the assumptions are given--and this is very important.

The four papers cited as references by the author were covered respectively by Abstracts and Reviews Serial Numbers 147, 40, 396, and 560. The reader interested in this topic may wish to see also the papers covered by Abstracts and Reviews Serial Numbers 277, 488, 780, and 803. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Where components must be improved

AUTHOR: (Editorial Matter)

SOURCE: missiles and rockets, vol. 12, June 17, 1963, pp. 40-41

PURPOSE: To report on a survey conducted at Marshall Space Flight Center to determine which vehicle components most require improvement, and what improvements should be made.

ABSTRACT: Contractors and government personnel concerned with the production of reliable vehicle components have been hampered by a lack of detailed information as to which components most require improvement, and what improvements should be made. To fill this information gap, the Marshall Space Flight Center, which is in charge of the Saturn vehicle program, recently completed a survey of all its technical divisions. The effort was coordinated by John H. Graham, of the Applications Office of Marshall's Research Projects Division.

The article consists of a brief listing of some specific problem areas, together with two charts giving areas requiring improvement for various listed components. One chart lists electrical components, while the other covers the entire range of vehicle components. (Author in part)

REVIEW: The material in this article should be of considerable interest to design and production engineers concerned with improving the reliability of space vehicles. Although the article is quite short, the chart form of presentation serves to convey the information effectively and concisely. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analytical aspects of reliability in re-entry systems development

AUTHOR: D. R. Earles, Research and Advanced Development Division, AVCO Corporation, Wilmington, Massachusetts (current affiliation: General Electric Company, Daytona Beach, Florida)

SOURCE: 34 pp., presented at the Air Force Reliability Seminar at Headquarters, Electronic Systems Division, Air Force Systems Command, Laurence G. Hanscom Field, Bedford, Massachusetts, September 11, 1962

PURPOSE: To summarize the analytical portions of the re-entry system reliability problem.

ABSTRACT: Though re-entry bodies have been in existence for only a few years, they have already undergone drastic changes. Today's nose cones use ablative cooling in the place of the earlier heat sinks and have shapes considered much too radical just a while ago. In this review of current re-entry system reliability analysis techniques, the re-entry problem is discussed, the analytical objectives of a re-entry system reliability program are defined and possible analytical methods used in obtaining the objectives during system development are delineated.

The analytical aspects of reliability in re-entry systems development pertain to three basic areas: reliability apportionment, prediction and measurement. There are analytical tools available in today's reliability technology for at least crude solutions to the reliability problems in all three areas. Although these tools are available, the optimum method must be tailored for a specific system and development program. (Author)

REVIEW: This paper is of a general nature and does not contain any essentially new information. However, it serves its purpose of summarizing the principal facets of the re-entry system reliability problem. Thus it will be useful to those who wish to obtain a general picture of the main considerations involved. For details, other references (of which the author cites eight) will have to be consulted. ##

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Codes 811;820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Integrating statistical applications into a reliability program

AUTHOR: George J. Levenbach, Bell Telephone Laboratories, Whippany, New Jersey

SOURCE: 16 pp., presented at the A.S.Q.C. Middle Atlantic Conference, Washington, D. C. March, 1962

PURPOSE: To examine some of the problems involved in the integration of a statistical approach into a reliability program.

ABSTRACT: Statistical methods have played a substantial part in the development of Reliability as a branch of Engineering Science. However, the effective inclusion of statisticians on the reliability team is still, to some extent, an unsolved problem. This paper discusses some of the considerations which this problem entails, by first examining the role of the reliability organization in relation to the project activity, then giving a general review of statistics with respect to engineering, and finally using a few examples to illustrate the integration of statistics into the reliability organization.

It is concluded that the main conditions for the successful integration of statistics into the reliability function are (a) project management receptive to the reliability function; (b) effective cooperation and communication within the reliability organization; and (c) the availability of capable applied statisticians. (Author in part)

REVIEW: This paper is well written and appropriately documented (seven references are cited); it should serve a very useful purpose. It is recommended as worthwhile reading for those who want or need a better appreciation of the role which the statistician can play in a reliability organization. The dangers and limitations as well as the merits connected with the use of statistics are frankly discussed. Some of the points made constitute, in effect, advice which is often ignored by some of those who apply statistical methods to reliability problems.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction of durability of elements and automatic systems with vectorial determining parameters

AUTHOR: G. V. Druzhinin (USSR)

SOURCE: JPRS:4836, 2 August 1961, 10 pp., U. S. Joint Publications Research Service, 1636 Connecticut Avenue, N. W., Washington 25, D. C. (distributed by Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 61 31610, price $0.50)

PURPOSE: To predict systems and element durability on the basis of the state of the elements at the present time.

ABSTRACT: Durability is defined to mean the ability of elements and systems to remain in perfect order during storage or operation. Statistical studies of durability deal with random change processes in determining element parameters as a result of wear or deterioration. In earlier work it has been assumed that each element is characterized by a single determining parameter. There are cases, however, when a system or element is characterized by several determining parameters (a vectorial determining parameter). In such cases it is necessary to deal with vectorial random processes of change in the determining parameters and the statistical bounds of elements.

The characteristics of vectorial determining parameters and statistical bounds of elements are discussed. The calculation of the durability of elements and of systems with vectorial elements and systems determining parameters is considered.

REVIEW: This is a mathematical paper which will be of interest to the theorist rather than to the design engineer. The quality of the reproduction is poor in places, especially in the displayed equations. The reader may in fact have to work through some of the mathematics if he wishes to be sure of the results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the determination of additional indexes of the operational reliability of computer systems used in automatic equipment

AUTHOR: O. N. Radimov (USSR)

SOURCE: JPRS:9791, 4 August 1961, 11 pp., U. S. Joint Publications Research Service, 1636 Connecticut Avenue, N. W., Washington 25, D. C. (distributed by Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 61 27377, price $1.60)

PURPOSE: To consider the problem of determining the revolving stock of computer systems necessary to maintain uninterrupted operation, given that failed units are repaired and placed in a reserve supply, from which replacements for failed units are drawn.

ABSTRACT: The situation considered is one in which computer systems are carrying out program control of automatic equipment. A computer system which has failed is repaired and is replaced by a system in good working order which has been kept in reserve. After repair the computer is added to the reserve supply. In order that such a system may provide uninterrupted functioning of the equipment, it is necessary to have a certain revolving stock of spare computer systems. This paper is concerned with the determination of the revolving stock under such conditions.

The number of malfunctioning computer systems coming in for repair, the number of workers used in repair, and the time taken for repairs are treated as random values. The aggregate of all the computing systems which are in use is examined in various possible conditions. The revolving stock necessary to exclude the possibility of idle time of the automatic equipment is determined as the average number of computer systems in repair.

REVIEW: This is a mathematical paper which will be of more interest to the theorist than to the engineer. The reproduction is rather poor in places, particularly in the displayed equations, and some symbols have been left out. The reader interested in the paper will find it desirable to work through the mathematics in order to be sure of the results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure therblig failure rates

AUTHORS: D. R. Earles, Chief, Reliability Analysis Section and M. F. Eddins, Senior Scientist, Research and Advanced Development Division, Avco Corporation, Wilmington, Massachusetts (current affiliation: General Electric Company, Daytona Beach, Florida)

SOURCE: 18 pp., presented at the 1962 Western Electronic Show and Convention (WESCON), Los Angeles, California, August, 1962

PURPOSE: To present the concept of a "failure therblig" and a tabulation of failure therblig failure rates.

ABSTRACT: The concept of a "failure therblig," defined as a design feature failure function, is presented. This function is associated with a failure rate related to the internal and external operating stresses and the inherent strength of a design feature. The term "therblig" was coined by Frank B. Gilbreth in the early days of industrial engineering to describe the elementary subdivision of a cycle of human motion. Therbligs are used to predict and set production rates, and to perform motion studies. Where therbligs are related to time rates, failure therbligs are related to failure rates. Where therbligs are related to human functions, failure therbligs are related to hardware functions. Where therbligs are used in motion studies to eliminate ineffective movements, failure therbligs are used in reliability studies to simplify design concepts and eliminate ineffective complexity. Failure therblig failure rates are determined and a tabulation presented. Failure therblig rates are used in an abbreviated simplicity analysis and reliability prediction of a command receiver converter oscillator circuit. (Authors)

REVIEW: This paper is an extension of the one covered by Abstract and Review Serial Number 286. The extension essentially takes the form of a rather extensive table of failure therblig failure rates for a wide variety of components (principally electrical or electronic items). The first author, in a private communication, has indicated that there are typing errors in the Coil Failure Rates found in the table. No doubt he will furnish corrected values to those who may request them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of germanium power transistors

AUTHOR: Ralph Greenburg, Motorola, Inc., Semiconductor Products Division, Phoenix, Arizona

SOURCE: 5 pp., presented at the 1962 Western Electronic Show and Convention (WESCON), Los Angeles, California, August, 1962

PURPOSE: To show that germanium power transistors, when properly made and correctly applied, can be used at temperatures up to 140°C.

ABSTRACT: The evidence obtained through extensive quality control evaluations and through the investigations of power transistor problems in field equipment has provided conclusive proof of the inherent reliability of germanium alloy devices. Transistors that have been properly cleaned during manufacture, that have a true hermetic seal and established controlled ambient conditions, that are stored at temperatures below 140°C and are used in circuits designed to prevent thermal run-away and excursions beyond the safe operating area have a failure rate competitive with some of the most reliabile components on the market today.

Of the failures that have been encountered in Motorola's applications engineering department, by far the majority were caused by overvoltage applications because safe operating areas were either ignored or not clearly defined. The second most frequently encountered failures were due to improperly designed bias circuits resulting in thermal runaway. (Author)

REVIEW: This report deals largely with potential reliability. The user has no way of knowing if his transistors have actually been prepared according to the instructions here. In terms of application, if the manufacturer has not given complete and unambiguous specifications it certainly is not fair to criticize the user for misapplication. (The author seems to agree with this.) Although the author does minimize temperature (less than 150°C) as a life factor, his own curve shows a factor of over 10 increase in failure rate (of presumably properly made units) from 90°C to 130°C. No explananation is given of the reasons for legitimate failures that do occur in properly made germanium transistors. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of systems under random demands

AUTHORS: Kenneth M. Hall, Development Engineer and Kenneth M. Zenkere, Engineering Specialist, Sylvania Electric Products Inc., Reconnaissance Systems Laboratories, P. O. Box 188, Mountain View, California

SOURCE: 14 pp, presented at the 1962 Western Electronic Show and Convention (WESCON), Los Angeles, California, August, 1962 (NASA accession number N62-17837)

PURPOSE: To present an expository summary of finite Markov chains and to show how they can be used to construct reliability models which incorporate random demands.

ABSTRACT: The configuration of a system is often dependent on operational conditions and can change as the conditions change. These changes may be totally or partially due to changing demands for various portions of the system. The problem posed is that of evaluating the worth of the system when certain subsystems are needed in accord with some underlying distribution.

It is shown in this paper that when a system has the Markov property over a denumerable state space, which includes an operational demand model in its structure, then the embedded Markov chain can be utilized as a model for the system. The chain models can be used for evaluating several significant system measures.

It is pointed out that at times it is necessary to define various measures as limits of sequences. This is an important result, since the differences in adjacent terms of the sequences may be appreciable before the limits are reached (within specifiable bounds). In some systems these limits may never be reached during the operational life of the equipments, and in those cases other measures must be specified. (Authors in part)

REVIEW: This is a theoretical paper which may be of interest to those who are concerned with the construction of mathematical models for evaluating the reliability of systems. The expository treatment of Markov chains is unlikely to be helpful to those who do not already have some acquaintance with the topic. Similarly, without this knowledge the examples will not be meaningful. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to build reliability into welded circuits

AUTHOR: C. R. Olsen, Manager of Quality Assurance, Raytheon Company, Sudbury, Massachusetts

SOURCE: The Iron Age, vol. 191, June 6, 1963, pp. 82-83

PURPOSE: To give a brief discussion of resistance welding.

ABSTRACT: Resistance welding is experiencing rapid growth as a joining tool in electronic packaging. The key to reliability of welded circuits is through simplification. The number of component types, materials, and combinations of sizes of lead materials should be kept at a minimum. Good consistent welds hinge on detailed control of materials, machines, and man. Control is assured through inspection of incoming components with weldable leads, rigid testing of new material going into production for the first time, control of machines with respect to electrodes and insulation, and the continous checking of the quality of the work performed by each operator.

REVIEW: This is a brief article on how Raytheon tackles the problem of providing reliable resistance-welded electronic circuits; it is a newsy type article designed for the layman. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System worth and incentive contracts

AUTHOR: W. C. Fredrick, ARINC Research Corporation, Washington, D. C.

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 6-15

PURPOSE: To propose a method of contractual incentives based on system worth evaluation and demonstration.

ABSTRACT: The types of contracts now used for procurement of military systems and equipments do not provide a proper stimulus for the development of highly effective systems at reasonable cost. Incentive-type contracts which carefully associate fee with the contractor's performance in all important areas of system worth can be of great value in coping with rapidly increasing system costs and the need for higher levels of performance, reliability, and maintainability. Methods of relating incentive fees to specific system-worth factors are described in this paper. (Author)

A major section of the paper is concerned with the deficiencies in present contractual methods used by agencies of the Federal Government. These contract types include CPFF, FFP, CPIF, and FPI. The calculation of system worth is described in general terms, and a step-by-step procedure is given for relating system worth to contractual arrangements of the incentive type.

REVIEW: This is a well written, logically planned thesis principally directed to Government Procurement officials. It is not likely to be of use to engineers as such. The paper is highly critical of the paper work and reports required of current contractual methods--yet the proposal appears to create even more reports, evaluations, and potential chaos. In the definition of a mission for a system many modes or missions are involved and the more complex airborne, seaborne, and fixed units could easily have ten basic missions. In developing an estimate of reliability which is not subject to varieties of interpretation, the industry would have to stand still, as the data on currently-produced parts will not be available for another year or two. Also, the definition of failure, the mathematical model, the environmental profile, and the human interface would have to be so well defined that the purpose of reducing costs in demonstrating reliability would be defeated. Logistic times would be equally difficult to determine and also would not be under the control of the contractor. The "value" of operational readiness is also difficult to assess and is not controllable even if it could be defined contractually. The proposal at this point in time seems to be beyond the capability of the industry. However, the concept should be explored more fully and tried out in practice. Procurement methods in fact require

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a revamping, but this may be due to the structure of the agencies which use one group for research, another for production, and a third for maintenance. As the author suggests, stepped contracting with one contractor involved all the way and a fee based on the probability of mission performance and/or availability to perform the functions assigned is possible and should be considered.

The approach proposed in this paper deserves encouragement and careful consideration. While any method involves problems, it must be kept in mind that it is not a question of problems versus no problems, but rather a matter of finding the approach which leads to the problems which are the easiest to live with in field use as well as in production. It would have been helpful if the author had given a longer list of relevant references to assist the reader in finding other works in this area. ##

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Codes 810;815;816;
870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Funding reliability programs

AUTHOR: E. F. Dertinger, Equipment Division, Raytheon Company

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 16-33

PURPOSE: To present a series of problems which are faced by the government in properly specifying, and by contractors in meeting, reliability requirements on various types of contracts.

ABSTRACT: Progress in the areas of properly evaluating the reliability tasks to be accomplished and obtaining the necessary funds for the conduct of reliability programs has been severely limited. Six major reasons for this limited progress are:

1. Lack of valid data concerning the true costs of unreliable weapon systems and subsystems, and therefore, lack of appreciation of the problem by government project and reliability personnel.

2. Lack of true understanding of reliability program activities by both government and industry high-level management and project (contract control) groups.

3. Confusion created by both government and industry relative to reliability, maintainability, quality control, quality assurance, product assurance, etc., functions.

4. Frequent conduct by industry of half-hearted, costly, unproductive reliability programs ... often by completely unqualified personnel.

5. Lack of coordination between government project groups and government reliability groups.

6. Absence of properly specified <u>quantitative</u> reliability requirements in requests for bids.

These problems must be solved prior to finding the funds necessary for reliability programs. The possible solutions are explored in detail. A theme carried throughout the paper is the problem of communication. Factual cost data on various military and space projects are used to back up the statements made. (Author in part)

REVIEW: This paper could well be recommended as mandatory reading for corporate executives, military procurement and maintenance chiefs, marketing specialists, and industrial association personnel. The paper is of general interest to designers. The ideas expressed may be controversial, but the material is factual and the conclusions are valid. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The role of the buyer in reliability

AUTHOR: R. T. Dewey, The Boeing Company, Seattle, Washington

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 34-39

PURPOSE: To describe the methods developed by and for the buyer to assist him in purchasing products which meet a reliability objective established by the dictates of highly reliable systems.

ABSTRACT: This paper discusses subcontract source selection, contracting methods, and contract surveillance from a reliability standpoint. The two basic premises on which a buyer operates are:

1. Contractor's reliability capability, both past performance and proposed programs will be a major factor in all source selection actions, and;

2. Equipment produced by suppliers must be subjected to the same reliability disciplines as that produced by the prime contractor.

The various reliability activities in which a buyer participates are described.

The major functions of the Materiel Reliability Engineer are: specification review, supplier proposal analysis, reliability cost analysis and negotiation, training and guidance of materiel personnel, coordinating with all other groups involved in the item being procured, and auditing on reliability matters. These functions are briefly described.

Three contracting methods used by the Boeing Company are:

1. Demonstrated Test Method.
2. Level of Effort Method.
3. Task Accomplishment Method.

These methods are described. Techniques of contract surveillance are briefly discussed. (Author in part)

REVIEW: This is a general paper which appears to cover the major non-controversial points adequately. Its value would have been enhanced, however, if comparisons had been used to show the value of the philosophy presented, and if relevant references had been cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Future needs in research and training

AUTHOR: M. M. Tall, Administrator, Defense Reliability and Maintainability, Defense Electronic Products, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 40-42

PURPOSE: To bring the future of reliability into perspective.

ABSTRACT: Reliability has "arrived" in one sense. Statistics has been applied to the problem, estimates of reliability can be made beforehand, new fields such as maintainability have spun off, standards and controls have been established, and departments organized. But are we now on a plateau and going no higher? Are we degenerating into handbook engineers? Research into the fields of materials, processes, failure mechanisms, etc. needs to be pushed hard. Reliability engineering must regain its sense of urgency.

Competent engineering skills are necessary to start reliability on the road again. The rotation of engineering personnel through reliability tasks and the rotation of reliability personnel through other engineering tasks may bring sound experience into reliability so that it may regain its impetus.

REVIEW: This is an exhortation to those in the reliability field to go on to solve more problems. While we constantly push research for the future we should bear in mind that if we were doing as well as we know how now, a lot of equipment would be much more reliable than it is. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Systems reliability engineering graduate curricula

AUTHOR: Thaddeus L. Regulinski, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 58-61

PURPOSE: To describe the development and content of a graduate curriculum in systems reliability engineering which is in use at the Air Force Institute of Technology.

ABSTRACT: Capable engineers are needed for systems analysis and engineering management. The curriculum proposes to fill this need in an 18-month program of study. There are three main course sequences: mathematics (6 courses), engineering (8 courses), and management (5 courses). In addition, there is provision for electives (2 courses) and independent study (4 courses). The article discusses each sequence in some detail.

REVIEW: This is a course of study which would be excellent graduate preparation for any systems engineer and of which any school might well be proud. Since this curriculum is specialization, it is encouraging to have it above the "bachelor's" level. The list of 21 references includes some very competent works in the various relevant fields. The standards set in the courses are apparently commendably high. In a private communication the author has stated that the course is open to students who have an overall grade point average (GPA) of 3.00 or better in their undergraduate work in engineering, mathematics, or physics. Upon graduation from the course, the student receives a master's degree in Systems Engineering. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A proposed curriculum for reliability engineering

AUTHOR: Harold C. Jones, University of Maryland, College Park, Maryland

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 62-65

PURPOSE: To present a proposed curriculum for reliability engineering.

ABSTRACT: Assuming that a separate reliability engineering curriculum is desirable, one is proposed. There are ten "arts" courses -- English, history, economics, etc.; general chemistry; conventional mathematics through advanced calculus (4 courses); a few general engineering courses; four probability/statistics/reliability courses; and the balance generally split between conventional electrical and mechanical-design engineering. It totals 148 hours with no electives. The courses are discussed in some detail.

REVIEW: A first reaction is that reliability engineering is too narrow a field for an undergraduate and that a course so named would be objectionable. The curriculum that is presented, however, would be excellent preparation for an electrical/mechanical engineer. If the course were renamed, it would be a good one -- outside of the usual objections calling for more of the humanities, mathematics, physics, electives, etc. It would be a rough course, but good training for a four-year engineer. It should provide adequate background for graduate study, if such is desired. ##

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816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Military management of missile quality control/reliability programs

AUTHOR: R. W. Smiley, CDR, USN, Engineering & Inspection Division Officer
Bureau of Naval Weapons Representative (Special Projects Office)
Sunnyvale, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 66-68

PURPOSE: To describe the Polaris philosophy of reliability management.

ABSTRACT: The military, recognizing the difficulty of measuring definitively the output of Quality Control/Reliability programs, controls contractors' efforts in these areas by "Input Contracting". Such contracts specify elements of programs and the level of effort for work.

Today's missile programs demand high reliability, not only for strategic reasons, but for economic as well, and reliability attainment must be a matter of profit over cost. Reliability dollars are spent for certain specified efforts which can be called "Painstaking attention to details in a system of checks and balance". The military manages these dollars by first defining in detail each effort, system or discipline required, second negotiating the desired level of effort for each element, and third by closely monitoring compliance with the negotiated effort. This scheme can be called "Input Contracting". Even with incentive contracts, when the fee is partially determined by the attained level of quality/reliability, the military continues to use the "Input Contracting" scheme. (Author)

REVIEW: Although very short, this paper is worthwhile reading for procurement and management personnel, as well as for cost-conscious manufacturers who can spend money improving reliability and make a greater profit while doing so. Among the most vital messages in the paper are the following: (1) reliability is needed to reduce the cost of military preparedness, (2) reliability is effected by "painstaking attention to details in a working system of checks and balances," (3) methods for accomplishing high performance reliability are contractual and directed by edict, (4) an upper limit on reliability is set during the R & D phase, (5) reliability demonstration is costly and time-consuming, and is avoided in the Polaris approach, (6) incentive contracts are being issued on the basis of demonstrated results in acceptance tests rather than life testing, and (7) "input contracting" can be put on an incentive basis. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Parts oriented reliability programs and problems

AUTHOR: C. S. Bartholomew, The Boeing Company, Seattle, Washington

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 69-73

PURPOSE: To develop a theory for parts oriented reliability programs.

ABSTRACT: A parts oriented reliability program is defined as including all the design and production assurance measures required to develop the full reliability potential of the parts to a point where further reduction in equipment failure is limited by the failure rates of the parts themselves, and seeks to reduce the failure rates of the parts by the imposition of design and production assurance controls on the part sources. Figures of merit for design and production are defined. Factors which affect design errors, production defects, and inherent unreliability are listed. After these measures have been incorporated in a reliability program, it is appropriate to consider what may be done by way of part improvement to further reduce equipment failure rates. The decision as to how much part improvement is cost effective in terms of mission cost is illustrated. The establishment of a hi-rel parts manual is shown to be an important factor in achieving hi-rel systems. Another important facet is the establishment of part improvement programs which are concurrent with design or with production. The problems which this imposes are examined. The incorporation of screening in the product specifications is shown to be desirable. Problems in the development of hi-rel parts, including scheduling, documentation, standardization, and costs are also discussed.

REVIEW: This paper contains the type of material which one might expect to find in proposals or justification documents chiefly for the attention of accounting or legal personnel. This is not meant to imply that cost effectiveness considerations are of no interest to the technical specialist in reliability, but rather that this paper does not go very deeply into the technical aspects of the subject, and relies a lot on general statements which are sometimes vague. No actual development is given for the equations which are cited, and no references are mentioned. (Incidentally, Equation 4A seems to be missing.) The author cites a commercial example, but later refutes the advantage of using high-reliability parts in commercial equipment on the basis of cost, thus leaving rather conflicting impressions. It is claimed that the development of military specifications for high-reliability parts will create a demand for these parts. It is to be hoped that such will in fact prove to be true. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--small companies--space subsystems

AUTHOR: Melbourne D. Johnson, Santa Barbara Research Center, A Subsidiary of Hughes Aircraft Company, Santa Barbara Airport, Goleta, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 74-79

PURPOSE: To describe specific, scheduled reliability program tasks and their implementation in the reliability organizations of small companies.

ABSTRACT: This is a discussion of the way in which reliability activities may be implemented in the small company (200 to 1500 total employees) in order to meet the reliability requirements of national missile and space programs. The inherent advantages which small companies have in this respect include the following: (1) they are primarily staffed with a high density of experienced specialists, (2) the percentage of total employment assigned to reliability is relatively high, (3) they are able to move quickly with a high concentration of effort resulting in timely implementation of reliability tasks and faster delivery, and (4) they are often in a position to provide more favorable prices and can devote a larger percentage of the contract price specifically to reliability tasks. They are also in a position to provide a highly effective and comprehensive reliability program due to simplicity in organizational structures and close project team and management effort. This paper describes a method of organizing, planning, implementing, and controlling an effective reliability program for the small company. (Author in part)

REVIEW: This is a typical paper on the management of project reliability. Judging by other papers which have been written on this topic, there is not complete agreement among managers on all of the points which are made. An example of this appears to be the relative importance assigned to the organizational placement of the reliability group in the company. However, a statement made by the author in a private communication seems to summarize the basic requirement quite well as follows: "Individual capability (of the reliability engineer) is a major attribute, but it can be severely limited by incorrect organizational placement and lack of description of responsibilities and authority. (Reference MIL-R-27542)" ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The computer reliability report

AUTHOR: Irvin R. Whiteman, C-E-I-R, Inc., Los Angeles Center, 9171 Wilshire Boulevard, Beverly Hills, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 80-83

PURPOSE: To discuss the advantages of using computers in reliability reporting.

ABSTRACT: The major factors involved in using computers in comprehensive reliability efforts are presented. Among the topics discussed are: computer speeds, input data format and accuracy, pre-programmed report requirements, sources of data, methods of analysis, format and purpose of reports, and data coding. The need for maintaining "clean" data is stressed in terms of efficient utilization of computers in reliability activities.

It is pointed out that in order to develop a satisfactory reliability reporting system utilizing the mathematical tools which have been, and are being developed, advances must take place along the following fronts: (1) methods of obtaining data, (2) transmission of data, (3) basic methods for maintaining records, (4) methods for keeping errors out of records, (5) methods for extracting intelligence out of the records, and (6) reliability analysis. Errors may become a severe bottleneck. There will be a fertile field for years to come in solving the problems of reliability analysis. The solutions must be obtained and made available in time for suitable judgments and corrective action to take place. The modern-day computer can serve in this role. (Author in part)

REVIEW: This is an excellent sales-type paper on why reliability can use computers to aid or speed the task of analysis and reporting. There is little that is new or unique about the material presented. It would have been most valuable to have given some numerical examples of manual versus computer processing of data. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of repairable systems

AUTHOR: George Nagy, Goodyear Aircraft Corporation, Akron, Ohio

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 93-108

PURPOSE: To generalize the concept of reliability and extend it to repairable systems.

ABSTRACT: Reliability (R) may be defined as the probability of at least A% uptime (satisfactory operation) during time T, where A represents availability. For "one-shot" devices, such as missiles, A is 100. For repairable systems, which may repeatedly fail and be repaired, A may be chosen less than 100. The magnitude of R depends on the mean time-to-failure (MTF) and the mean time-to-repair (MTR). Curves of R vs A, T, MTF, and MTR are provided, which may be used to develop a system at the design stage so as to satisfy a customer's specifications on reliability, R, and availability, A. Given R, A, T, and the system's drawings, an MTF is first estimated. From the curves, for this R, A, and MTF, the required MTR is noted. Then the MTR of the system is estimated by a formula developed in the paper. If the estimated MTR is larger than the required value, the formula spotlights those components which must be redesigned for speedier repair to satisfy the customer's R and A--at the design stage. Methods of designing availability tests are described. (Author in part)

REVIEW: This paper contains results which may well be of considerable use to design engineers. The mathematical derivations are relegated to an appendix, while specific and detailed "how to apply" steps and descriptions are given in the main text. Relevant references are cited. The basic assumptions are that failure and repair times are exponentially distributed. The curves of R vs MTF and MTR are given for T = 1000 hours and A = .750, .800, .900, .950, .975, .990, .995, and .999. They may be scaled to any other time period, T_o, simply by multiplying MTF and MTR by $T_o/1000$. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The practical significance of reliability predictions

AUTHORS: Charles R. Thomas, Victor Selman, and Benjamin Ellison, International Electric Corporation, Subsidiary of ITT, Paramus, New Jersey

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 1-4--1-8

PURPOSE: To describe several uses of reliability predictions.

ABSTRACT: This paper describes several uses of reliability predictions in furthering the objectives of project management. These objectives are reducing costs, significant improvement of products, and outperforming the competition. The reliability prediction is an "input," essentially a design tool, rather than an "end product". This paper describes quantitative methods of: comparing alternative designs for contract compliance, manufacture and evaluation costs, and field maintenance costs; determining points of effective application of improvement funds; isolation of design weaknesses where significant improvements can be made; revealing sections where costs may be reduced by reducing excessive reliability; evaluating credibility of test data; test schedule planning and funding; estimating spares, and maintenance requirements and facilities. (Authors)

REVIEW: This is a relatively brief paper, considering the number of topics mentioned in the ABSTRACT. Consequently, none of these are covered in much detail. References are cited for the mathematical expressions on which a reader might desire more detail. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Data exchange programs conducted by U. S. Naval Ordnance Laboratory, Corona, California

AUTHOR: S. Pollock, U. S. Naval Ordnance Laboratory, Corona, California

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 3-2--3-19

PURPOSE: To describe four separate and distinct Reliability Data Exchange Programs being conducted by the Naval Ordnance Laboratory.

ABSTRACT: This paper describes four separate and distinct data exchange programs being conducted by the U. S. Naval Ordnance Laboratory, Corona, California under the sponsorship of the Bureau of Naval Weapons (BUWEPS) and the Special Projects Office (SPO). These are: The Fleet Ballistic Missile Weapon System (FBMWS) (POLARIS) Component Reliability History Survey (CRHS); The Interservice Data Exchange Program (IDEP); The BUWEPS Guided Missile Data Exchange Program (GMDEP); and The BUWEPS Failure Rate Data Exchange Program (FARADA).

The basic objectives of these data exchange programs are directed toward reducing duplicate expenditures of the testing costs of missile parts/components, expediting the development of new weapon systems by avoiding repetition of tests already accomplished and to enhance the reliability of Navy missile systems, both guided and ballistic, in Fleet use. These objectives are to be accomplished by the acquisition of reliability data on parts/components proposed for use in these missiles from many and varied sources, including other missile programs and on a nation-wide basis, from tests conducted under controlled laboratory conditions, during production, and during service use. These data are then presented in a concise, uniform and unbiased manner to design engineers for the purpose of assisting them in the selection of parts/components proposed for use in various missiles and weapon systems.

Each of the programs is described in some detail. Illustrative figures showing sources of information and some typical forms are given. (Author in part)

REVIEW: This is a very worthwhile description of four Reliability Data Exchange Programs. As such, it will be of considerable interest and value to any design engineers who are not already fully aware of the existence of these programs and what they have to offer. ##

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Serial Number 878
Code 814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and value engineering

AUTHOR: M. M. Tall, Administrator, Defense Reliability and Maintainability, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 4-2--4-8

PURPOSE: To discuss the problem of meeting reliability requirements within the constraints of the available resources.

ABSTRACT: Reliability is a major "value" attribute that must be balanced with cost in an effective value engineering program. The achievement of the severe reliability requirements imposed by our customers under equally severe constraints of dollars and time, pose many difficult decisions for project management. This decision process can be facilitated with an effective reliability and value analysis during the system concept phase of a project. The relationship between reliability and value during the concept phase is discussed. In addition, the types of analyses which contribute to the balancing of reliability and cost objectives are indicated.

The concept of system effectiveness is described and contrasted with the "black box" approach. The application of the system effectiveness approach is illustrated with a simple missile fire-control system. Typical data are introduced for the purpose of illustrating the computations. (Author in part)

REVIEW: This paper will be worthwhile reading for anyone concerned with guiding the development of a system toward the achievement of a required reliability at a minimum investment. The main points are made through the medium of a fairly simple example, which contributes to the clarity of the presentation. The reader will, of course, have to think in terms of applying the concepts to his own specific situation. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of microelectronic circuit packages as compared to that of conventional circuit packages

AUTHOR: Joseph P. Morone, Jr., Microcomponents Department, P. R. Mallory & Company, Inc., Indianapolis, Indiana

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 6-2--6-8

PURPOSE: To provide qualitative comparisons of the reliability determinant characteristics of conventional and microminiature circuit packages.

ABSTRACT: High reliability and small size in electronic circuits are foremost among the requirements of many military, space, and industrial applications. These requirements have stimulated new advances in electronic circuit packaging techniques. As a result, the reliability of conventional packaging systems has been upgraded, while entirely new microminiature packaging concepts have been developed. No single method meets all of today's requirements, nor is it likely that any one method will do so in the near future. Conventional wired and printed circuits will fill the needs for most low quantity, high powered, or special circuit applications. Microminiature systems using discrete component parts will satisfy the needs for many small linear control and communication devices of low or medium power. Thin film, solid silicon circuits, and functional blocks will find their biggest application in highly repetitive, low power, digital computer and control circuits. Most complex electronic systems of the future will find combinations of these several packaging systems most advantageous. The current packaging approaches are described under the headings: wired circuits, printed circuits, cordwood packing, disciplined geometry assemblies, thin films, solid silicon circuits, and functional blocks. The factors considered as most important to the reliability of an electronic package are: the number of parts; the number, length, and type of interconnections; simplicity of design and construction; mechanical, thermal, and climatic adequacies; electrical performance levels; and maintainability and repairability. The relative advantages of the various packaging techniques are discussed in terms of these reliability determinants. (Author in part)

REVIEW: This paper accomplishes its purpose of providing qualitative comparisons of the various current approaches to electronic circuit packaging in terms of the more important factors affecting reliability. The material is presented concisely but no references are cited. The reader who desires more detail or substantiating data will therefore have to look elsewhere for it. ##

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Serial Number 880
Codes 612;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A Monte Carlo simulation of the operational effectiveness of multimoded systems

AUTHOR: Kenneth Curtin, RCA Surface Communications Systems Laboratories, New York, New York

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 7-2--7-7

PURPOSE: To describe a Monte Carlo technique for predicting and evaluating system reliability.

ABSTRACT: A variation of system redundancy is the multimoded concept, in which all, or selected numbers of, the system components can be switched into modes which give varying degrees of task performance. The operational effectiveness of a moded system may be determined by computing the probability of operation of each mode. However, since the modes do not perform the system task with equal effectiveness, their probability of operation must be weighted by an effectiveness factor. Then the operational effectiveness of the i th mode is $OE_i = R_i E_i$, where R_i is the probability of system operation in the i th mode at any specified time and E_i is the effectiveness of the i th mode. Hence the operational effectiveness of a multimoded system consisting of n modes is given by

$$OE = \sum_{i=1}^{n} R_i E_i .$$

A Monte Carlo technique is used to predict and evaluate the system reliability. The technique developed influences system design by indicating the modal configuration that optimizes system operational effectiveness. In addition, the degradation of a system can be quantitatively stated, equipment changes can be evaluated, and different tactical operations can be compared.

REVIEW: This is a brief but adequate description of the proposed procedure. Presumably more details, if desired, may be found in two references cited by the author. The underlying assumptions are that component failures occur independently and that failure times are distributed exponentially. An obvious limitation on the applicability of the method is the availability of E-values specific to the type of system, and of valid failure rates for the functional groups. ##

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Serial Number 881
Codes 431;820;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Logical analysis of redundant reliability flow networks

AUTHOR: S. W. Leibholz, Auerbach Corporation, Philadelphia, Pennsylvania

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 8-2--8-12

PURPOSE: To consider the problem of finding the logical functions which describe the system performance level associated with each state of a redundant system.

ABSTRACT: Reliability prediction for a redundant system generally involves two models: the statistics of malfunction and recovery of each element, and the information flow which describes the interconnection of the elements. This paper deals with the logical analysis of the reliability information flow. For a given system, this flow is a form of network in which each step represents functions performed in a component equipment. The most useful techniques of analysis appear to be offshoots of those involving Boolean matrices. The objective is to convert a system block diagram and function information flow into a logical description of the conditions under which the system will perform. Special attention is given to the "quorum" problem, to the general treatment of systems having multiple levels of effectiveness (i.e., consideration of models where reduced performance states are involved), and to methods for computer analysis and synthesis. (Author)

REVIEW: This is a mathematical paper, the main technique involved being Boolean matrix analysis. Accordingly it will be of more interest to the theorist than to the design engineer. It is worth noting that consideration is restricted to situations in which each element is binary in operation, that is, it is either operating or not operating. There would seem to be a fertile field for the theorist in the consideration of the applicability of relatively sophisticated mathematical techniques to situations in which drifts in component characteristics are taken into account.

The author in a private communication has indicated that the question of situations in which the elements have multi-valued states of operation came up in the discussion following his presentation, and that such situations can be handled by a simple extension. He has also indicated that a practical application of this technique in combination with that in the paper covered by Abstract and Review Serial Number 719 is currently being attempted.
##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Graphic method for solving reliability logic configurations

AUTHOR: William E. Marshall, Minneapolis-Honeywell Ordnance Division, Hopkins, Minnesota

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by the Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 9-2--9-8 (virtually the same paper as in the Proceedings of the Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 243-249)

PURPOSE: To present a method for solution of reliability logic configurations.

ABSTRACT: In some instances, reliability logic configurations include unavoidable duplication, triplication, etc. If this is disregarded, probability calculations will be in error. This duplication can be properly taken into account by considering the logic configurations. (Author)

A method for solving reliability logic configurations is described through the medium of an example involving a three-phase solid state inverter, with a failure-detecting and switching circuit and a standby-redundant, single-phase inverter. The three-phase output is furnished by three single-phase inverters. If one of these fails, the failure-detecting and switching circuit connects the stand-by inverter in place of the failed inverter. The logic statement for system failure is: The system will fail if one of the primary single-phase inverters fails, and if either the failure-detecting and switching circuit fails or the redundant single-phase inverter fails, or if more than one of the primary single-phase inverters fail.

It is stated that the above logic statement is inadequate for setting up reliability logic equations. A complete logic statement in block diagram form is given, and the exact expression for the probability of system failure is obtained. An expression obtained by disregarding triplication is also given. The effects of disregarding duplication, triplication, etc. are discussed.

REVIEW: This paper deals with an important subject and could be of assistance to reliability engineers in some situations, but it does seem to overcomplicate and misrepresent the problem considered. For a person with a working knowledge of elementary probability theory and an awareness of the underlying assumptions, the logic statement is quite adequate for writing the correct expression for the probability of system failure. For those without this background (and even for

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those with it), it is desirable to make a complete tabulation of the system/black box possible outcomes, in order to be sure that all of the possibilities have been included. This is especially true when the system has many possible modes of success.

The author's diagrammatic approach is not explained except through a rather simple example. If the problem were more complicated, the diagrammatic approach would presumably also be complicated, and the paper does not make it clear how one should proceed. In fact, for a complicated system, it may take less time to make the complete tabulation of the possible outcomes, as mentioned above, than to use the diagrammatic approach. For the example in the paper the tabulation is given below. Each column corresponds to a combination of black box outcomes, the 16 columns corresponding to the 16 possible system outcomes. The notation A,B,C corresponds to that of the author, and D* is used to denote the combination of D and E in series. An s denotes success and a blank space denotes failure.

A	s	s	s	s	s	s	s	s								
B	s	s	s	s					s	s	s	s				
C	s	s			s	s			s	s			s	s		
D*	s		s		s		s		s		s		s		s	
System	s	s	s		s				s							

In notation corresponding to that of the author one would then write the probability of system success as
$P(A)P(B)P(C)P(D^*) + P(A)P(B)P(C)P(D^{*\prime}) + P(A)P(B)P(C')P(D^*) + P(A)P(B')P(C)P(D^*) + P(A')P(B)P(C)P(D^*)$,
which is easily simplified to
$P(A)P(B)P(C) + [P(A)P(B)P(C') + P(A)P(B')P(C) + P(A')P(B)P(C)]P(D^*)$.

The expression for the probability of system failure when duplication is disregarded is, of course, wrong as the author has stated. The reason for this may be explained as follows. The multiplication law of probability may be stated in the form $P(A \text{ and } B) = P(A)P(B|A)$, where $P(B|A)$ denotes the probability of the occurrence of B given that A has occurred. When A and B are independent events, $P(B|A) = P(B)$, so that $P(A \text{ and } B) = P(A)P(B)$. But when we replace B by A we get $P(A \text{ and } A) = P(A)P(A|A) = P(A)(1) = P(A)$, and <u>not</u> $\underline{[P(A)]^2}$, which results if we simply set $B = A$ in $P(A)P(B)$. The examples in Appendix A in the paper are confusing since so much space is devoted to the incorrect expression.

The almost blanket encouragement to set success probabilities equal to one in the numerical calculations should have been accompanied by some words of caution or suggestions as to when this is appropriate. If, for example, success probabilities

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

appear as three factors in a term and their values are 0.95 each, the approximation amounts to setting 0.86 equal to 1.00.

It should be noted that if one calculates probability of success (rather than the probability of failure) with the author's success logic diagram, the correct answer follows readily, since the success situations are all independent, as will generally be the case. Most of the difficulty in the example stems from drawing a success diagram and then calculating failure probabilities.

Those who prefer the author's diagrammatic approach should heed the cautions expressed above to avoid incompleteness in complicated cases. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Applications of flow graph techniques to the solution of reliability problems

AUTHOR: W. W. Happ, American Micro Devices, Inc., Phoenix, Arizona

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 10-2--10-34

The text of this paper is the same as that of the paper covered by Abstract and Review Serial Number 711. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of the Darnell Report in component specification control

AUTHOR: E. N. Wyler, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 11-2--11-6

PURPOSE: To discuss the application of the philosophy and concepts of the Darnell Report to the writing of component specifications.

ABSTRACT: The contents of the Darnell Report and some of the history leading up to its preparation are reviewed briefly. It is indicated that the portion of most interest to reliability engineers deals with the mechanics of the specifications. The basic concept of the specifications calls for qualification inspection and re-evaluation of qualification, acceptance inspection, and failure-rate testing by a sequential sampling scheme. These aspects are discussed briefly.

Of all of the specifications which have been drafted incorporating the principles of the Darnell Report, perhaps the most time and effort has gone into the preparation and coordination of the military specification for film resistors. This document is the "established reliability" version of MIL-R-10509, and can serve as a good example of the application of the Darnell Report in specification control. The problems encountered in work on specifications conducted at Battelle Memorial Institute are discussed. These problems in producing procurement documents of a practical and useful nature are associated with the sampling plans for qualification, acceptance, and failure-rate certification tests. It is pointed out that the Darnell Report was not meant to be a handbook for preparing high-reliability specifications and should not be used as such. However, through implementation of the recommended plans and procedures, radical improvements in specification control should be realized. (Author in part)

REVIEW: This is a relatively brief discussion which will be of interest to those concerned with specifications implementing the Darnell Report recommendations. Other papers on the Darnell Report have been covered by Abstracts and Reviews Serial Numbers 172, 478, and 671. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: In-process control for high reliability component parts

AUTHOR: W. R. Arnold, Vitramon, Inc., Bridgeport, Connecticut

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 12-2--12-7

PURPOSE: To present the general requirements for process controls which will result in the production of high reliability components, and to discuss some particular problems in their implementation.

ABSTRACT: Repeated failure to comply with a Darnell type specification results in the loss of qualification. The electronic component manufacturer, having accepted the obligation of producing units in accordance with such a specification, is forced to establish stringent controls over the production line. Control of the administrative procedures for instituting new designs, material, or processing methods are equally as important as control of the existing production processes.

The general requirements for controls which will result in a stable production process for high reliability components are presented. The necessity for process controls is discussed in terms of such factors as process variation, failure analysis, and the nature of the production line. A good process control system must include (a) a system for controlling all inputs, (b) a system for detecting harmful effects on the product due to undetected variance in the inputs, (c) a failure analysis system to determine the causes of harmful effects, and (d) a corrective action system to eliminate the causes of harmful effects. Particular problems associated with the institution of a Darnell specification at Vitramon, Inc. provide specific illustrations of necessary process controls. (Author in part)

REVIEW: This is a description based on the experience of one company in solving some of the problems associated with the production of high reliability components. As such it will be of interest to those who are concerned with similar problems. Other papers concerned with Darnell type specifications have been covered by Abstracts and Reviews Serial Numbers 172, 478, 671, and 884. ##

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Serial Number 886
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of component parts in military equipment

AUTHOR: Eugene Slaughter, General Precision Inc., Aerospace Group, Kearfott Division, Clifton, New Jersey

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 13-2--13-5

PURPOSE: To discuss a technique used to analyze the application of component parts in electronic equipment.

ABSTRACT: This paper describes the techniques which should be used to select component parts for military equipment. The component parts constitute the base for each piece of equipment, and through diligent investigation of each component application, circuit requirement, and environmental requirement, the proper component can be selected and a firm base established. Only through wise surveillance and investigation by competent people can the proper component be selected for each given application.

Equipment cost today is so steep that it is a necessity to have the proper component part in each circuit application. Only through the efforts of adequate engineering on each component part that is being used in a circuit, will the many component failures be eliminated and equipment losses be substantially reduced. Each component application must be thoroughly reviewed with respect to its circuit requirements before a sound selection of the part can intelligently be made. Component Application Engineering or the equivalent in the present day electronic field must be used by corporations which design and manufacture intricate electronic circuitry. The Design Engineer, having the responsibilities of designing the intricate circuits of today's electronic equipment cannot be expected to maintain full cognizance over the increasing number of components available. Therefore, through the united efforts of Component Application Engineers, Standard Engineers, and Design Engineers, a higher quality of components can be specified and used in the equipment of tomorrow. (Author)

REVIEW: As the author has pointed out, the proper specification and selection of component parts and the avoidance of incorrect applications are key problems in the production of reliable electronic equipment. The organized procedure which is described briefly in this paper is an example of a way in which these considerations can be implemented. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component part reliability assurance vs. delivery time

AUTHOR: C. H. Zierdt, Jr., General Electric Company, Semiconductor Products Department, Syracuse, New York

SOURCE: Proceedings Third Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapters, PGCP, PGPEP, and PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; October, 1962, pp. 14-2--14-8

PURPOSE: To discuss some possible ways of alleviating the problem of long delivery times in the purchase of high-reliability parts.

ABSTRACT: When the buyer exercises his prerogative by requiring special part selection or testing, delivery time is extended to accomodate the required testing. Life testing is a notable delaying factor, as 1000 hours equals at least six weeks; 100% tests of any nature also contribute to the difficulty. Scheduling the use of limited testing facilities adds time to that required for the testing mechanics.

Early discussion of a proposed purchase spec with qualified vendors can save time by minimizing negotiation and interpretation after the purchase order is placed. Specification acceptance of standard tests, and permission of "bonded warehousing," can alleviate delays considerably. On some products, valid life test assurance can be had in as little as one week by proper choice of test conditions; in a growing number of cases, life testing may very profitably be waived in favor of highly effective 100% screening operations which actually reduce subsequent failure rates, rather than simply assuring a maximum. (Author in part)

REVIEW: This is a realistic discussion of the problem considered, and the implementation of the proposed ideas should prove to be effective. The paper is worthy of the attention and consideration of those concerned with the purchase of high-reliability parts. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design of a repairable redundant computer

AUTHOR: Rein Teoste, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts

SOURCE: IRE Transactions on Electronic Computers, vol. EC-11, pp. 643-649, October, 1962

PURPOSE: To present the design of a computer which can still operate satisfactorily while a part of it is being repaired.

ABSTRACT: A repairable redundant machine must have (1) a negligible probability of system failure, (2) at least two paths for computation, so that one component can operate while another is being repaired, (3) a detection and display for component failures so that repairs can be made promptly, and (4) a connecting device to select and transmit the signal from an unfailed component.

The author reviews what has been done in improving computer reliability. First, by the use of several computers with the same input, and with the output taken from one unit until it fails, then from the next unit, and so on [1]. Next, by the break-up of the system into smaller parts to which this method of redundancy is applied [2,3]. Failure detection by coding methods is discussed, as well as a combination of coding and redundancy [4]. Microlevel redundancy is mentioned [5], with the comment that reduced failure probability is accompanied by increased difficulty of detection of failed components [6]. Von Neumann's majority gate concept is mentioned [7], along with a majority gate with failure indication [8].

The next section of the paper is devoted to a discussion of Von Neumann's multiplexing scheme. In this method many identical units operate on the same inputs and each unit feeds each of the same number of restoring organs, each of which, in turn, feeds only one of the units in the following stage. This system will correctly pass information even though either a minority of the units in a stage fail or if a minority of the restoring organs fail, or both. The author notes that accumulation of failures in parts of a machine will ultimately cause the machine to fail. Failure detection and failure repair will be added to the Von Neumann multiplexing scheme.

The author presents a reliability model which shows how much improvement in reliability can be expected if more components are used than are needed for the computer to perform adequately. Failure rates are defined, and operating (repairing) conditions are specified. The failure mechanism is specified by the Poisson process. Failure probability is calculated for the redundant

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

machine by a four-point procedure described in the paper. (Multiplexing is used in the postulated machine, using triple redundancy of each unit, and three majority gates.) Cost, in terms of the increase in the number of parts, is found to be $c = 3(1 + aN/m)$, where a is the number of one-active-element circuits in a majority gate, N is the number of redundant blocks in the machine, and m is the number of active-circuit elements in a non-redundant computer.

Gain in failure rate, G, (the object of the investigation), is shown to be $G = 6\lambda_o T(1 + aN/m)^2/N$, where λ_o is the rate of non-redundant computer failures, and T is the time to repair a failure. The equation is plotted with $\lambda_o T$ as the abscissa and $G/(1 + aN/m)^2$ as the ordinate to give gain as a function of repair time.

The optimum value of N is shown to be equal to m/a, if cost is not considered. If maximum life per component is important, optimum N is equal to m/2a. Cost and gain are plotted as a function of N/m for a = 9. An example is given.

The conclusion states that "mean time between failures of digital electronic equipment can be increased by several orders of magnitude by use of Von Neumann multiplexing redundancy. This is achieved by introducing redundancy on low-component organization level and by minimizing the repair time." All equations are derived in the paper.

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[3] R. Teoste, "Reliability of redundant computers," Lincoln Lab., M.I.T., Lexington, Group Rept. 21G-0029, March 22, 1961 (ASTIA 260494)

[4] D. B. Armstrong, "A general method of applying error correction to synchronous digital systems," Bell Sys. Tech. J., vol. 40, pp. 577-593, March, 1961

[5] E. F. Moore and C. E. Shannon, "Reliable circuits using less reliable relays," J. Franklin Inst., vol. 262, pp. 191-208

and pp. 281-297, September, October, 1956

[6] R. Teoste, "Some reliable redundant circuits," Lincoln Lab., M.I.T., Lexington, Group Rept. 21G-8001, June, 1961 (H-423)

[7] J. Von Neumann, "Probabilistic logics and the synthesis of reliable organisms from unreliable components," in "Annals of Mathematics Studies," Princeton University Press, Princeton, N. J., No. 34, pp. 43-98, 1956

[8] S. Schneider and D. H. Wagner, "Error detection in redundant systems," 1957 Proc. Western Joint Computer Conf., pp. 115-121

REVIEW: This is an exceptionally thorough and well-grounded presentation, and should be of considerable value to persons interested in the concept of achieving reliability by a combination of redundancy, failure detection and repair. The author writes with clarity and detail, and his points are well made. ##

Serial Number 889 -1
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating breakdown voltage characteristics of field-effect transistors

AUTHOR: Will Parmer, Semiconductor Components Division, Texas Instruments Incorporated, Dallas, Texas

SOURCE: Electronic Equipment Engineering, vol. 11, May, 1963, pp. 54-57

PURPOSE: To explain the current-voltage characteristics of the standard field-effect transistor and to recommend the use of certain specific parameters for describing the breakdown characteristics.

ABSTRACT: The action of a field-effect transistor is described and its breakdown phenomenon contrasted to that of the familiar bipolar transistor. The absence of the punch-through phenomenon in the field-effect transistor means that its breakdown characteristic does not exhibit a negative resistance (unlike the bipolar transistor) and that with adequate current limiting it is even possible to operate continuously in the breakdown region.

The various breakdown parameters that can be measured and specified are discussed and certain ones are seen to be more informative than others. The two primary parameters are: (1) I_{GSS} at a gate-source voltage above the pinch-off voltage and (2) BV_{DGO}. Special uses may require more specifications.

REVIEW: This is a qualitative paper intended for the circuit designer working with field-effect transistors. The explanations of the field-effect action are generally accurate and clear, although the nomenclature is largely undefined and sometimes non-standard. A reference is made to the "anode end" of the field-effect transistor. From the accompanying text this term apparently means the gate circuit, but since this particular reference is the one and only occasion on which the term appears, the reader must deduce this for himself. The text further obscures this deduction by stating that the reverse breakdown voltage of the diode on the right in Figure 4 determines the breakdown voltage of the transistor, while the symbols used indicate just the opposite--the diode on the left is reverse biased under the indicated polarities and its breakdown voltage should determine the breakdown voltage of the transistor. In a private communication, the author has clarified the interpretation. A consistent picture is obtained by reversing the polarity of the diodes from that shown in Figure 4. (Conventionally, the arrows indicate the p-side of the junction.) Doing so implies that the channel is n-type and the gate region, p-type. The "anode end" referred to is the ancde end of the diodes, i.e., the gate region.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

In the second section of the paper, the announced purpose of which is "to determine the simplest and most useful methods of specifying the pertinent (breakdown) parameters," the sequential order of ideas disappears after the first two steps and the paper ends after a discussion of a series of independent ideas. A summary probably would have helped.

In spite of the above comments the paper makes some worthwhile points in sufficient detail to be helpful and with ample originality to convince the reader of the author's familiarity with his subject. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A survey of some mathematical models in the theory of reliability

AUTHOR: George H. Weiss, University of Maryland and National Bureau of Standards

SOURCE: Statistical Theory of Reliability, Proceedings of an Advanced Seminar conducted by the Mathematics Research Center, United States Army, at the University of Wisconsin, Madison, May 8-10, 1962, edited by Marvin Zelen, The University of Wisconsin Press, 1963, pp. 3-54

PURPOSE: To review some of the major ideas and results in the modern theory of reliability.

ABSTRACT: This paper is a discussion of the model aspects of reliability, including the topological aspect, the time dependence of reliability, and several models relating to the economics of equipment maintenance.

Topological Reliability

In this section the author discusses the dependency of system reliability on the topology of the system, or "system connectivity." The inclusion-exclusion method for combining probabilities is used to give general results when the system consists of a number of possible paths from input to output. This is applied to the case of N independent components in series and in parallel. Work by Gates and Broussard is quoted in this connection. The Birnbaum, Esary, and Saunders work with structure functions and coherency is briefly described.

It is pointed out that in the case of two failure modes, (for example a relay may fail by staying open or by staying closed), redundancy may actually decrease reliability. Papers cited in connection with the problem of optimum redundancy are those by Von Neumann on the "majority organ" and subsequent work by Moore and Shannon. Finally the connection between reliability of communications systems and error correcting codes is mentioned.

Time Dependent Reliability

The previous section was concerned with mechanisms which are called on to perform at most once only. In this section the author considers problems of time dependence. He describes various lifetime distributions in terms of their hazard rates, and their "reliabilities." (The reliability $R(t)$ is defined as $1-F(t)$ where $F(t)$ is the distribution function.) The limiting exponential law for N components is quoted along with the appropriate literature, and, in particular, the work of Drenick.

Renewal Theory and Some Applications

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

The author next reviews various aspects of renewal theory. In particular, he gives certain relations between the renewal moments, the asymptotic forms of the mean and variance of the number of renewals, and discusses the age distribution of the item at present in use. Examples of the application of these techniques in relatively simple maintenance situations conclude this section.

Maintenance Policies
In this section, problems concerned with costs and gains are discussed. Two general classes of problems are noted in this connection. The first is related to inventory theory and is concerned with the optimal supply of spare parts or redundant elements. The second refers to inspection procedures and replacement policies. In connection with the first, or "spare parts" problem, works by Mine, Bellman and Dreyfus, and Albert and Proschan, are cited. A typical case dealt with is that of a series network of elements with known reliabilities, where it is desired to add redundant elements to maximize the reliability, while keeping the cost below some specified total amount.

For the second or "regenerative maintenance" problem, work by a number of authors is cited. The earliest paper quoted is one by N. R. Campbell concerned with the replacement of street lamps. More general formulations of the maintenance problem given by Savage, and (in a more specific situation than the work of Savage) by Barlow, Proschan, and Hunter are described. It is stated that most of the work done to date involves periodic maintenance policies and an infinite "usage horizon". (That is, the equipment is to be kept operating for an infinite time.) Various types of problems are discussed and the works of a number of authors are cited. Included among these are papers by Barlow and Proschan, Barlow and Hunter, Coleman and Abrams, and Flehinger.

REVIEW: This paper provides a very readable review of literature. While the three types of problem into which the material is divided are not mutually exclusive, yet this division is helpful to the reader who wishes to review a particular area of work. In the first section general formulae are given for the case of elements which are not necessarily independent. However, it does appear that it would be difficult to apply the results if the elements were not independent. In certain places the notation could be slightly simplified--for example in the renewal theory section there appears to be no need to use $f_1(t)$ and $\rho_1(t)$ for the same quantity. However, these criticisms are of a very minor nature and the paper is certainly to be recommended to anyone wishing to obtain an overall picture of this literature. ##

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Serial Number 891 -1
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy for reliability

AUTHOR: Frank Proschan, Boeing Scientific Research Laboratories, Seattle, Washington

SOURCE: Statistical Theory of Reliability, Proceedings of an Advanced Seminar conducted by the Mathematics Research Center, United States Army, at the University of Wisconsin, Madison, May 8-10, 1962, edited by Marvin Zelen, The University of Wisconsin Press, 1963, pp. 55-74

PURPOSE: To expose selected topics in the mathematical theory of redundancy.

ABSTRACT: The paper is an expository review of the literature of selected topics in redundancy. The first subject considered is the maximization of the reliability of a redundant system subject to linear constraints. The system consists of k stages, where the i th stage consists of n_i, ($i = 1, \ldots, k$), components in parallel, each of which has independent probability p_i, $0 < p_i < 1$, of functioning. The system performs if and only if each stage functions. The problem is to choose the vector of positive integers $\underline{n} = (n_1, \ldots, n_k)$ to maximize the system reliability subject to the constraints $\sum_{i=1}^{k} c_{ij}\, n_i \leq c_j$, ($j = 1, \ldots, r$), where $c_{ij} > 0$ for all i and j. For r = 1, both an approximate and an exact solution are known. For r = 2, the problem may be solved on a computer by dynamic programming methods. For any r, a general solution using non-linear programming methods is given explicitly in the paper.

A related problem is that in which the redundant units are in standby condition, ready to be switched into operation as soon as failure occurs. Given the failure distribution $F_i(t)$ of the components in the i th stage, and that the components are independent, it is desired to maximize the probability of survival of the system until time t_0. The constraints are as above. A solution is known for r = 1. The case when $F_i(t) = 1 - \exp(-\lambda_i t)$ is especially tractable.

A second major area relates to systems for which the components are subject to two types of failure, types 1 and 2. A type 1 failure of a single component causes the subsystem containing it to fail, whereas a type 2 failure of all the components in a subsystem causes the subsystem to fail. Moreover, failure of type 1 of all the subsystems causes system failure, while failure of type 2 of a single subsystem causes system failure.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

These types may be illustrated by a network of relays arranged so that there are m subsystems in parallel, each subsystem consisting of n relays in series. An open circuit of a relay constitutes a type 1 failure, whereas a short circuit of a relay constitutes a type 2 failure. If the network consists of n subsystems in series, with each subsystem containing m relays in parallel, an open circuit failure is a type 2 failure and a short circuit failure is a type 1 failure.

For both network configurations, the system reliability is given by the same function of m, n, and the probabilities p_1 and p_2 of the two types of failure. An exact solution is stated explicitly for that value of m which maximizes the system reliability.

Under mild further assumptions, it is sought to maximize the expected time until system failure. A solution for the optimum number m^* is obtained for n = 1 and general failure distribution functions. For the special cases of the exponential and uniform distributions, numerical results are calculated for m^* up to 10.

The third subject area is concerned with qualitative aspects of redundant systems. A structure function $\Phi(\underline{x})$, where $\underline{x} = (x_1,\ldots,x_n)$, $x_i = 1$ or 0, $(i = 1,\ldots, n)$, according as the i th component is operating or has failed, assumes the value 1 or 0 depending on whether the structure is performing or has failed. A coherent structure is such that the functioning of a component contributes to the functioning of the system, the failure of all components causes system failure, and the success of all components causes system success. A minimal path is a subset of components such that if they all function, the system functions; but if they do not all function, and no other components function, the system fails. A minimal cut is a subset of components such that if they all fail, the system fails; but if one or more of them functions, and all other components function, the system functions. The structure function $\Phi(\underline{x})$ of a coherent system can be expressed in terms of minimal paths, or alternatively in terms of minimal cuts. The system reliability is bounded above and below, respectively, by replacing x_i by p_i in the minimum path and minimum cut expressions for $\Phi(\underline{x})$, where the p_i are independent component probabilities.

For a two terminal circuit, composed of relays with common probability p of closure and circuit reliability h(p), a plot of h(p) is an S-shaped curve proceeding from (0,0) to (1,1), provided that $h(p_o) = p_o$ for p_o lying between 0 and 1. The curve is below the diagonal from (0,0) to $(p_o,0)$ and above it elsewhere. If a relay

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is such that the probability of failure to open when commanded to open is less than p_o and to close when commanded to close is less than $1-p_o$, the reliability of the circuit can be improved by replacing each relay by the circuit. This process may be iterated successively using the same function h(p) to achieve any desired circuit reliability.

This result has been generalized to the larger class of coherent structures, and more refined results have been obtained relating crossings of h(p) with curves of the form $h(p)(1-p) = cp(1-h(p))$, $c > 0$, as a function of the numbers of minimal paths and cuts of size 1. Finally, the S-shape property has been extended to coherent systems of unlike components.

REVIEW: This is an eminently good expository paper. The paper should be readily understood by many mathematicians and engineers.

In discussion of the paper, Mr. I. Rotkin observed that when several identical units are in parallel, they share the load, and that when one or more units fail, it often happens that the remaining units work harder, thereby reducing their life expectancy. He also observed that units often are not connected directly in parallel or series, but through some intermediate device which has characteristics of its own. He invited mathematical analysis of these cases. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintenance and replacement policies

AUTHOR: Richard E. Barlow, General Telephone and Electronics Laboratories, Incorporated

SOURCE: Statistical Theory of Reliability, Proceedings of an Advanced Seminar conducted by the Mathematics Research Center, United States Army, at the University of Wisconsin, Madison, May 8-10, 1962, edited by Marvin Zelen, The University of Wisconsin Press, 1963, pp. 75-93

PURPOSE: To describe some of the models and results relevant to replacement problems.

ABSTRACT: In many situations, failure of a unit during actual operation is costly or dangerous. If the unit is characterized by a failure rate that increases with age, it is wise to replace it before it has aged too greatly. On the other hand, one cannot plan too frequent replacements without incurring excessive costs. Thus, one of the most important replacement problems is that of specifying a replacement policy which balances the cost of failures against the cost of planned replacements.

A cost function is written, expressing the expected cost in terms of the cost of replacing failed units, the cost associated with exchanging non-failed items, the number of actual failures, and the number of exchanges of non-failed items in a specified interval of time. Strictly periodic, random periodic, and sequentially determined policies are defined. The literature dealing with these is briefly reviewed. Reference is made to preparedness models, in which it is assumed that the actual state of the equipment at any time can be ascertained only by inspection.

Optimal replacement policies can be such only with respect to a given failure distribution. For example, if the hazard rate were decreasing with the age of the item, no replacement should be considered, since replacement before failure would result in replacing an aged component with a "worse" component. Thus the class of distributions for which the hazard rate is increasing with age is of the most practical interest insofar as replacement policies are concerned. The assumption of an increasing hazard rate is also a natural one, since most devices tend to wear out with time. The properties of distributions with increasing hazard rate are discussed. Replacement policies of the strictly periodic type are evaluated under the following headings: (a) replacement policies for a single unit, (b) block replacement, (c) optimum replacement intervals, and (d) preparedness models. (Author in part)

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REVIEW: This is a competent mathematical paper in an area in which a considerable amount has been written by the author and others. (See, for example, Abstracts and Reviews Serial Numbers 401 and 451.) The author cites 16 relevant references, and the paper serves in part as a brief review of this literature. This feature will make it helpful to those who wish to make a study of the work that has been done in the area. Some worthwhile comments on the practical aspects of replacement policies are found in the discussion of the paper. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimum checking procedures

AUTHOR: Larry C. Hunter, General Telephone and Electronics Laboratories, Incorporated

SOURCE: Statistical Theory of Reliability, Proceedings of an Advanced Seminar conducted by the Mathematics Research Center, United States Army, at the University of Wisconsin, Madison, May 8-10, 1962, edited by Marvin Zelen, The University of Wisconsin Press, 1963, pp. 95-113

PURPOSE: To consider the problem of determining optimum procedures for the checking of systems (a) for relatively simple models assuming general failure distributions and (b) for more complicated models under the assumption of exponential failure.

ABSTRACT: The problem of checking or inspection arises in connection with systems which are deteriorating. Deterioration is stochastic and the condition of the system is known only if it is inspected. The optimization problem is to minimize the total expected costs of the lapsed time between system failure and detection of failure, and the costs of checking. For military systems, the costs of an undetected failure are often interpreted as lost readiness time with a consequent reduction in the operational availability of the system. For consumer goods, there are costs for keeping a unit which has failed or for delivering a defective item. For a production system, this cost is often measured by defective items produced.

Many different checking models have been treated in the literature, all of which take into account, in some manner, the costs of checking and of undetected failure. In other respects many variations have been allowed for. In this paper, consideration of the subject is divided into two parts. The first part considers optimum checking procedures with general failure distributions, for the less complicated models. The second part considers more complicated models under the assumption of exponential failure.

An optimum checking procedure is defined to be a sequence of specified check times which minimizes an objective function, which represents the expected loss based on the fixed cost of each check and the cost associated with the time elapsed between system failure and its discovery at the next check. The main results in the form of four theorems are obtained for the case of sequential checking procedures. Several illustrative examples are given. The main results in the literature on periodic checking procedures are summarized. For the case of the exponential failure distribution the problem is treated by maximizing a different objective function -- system availability. (Author in

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part)

REVIEW: This paper appears to be a more detailed and somewhat extended discussion of the topic considered by the author (and associates) in the paper covered by Abstract and Review Serial Number 128. It is a competent mathematical treatment of a problem of considerable practical importance. Twelve references are cited, which should be helpful to the reader who wishes to make a study of the problem. A worthwhile adjunct to the paper is found in the discussion by Dr. Flehinger. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Confidence limits for the reliability of complex systems

AUTHOR: Joan Raup Rosenblatt, National Bureau of Standards, Washington, D. C.

SOURCE: Statistical Theory of Reliability, Proceedings of an Advanced Seminar conducted by the Mathematics Research Center, United States Army, at the University of Wisconsin, Madison, May 8-10, 1962, edited by Marvin Zelen, The University of Wisconsin Press, 1963, pp. 115-148

PURPOSE: To present a general method for estimating the reliability of a system from test results on its subsystems.

ABSTRACT: This paper treats estimation of a probability R interpreted as "system reliability," when the estimate is to be based on data obtained from subsystem tests. A mathematical representation of the dependence of R on subsystem characteristics is assumed to be given. A general formulation of the problem is given leading to a widely applicable method for distribution-free estimation of R and application of the general method is illustrated in several particular cases. Comparisons with "exact" methods, and with alternative approximate methods are discussed. (Author)

It is assumed that the performance of a system can be described by some quantity x_0 which is a function of the values of certain characteristics $x_1,\ldots,x_k$ of k subsystems. I.e., $x_0 = f(x_1,\ldots,x_k)$. Corresponding to x_i, $(i = 1,\ldots,k)$, is the random variable X_i whose probability distribution F_i is given by the distribution of values of x_i in an ensemble of like subsystems of the i th type. The reliability of a system assembled from randomly selected subsystems is defined as $R = \Pr[f(X_1,\ldots,X_k) \geq c]$, where c is a specified number. Under the assumption that $X_1,\ldots,X_k$ are statistically independent, R is estimated as follows: Obtain n_i test results for the i th subsystem, and calculate all $\pi_i\, n_i$ possible values of x_0. The frequency with which $x_0 \geq c$ is the estimate $\hat{R}$ of R. Under suitable conditions, $\hat{R}$ is a minimum variance unbiased estimator for R. Roughly speaking, sufficient conditions are that the set of allowable distributions $F_1,\ldots,F_k$ must be rather large, including a large class of discrete distributions. If the n_i tend to infinity in such a way that n_i is proportional to $a_i m$, where the

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a_i are fixed constants and $m = \min(n_1, \ldots, n_k)$, then $m(\hat{R}-R)$ is asymptotically normally distributed as $m \to \infty$ with variance $\sum_{i=1}^{k} \xi_i/a_i$, where the ξ_i are quantities which can be estimated from the test results, as is illustrated for $k = 2$. Accordingly, for m sufficiently large, a nearly exact lower confidence limit for R can be obtained by the procedure used in determining a lower confidence limit for the mean of a normal distribution with known variance. For moderate m, it may be preferable to regard $\hat{R}$ as binomially distributed.

The general problem is specialized to the case in which the test results for the subsystems are classified as successes or failures, are denoted respectively by 1 and 0, and $x_0 = 1$ corresponds to system success. The system reliability is $R = f(p_1, \ldots, p_k)$, where $p_i = Pr(X_i = 1)$, and its estimate is $\hat{R} = f(\hat{p}_1, \ldots, \hat{p}_k)$. The methods suggested by several authors for determining a lower confidence interval are reviewed.

Another special case considered is that in which the subsystems have the negative exponential lifetime distribution, $\exp(-x/\theta_i)$, $x > 0$. A system success occurs if $x_0 = \min(x_1, \ldots, x_k) \geq$ time t, where x_i is the lifetime of the i th subsystem. It is shown that a lower confidence limit for $R = \exp(-tk/\theta^*)$, where $\theta^* = k(1/\theta_1 + \ldots + 1/\theta_k)^{-1}$, may be derived by using the χ^2_{2kn} distribution to put a lower confidence limit on θ^*. The general distribution-free method reduces in this case to the zero-one case discussed above. For three other special cases an exact lower confidence limit is found. Finally, there is a list of thirty-two pertinent references.

REVIEW: This is an excellent paper. It treats an important and difficult problem in a broad mathematical framework. It is gratifying to learn that the attractive procedure of simulating system results from subsystem test results has certain optimum properties.

In the discussion of Dr. Rosenblatt's paper, it is pointed out by Mr. I. Rotkin that systems may be constructed by assembling subsystems which have desired characteristics, thereby controlling, within limits, the statistical distribution of the characteristics of the assembled systems. Drs. H. Reinhardt and M. Zelen point out the importance of combining prior information about reliability with small sample test data. ##

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Serial Number 895 -1
Codes 821;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Problems in system reliability analysis

AUTHOR: William Wolman, National Aeronautics and Space Administration

SOURCE: Statistical Theory of Reliability, Proceedings of an Advanced Seminar conducted by the Mathematics Research Center, United States Army, at the University of Wisconsin, Madison, May 8-10, 1962, edited by Marvin Zelen, The University of Wisconsin Press, 1963, pp. 149-166

PURPOSE: To discuss briefly two problems in the reliability analysis of complex systems.

ABSTRACT: This paper treats two problems, of which the first is the reliability growth of a complex system. It is supposed that a system can experience two types of failure during a flight test: (1) inherent system failure and (2) embryonic design weakness failure. The former is an inherent characteristic of the system which cannot be eliminated, but the latter can be eliminated by such measures as part substitution or changing a tolerance. It is assumed that there are k type 2 failures, of which one or more may occur during a flight test, but if they do occur, exactly one is eliminated. If a type 1 failure occurs, a type 2 failure cannot be observed. There are constant, independent probabilities q_o and q of the occurrences of the two types of failure. A formula is derived for the reliability of the system after $n \geq k$ flight tests.

The mathematical development is as follows. The system is defined to be in state i, $0 \leq i \leq k$, if i type 2 failures have been eliminated. The probabilities of it remaining in state i or proceeding to state (i + 1) are calculated and a transition matrix P is formed from them. It is pointed out that P^n contains the probabilities of going from state i to state j in n trials. In particular, it contains the probabilities $p_{oi}^{(n)}$ of eliminating i type 2 failures in n trials. The matrix P^n may be calculated from $P^n = Y^{-1} \Lambda^n Y$, where Λ is the matrix of characteristic roots of P, $X' = Y^{-1}$, and X is the matrix of the characteristic row vectors of P. This calculation is illustrated for k = 2. The reliability after n trials is expressed as

$$(1-q_o) \sum_{i=o}^{n} (1-q)^{k-i} \, p_{oi}^{(n)} .$$

The second problem is concerned with two component types, A and B, such that system failure can be due to either a type A failure or a type B failure. Various probabilities are considered, such

as the probabilities that failure of type A will occur, type B will occur, both types will occur, neither will occur, type A will occur before type B, and type B will occur before type A. Special formulae are developed for the special cases when both types are uniformly distributed over the same time interval and when both types have exponential life distributions. Two numerical examples are presented for the first case.

REVIEW: This paper is a competent treatment of the two problems considered. As such, it represents a contribution to the theory and practice of probabilistic and statistical methodology in reliability. This is an area in which much work remains to be done.

Some worthwhile adjuncts to the paper are contained in the discussion. In particular, Dr. Connor showed that the average number of trials to reach state j is easily calculable. Dr. Weiss then gave an explicit solution for the system reliability after n trials, which can easily be extended to the case when the probabilities for embryonic failures differ from each other. ##

Serial Number 896
Codes 431;838;872;
882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of repairable complex systems -- Part B: The dissimilar machine case

AUTHOR: Ronald S. Dick, International Electric Corporation, Paramus, New Jersey

SOURCE: IEEE Transactions on Reliability (formerly IRE Transactions on Reliability and Quality Control), vol. R-12, March, 1963, pp. 1-8 (presented at the 25th Annual Meeting of the Institute of Mathematical Statistics, September 10, 1962)

PURPOSE: To present a generalization of a reliability model for repairable systems which was given in a previous paper.

ABSTRACT: In Part A of this reliability study (see Abstract and Review Serial Number 504) it was assumed that one has a structure composed of A similar subsystems of which as many as N may fail and the system function will be unaffected. If between N+1 and L subsystems fail and the time spent in these states is less than t_o, after which the system is returned to states 0 to N for at least time t_1, the system function is also unaffected. Only if the time constraints t_o and t_1 are not met, or if the system falls into states between L+1 and A, is the system function a failure. This paper presents a generalization of the model given in Part A. The assumptions that failure and repair times are exponentially distributed are retained, but the model equations are changed so as to enable treatment of the following cases.

(1) The label case: it is necessary to know which of the similar machines are broken down in order to decide if a system failure has occurred.

(2) The parameter case: the values of the failure and repair rates are not the same on each machine.

(3) The type of failure case: the system goes from state i to i + j after a failure, $j \geq 1$, and to i - k after a repair, $k \geq 1$, whereas in Part A j = k = 1 only.

A procedure for finding dissimilar machine model equations with time delays before failure and time restoration constraints after repair are given. (Author in part)

REVIEW: As indicated above, this paper is a continuation of the work in the paper covered by Abstract and Review Serial Number 504. The reader will find it necessary to have the earlier paper available, in part because the definitions of the symbols are not repeated in this paper. The reviewer has not checked all of the mathematical details, but anyone wishing to use the results will find it desirable to follow the derivations closely. ##

Serial Number 897
Codes 773;844;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: High-power dynamic life tests of transistors

AUTHOR: K. W. Doversberger, Delco Radio Division, General Motors Corporation, Kokomo, Indiana

SOURCE: IEEE Transactions on Reliability (formerly IRE Transactions on Reliability and Quality Control), vol. R-12, March, 1963, pp. 9-17 (presented at the IRE WESCON, Los Angeles, California, August, 1962)

PURPOSE: To describe a program, the equipment, and results for dynamic life tests of germanium power transistors (Delco 251M-1).

ABSTRACT: In an effort to correlate failure modes observed on field return transistor failures to life test results, Delco Radio initiated a new type power pulse life test program. The program was added to the normally accepted storage and dc operating programs which did not supply adequate information on burn-through or punch-through failures. The test matrix was designed around a unique three-dimensional dynamic failure rate graphical model. This paper describes the engineering and development of the high-power test equipment required to prove the model. A number of photographs and illustrations of the equipment developed have been included. The design of test circuits for maximum reliability for dynamic testing are also discussed. At the conclusion of the paper, the actual results of the program which are applicable to circuit designers are presented.

There were two main types of tests: (1) A 400 cps multivibrator circuit providing 100 watts/pair to a resistive load, and (2) Pulses, 1 ms long, at power levels of 150, 300, and 600 watts peak power and voltages of 30 and 60 v (where possible). The tests were quite successful and rating charts were established of failure rate vs temperature and type of test. All types of operation had a factor of about two increase in failure rate for 10°C temperature rise. At 60°C junction temperature, the failure rates (%/1000 hr) were about

0.8	10a/60v pulse	0.01 switching, 5% duty cycle
0.06	10a/30v pulse	0.006 storage or 1a/20v dc
0.04	0.5a/30v dc	

(all based upon observed acceleration factors). (Author in part)

REVIEW: This paper is a rather brief, though satisfactory, presentation of the program. The author in a private communication has indicated that the quoted results are based upon 60% confidence limits, and that an exponential distribution was assumed. He has also stated that the complete testing program has been summarized in a Final Technical Report to Autonetics, and that the basic transistor covered by this report has been further improved since the 1961 tests. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability, democracy, and man in systems

AUTHOR: A. M. Freed, Human Factors Staff, Reliability Division, Liquid Rocket Plant, Aerojet-General Corporation, Sacramento, California

SOURCE: IEEE Transactions on Reliability (formerly IRE Transactions on Reliability and Quality Control), vol. R-12, March, 1963, pp. 18-22 (also Proceedings of the IEEE, vol. 51, pp. 1005-1008, July, 1963 and Industrial Quality Control, vol. 20, July, 1963, pp. 8-11)

PURPOSE: To discuss the question of man's value in the system and why the topic has arisen.

ABSTRACT: The very question of man's being an asset or liability to the system shows that we have not properly taken man's role into account. Human factors engineers have done much good where their efforts have been utilized in the design of equipment, but this is only a small portion of the problem. Things like design reviews have gotten partially at some of the other human problems.

There needs to be an overall awareness that in any and all systems, man is ubiquitous and that unavoidably he will make errors. The system should be designed to motivate people to make as few of these as possible themselves, and perhaps more importantly to work together in such a way that the mistakes of others are caught before they do harm. This requires attitudes of cooperation, new methods of supervision and training, and a realization that system goals and performance can become the goals of individuals. There are costs to such an approach of course, but for high reliability redundancy in people may be both the only way and the best way.

REVIEW: This paper is useful in pointing out that designers must view people in their systems as technical problems to be planned for if the systems are to be reliable. It is essentially nontechnical in that it is a general discussion of the problem. It does not go into details on the implementation of the ideas. Questions will arise, for example, as to how redundancy in people may be put into practice. Many problems will not be overcome until designers feel a personal need to solve them. One possible solution, although not suggested in the paper, might be to have designers serve an "apprenticeship" in the actual use of equipment, to see at first hand what the problems are. (The presence of the article in three places (see SOURCE) without adequate cross references is to be deplored.) ##

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882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effectivity: its application to a long-lived space system

AUTHORS: K. S. Packard and M. H. Goldstein, Airborne Instruments Laboratory, A Division of Cutler-Hammer, Inc., Research and Systems Engineering, Deer Park, New York

SOURCE: IEEE Transactions on Reliability (formerly IRE Transactions on Reliability and Quality Control), vol. R-12, March, 1963, pp. 23-31 (presented at the Sixth Symposium on Ballistic Missile and Aerospace Technology)

PURPOSE: To propose and illustrate a measure of "dependability" of a system.

ABSTRACT: In a complex system, there are several degrees of performance and it is difficult or impossible to apply the strict definition of reliability to the system. Another measure of "dependability" is introduced and called <u>effectivity</u>. The concept of performance loss is introduced and a <u>loss coefficient</u>, $a_i(t)$, is defined as the fractional loss in performance associated with the i th state at time t. The loss in over-all performance is

$$\mathcal{L}(t) = \sum_i a_i(t)\ P_i(t),$$

where P_i is the probability of being in the i th state. Effectivity is

$$\epsilon(t) = 1 - \mathcal{L}(t).$$

The average of $\mathcal{L}$ is taken in the usual way, that is

$$L(T) = [\int_0^T \mathcal{L}(t)\ dt]/T,$$

and the average effectivity is

$$E(T) = 1 - L(T).$$

If A_i is either 0 or 1, then E reduces to the availability; if no repairs are possible, ϵ is the reliability. An illustration is given of the use of this concept and several theorems are presented (without proof) to make the calculations easier. An appendix shows how the state probabilities are calculated from transition probabilities.

REVIEW: The concept introduced here is a good one. Since the paper was submitted 18 months before publication, the concept is no longer really new, but it deserves the attention of all who are interested in adequate measures of "dependability" of systems. (The example was not checked for internal accuracy.) ##

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Serial Number 900
Codes 821;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A model for the reliability estimation of space systems

AUTHOR: William Wolman, Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, Maryland

SOURCE: IEEE Transactions on Reliability (formerly IRE Transactions on Reliability and Quality Control), vol. R-12, March, 1963, pp. 32-39 (presented in part before the Washington Chapter of the IRE Professional Group on Reliability and Quality Control, Washington, D. C., September 14, 1961)

PURPOSE: To present a probabilistic model in set form for calculating overall system reliability.

ABSTRACT: The general problem and need for reliability estimation and prediction is discussed. Various types of reliability estimates are considered. A general probabilistic model is defined in a set-theoretic framework. The model considers the operation of a system over several time-periods where the operating mode of the system may change from period to period. A general expression is given for the reliability of a system and also upper and lower bounds. Several theoretical examples are shown by using the model and it is shown how particular applications yield different results depending on the physical situation considered. In addition brief mention is made of a particular reliability study, namely a certain phase of the 3-orbit mission of Project Mercury. (Author)

REVIEW: This is a general theoretical paper. It does not actually solve any problem, but it provides a framework for solving the problem. The use of set theory would appear to be very appropriate for dealing with relatively complex systems; it may in fact be the only reasonable approach. It is evident that the paper has been competently and carefully prepared. It will, of course, be necessary for any user of the ideas to follow through the derivations in detail. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Test duplication cut with data exchange

AUTHOR: Barry Miller, Assistant Avionics Editor

SOURCE: Aviation Week & Space Technology, vol. 79, July 15, 1963, pp. 87, 89, 91, 92

PURPOSE: To present a description of the Interservice Data Exchange Program (IDEP).

ABSTRACT: Interservice Data Exchange Program (IDEP), a three-service effort to eliminate unnecessary duplication in component parts testing through the exchange of reliability data among missile and space contractors, currently is circulating about 6,000 recent test reports. Between 300 and 400 new reports are entering its circulating bank each month.

Now starting its fourth year of full-scale activity, IDEP has saved aerospace parts users time and money--conservatively estimated to run into many millions of dollars. Today, participants in the program number about 130 of the nation's leading aerospace contractors situated at about 200 scattered facilities, among which are almost all large defense and space users of avionic and associated parts.

The reporting and distribution procedure is described briefly. The role of comments by government engineers on the individual reports is outlined. A plan to report on tests in progress (TIP) is mentioned. Some examples are cited of the quantitative and qualitative savings attributed to IDEP. It is pointed out that the Armed Services Technical Information Agency (ASTIA) began publishing late last year in its Technical Abstracts an abbreviated form of IDEP summary cards on selected tests, but that the ASTIA reports are not made available as quickly as are the original summaries. (Author in part)

REVIEW: This is a worthwhile description of IDEP, which will be of interest to those who are not already aware of the existence and value of this program. IDEP and three other data exchange programs were described in the paper covered by Abstract and Review Serial Number 877. ##

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Serial Number 902
Codes 811;862

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--it's all in the viewpoint

AUTHOR: Cdr. A. M. Carter, Jr., USN, Naval Air Station, Quonset Point, Rhode Island (now with The Cunneen Company, 1622 Chestnut Street, Philadelphia, Pennsylvania)

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 120-124, April, 1962

PURPOSE: To treat the problem of reliability as viewed by a naval overhaul and repair station (O&R).

ABSTRACT: For combat effectiveness, it is absolutely necessary that "proper" or "required" reliability be restored to an item during overhaul. For equally compelling economic reasons, it is necessary that no more repair effort be expended than is required to restore reliability to the "proper" level. The reliability of in-use weapons must be maintained for a long number of years. A real problem is to decide what is meant by "properly". There are no reliability guides in the manuals and much is left up to individual guesswork. The O&R performs reliability analysis because of fleet squawks (10%), O&R production problems (60%), "high frequency failure" reports (13%), contractor reliability tabulations (10%), accident reports (5%) and logistics problems (2%). The content of a reliability analysis includes the following: causes of failure, method of detecting failure, specify design requirements, assess reason for failure, and specify corrective action. These analyses are made only in special critical cases. Normally the depth of rework is determined by review of logbook, examination, repair as necessary at the bench, and surveillance by quality control. The present system lacks usable reliability indices and this should be corrected now. The raw information required is available now, and is being generated on a 24 hour basis by the best of laboratories--the Fleet user! The repair effort should then be gaged to just restore this "proper" level of reliability.

REVIEW: This is a "management" type paper, but in a different area than usual. The problems presented here are real ones and do need solution. It is somewhat difficult to see just how assigned reliability numbers can be translated into decisions of "fix" or "not-fix" when the correlation to reliability of the "fix" is not known. However, one of the fundamental jobs of "engineering management" is to do just that--to correlate the "fix" or "not-fix", and the "degree of fix" to required reliability of the item. For effective technical management, this "required" reliability must be specified for an item in numerical terms, and the extent of repair and rework specifically related to this level of reliability. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Cost-reliability relationships of launch vehicles

AUTHORS: D. S. Edmonds and D. G. Samson, The Boeing Company, Aero-Space Division, P. O. Box 3707, Seattle 24, Washington

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 125-129, April, 1962

PURPOSE: To relate development costs and missile failure costs to get an optimum reliability.

ABSTRACT: Empirical formulas are given for the total system cost as a function of the total number of launches, for the reliability of the launch vehicle as a function of the total number of launches, and for successful launches as a function of launch vehicle reliability and the total number of launches. Since development launches can be counted in the total number of launches, it is possible to express all development costs as equivalent launches. The reliability is improved during development by a design simplification, testing, and greater design margins of safety. The reliability to which a system should be developed before the operational program is initiated increases as the number of required successful launches increases. An exercise is included in this paper which indicates that payloads should be included on all research and development launches, unless the payloads are very expensive in relation to the vehicle cost. The inclusion of payloads on all launches will result in the minimum cost program to achieve a specified number of successful launches. Several curves and charts are shown.

REVIEW: This is a short paper and will be useful for approximate calculations insofar as the empirical equations fit the case in hand. In general, the exact fit is not known in advance and precise predictions are not to be expected. Many such calculations as these are intended more to get a feel for the way things are or could go than to provide specific recommendations. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Economics of reliability, maintainability and availability in complex systems

AUTHOR: A. S. Goldman, Technical Military Planning Operation (TEMPO), General Electric Company, P.O. Drawer QQ, Santa Barbara, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 130-141, April, 1962

PURPOSE: To show how availability, cost, reliability, and maintainability can be traded off to satisfy some fixed criteria.

ABSTRACT: Availability is defined as total uptime/total time, and is thus determined by the system mean down time and mean time to failure. If the latter two are changed, the system cost will in general change. Thus if cost is fixed, availability can be maximized; or cost can be minimized for a given availability. Similar statements hold true on the component level where availability or reliability and maintainability of the components can be adjusted to give the best value of some parameter within a given constraint.

A brief description is given of pulse train simulation as it relates to support concepts, provides an analytic interpretation of the concepts and a physical basis for economic analysis. Support concepts are viewed in the framework of resource allocation; a formulation is given of analytical relationships among the key support characteristics of reliability and maintainability relative to the choice criteria of costs and value in determining optimal combinations of reliability and maintainability on a system or component level. A major portion of the discussion is devoted to the cost and value of reliability, maintainability and availability. (Author in part)

REVIEW: The ideas on which this paper is based may be quite sound, but the message is not at all clearly presented. This may be due to the omission of details which the reader will need for proper interpretation of the discussion. Some examples of this are the following. (1) Maintainability is defined on p. 130 as "mean system downtime," and on p. 140 as "the probability that the system can be returned to service in a given period of time." Clearly these are not the same. (2) The actual constraints on the system are not clearly spelled out. (3) The definition "Δa = change of a unit of time of the availability" (p. 135) is difficult to interpret in view of the definition of availability (see ABSTRACT). (4) No proofs or derivations are given for the equations cited. However, 20 references are listed. In addition to these, the author in a private communication has suggested that the reader see also the following TEMPO reports: RM62TMP-42, RM62TMP-7, RM62TMP-39, and RM60TMP-70. ##

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Code 845

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some facts on the Interservice Data Exchange Program (IDEP)

AUTHOR: Ed L. Battle, Captain, USAF, Ballistic Systems Division, Air Force Unit Post Office, Los Angeles 45, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 142-146, April, 1962

PURPOSE: To provide information on IDEP and to indicate its relationship to other exchange programs.

ABSTRACT: The program was instituted to reduce parts testing costs and time by sharing information already obtained. IDEP is not intended to provide generic failure rate data, but rather to eliminate/ shorten tests, to confirm doubtful tests, to alter and guide tests by using the experience of others, to suggest better parts or vendors, etc. IDEP has grown and now permits exchanges on planned tests and proposed specifications, restriction of information received to limited areas, a cumulative monthly index of reports, etc. The program has grown in scope, services and number of participants. Savings are estimated to be large, especially those due to indirect benefits. Other exchange programs are listed and compared with IDEP. A bibliography (six papers) is given for further information. It is suggested that prospective participants address inquiries to IDEP Office, Aerospace Corporation, P. O. Box 95085, Los Angeles 45, California.

REVIEW: This is a good summary of facts regarding IDEP as of the date of the paper. More recent papers on this and other data exchange programs have been covered by Abstracts and Reviews Serial Numbers 877 and 901. The program deserves all the publicity and support it can get. It is important that designers have access to hardware-oriented information. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of industries' reliability organizations

AUTHOR: Vincent Bracha, Major, USAF, Ballistic Systems Division, Los Angeles

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 147-168, April, 1962

PURPOSE: To present an analysis of the results obtained from two questionnaires on reliability organization.

ABSTRACT: Various types of reliability organizations have been adopted by many aerospace and electronic industries. Form and operation of the organizations differ in detail, scope, and position within companies due to differences in over-all company product line, structure, and contractual requirements. This survey examines the current status of reliability organizations as they have developed during the post-war years.

Expounding reliability theory is all very well, but in tracing the transition from theory to practice, the collective experience and knowledge of industry is invaluable. The method most fruitful for drawing from this reservoir of virtually untapped information has been a survey of the companies and persons in industry now coping with the reliability problem. In the spring of 1960, the Navy submitted a 20-question reliability organization questionnaire to 196 of its contractors. The purpose of this questionnaire was to solicit information concerning the organizational alignment and functions of reliability activities in industry. In the fall of 1961, the Air Force Ballistic Systems Division conducted a similar survey, distributing a 10-question questionnaire to 80 participating contractors. The Air Force made no effort to limit its questionnaire to strictly Air Force contractors. This, coupled with the fact that most of these industries serve both the Army and Navy, gives justification for the assumption that considerable overlap exists between the two surveys.

It is the intent of this paper to collate and cross-reference the Air Force and Navy surveys...to analyze and draw conclusions where reliability is now organized in defense industries, and what the trends are in order to provide recommendations concerning future organizations. (Author in part)

REVIEW: This paper should be of considerable interest and value to those who are concerned with the organization of reliability functions in the defense, aerospace, and electronics industries. It summarizes a considerable volume of data on all of the discernibly relevant aspects of the organization problem. ##

Serial Number 907
Code 812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability as a function of institutional leadership

AUTHOR: Richard H. Brenneman, Advanced Technology, NASA Western Operations Office, Santa Monica, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 169-173, April, 1962

PURPOSE: To suggest how management can create a sense of "pride in reliability" in workers.

ABSTRACT: Equipment is requested, purchased, designed, built, used, and repaired by people. In all these and allied activities, good performance by all concerned is essential to reliability. How then to motivate all these people; how to create a "pride in reliability"? This is done by providing rewards to those who perform well. The form of the rewards may be different for the engineer and the factory worker. All want challenging assignments, recognition by their peers, and (not least) more money. For example, special clothing for the best factory workers, or awards that can be taken home and proudly displayed, are good ways to encourage and reward success. Another example is to use association. We associate delicate expensive things with cleanliness, high polish and "fancy trappings" -- the "Tiffany box" concept. Parts boxes can be lined with gold cloth. We handle expensive things with care--make the high-reliability parts look expensive and delicate; then we will handle and use them accordingly. It is, of course, essential that management exercise the leadership necessary to put these ideas into operation. This point is often overlooked, but cannot be overemphasized.

REVIEW: This is a "management-type" paper, but it should be of interest to the design engineer since people are part of his job. Some of the reasoning here is somewhat loose; for example, workmen are said to have lost pride, which must be reinstilled. But other statements show that pride was not lost, but merely transferred from quality to, say, quantity. The problem is to change the object of pride back again. Likewise, the statement that "everyone wants to know how he is doing" can perhaps be stated more realistically as "everyone wants to be told about it when he is doing well; otherwise he would rather avoid the subject." In other words, it may be that best results in dealing with the human element can be obtained through a judicious use of emphasizing the positive.

All in all, the paper attacks a basic problem -- how to get everyone to care-- and does so rather effectively. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Are reliability motivators really effective?

AUTHOR: Kenneth S. Teel

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 179-182, April, 1962

PURPOSE: To point out that the effectiveness of various methods of motivating workers to perform their work in a reliable manner can be measured quantitatively.

ABSTRACT: Two studies are described. The first, which involved an evaluation of the effectiveness of safety posters in the United States Air Force, measures the extent to which personnel correctly recognized posters that they had seen before. The second study, which was incomplete at the time of writing, measures employee attitudes in the integrated assembly area at Autonetics. The measures were developed for use in evaluating the influence of closed circuit television on worker reliability. As a result of these studies it is recommended that in any program designed to encourage workers to perform their work more reliably, some means of measuring its effectiveness should be included as an integral part of the program.

REVIEW: The main recommendation of this paper is that any program designed to encourage workers to perform in a reliable manner must have built-in methods of evaluation. This cannot be over-emphasized, and is unlikely to be overlooked by the competent engineer or manager. However, the difficulty arises in determining the method of evaluation to be used. The author has little to contribute here and tends to equate employee attitude toward a program with its effectiveness. The first study assumes that one measure of the effectiveness of any program designed to change work habits and attitudes is the extent to which employees "get the message". While it is a necessary condition for a change in the desired direction, it does not necessarily result in an improvement in worker performance.

In the second study, employee attitudes toward the programs were used as a measure of effectiveness since employee attitudes are related to job performance, which may be beneficially affected if employees react positively to the programs. The choice of measure of effectiveness was not too wise since there are too many assumptions involved. One is uneasily reminded of the Witch Doctor's explanation of an eclipse of the sun: "... if we beat the drums when the moon gobbles up the sun it will let it go and the sun will shine again". Summing up, this is a woolly paper for the reliability engineer and does not have much bearing upon reliability per se. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effective indoctrination to accelerate the acceptance of reliability controls

AUTHORS: Donald R. Thibodo and Mark L. Nigberg, Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 183-190, April, 1962

PURPOSE: To discuss methods suitable for the indoctrination of workers in the acceptance of reliability controls.

ABSTRACT: An initial objective of any operational reliability program should be the indoctrination of plant personnel so that reliability controls are accepted and practiced in all phases of development and production programs. This paper discusses the four basic elements which contribute to successful indoctrination. It also provides a typical program evaluation emphasizing the necessity of developing interest in the subject of reliability, introducing the individual to the company reliability program, training the individual in the reliability aspects of his job, and forming his attitudes through group discussion. The typical program outlined is designed to indoctrinate all individuals who directly influence product reliability. A number of communication media are used in effective indoctrination. The media must be analyzed and incorporated into the indoctrination program so that they precipitate reliability understandings and assist in the development of reliability consciousness. Indoctrination should be used to implement the reliability program. Effective indoctrination will shorten the time required to establish adequate reliability controls in the company. (Authors)

REVIEW: The title of this paper should have been: "Some opinions on how to indoctrinate workers in the acceptance of reliability controls". This is a "management" type paper on how to apply "Madison Avenue" methods to reliability control. A major point which is overlooked in the advocacy of these methods is that the employees undergoing indoctrination have been exposed to the exaggerations and half-truths of modern advertising for so long that they automatically close their minds to anything that resembles a commercial. The better educated workers (the authors claimed an audience from Ph.D's in physics to operators who had not finished high school) will probably feel that some of the methods suggested are an insult to their intelligence. The operators themselves may be able to suggest better methods.

Throughout the paper there is the implication that formal education in reliability theory is not as useful as the formation of proper attitudes and the use of the proper motivational appeals. ##

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Serial Number 910
Code 832

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction of personnel subsystem reliability early in the system development cycle

AUTHOR: Gerald F. Rabideau, Space Technology Laboratories, Inc., Los Angeles, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 191-198, April, 1962

PURPOSE: To discuss a preliminary partial solution to the problem of identifying the unreliable components of the personnel subsystem early enough in the system development cycle to permit economical and effective correction.

ABSTRACT: This paper considers the requirements for a method of predicting personnel subsystem reliability in terms of the human error potential which is inherent in the design. A new concept of error causation is presented, which accounts for human limitations, design deficiencies, environmental factors, and the interaction of all of these in creating a potential for human unreliability.

The proposed method is skeletal; much work remains to be done in order that it can be applied with a minimal expenditure of analytical time. Some of this work is currently under way. The paper attempts to show the relationship of the method to overall system development and especially to system engineering, analysis, design, and personnel subsystem development.

REVIEW: Although this paper deals with a subject that is in the "never-never" land between engineering, sociology, and perhaps psychology it is not marred by an overextensive use of disciplinary jargon. The section on the basic characteristics of human error is quite interesting and will be of some use to the engineer concerned with the effective interplay of man and machine. There are thirteen references. ##

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Serial Number 911
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Personnel subsystem reliability for aerospace systems

AUTHOR: Melvin S. Majesty, Captain, HQ Air Force Ballistic Systems Division, Los Angeles, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 199-204, April, 1962

PURPOSE: To describe the concept of the personnel subsystem.

ABSTRACT: In the development of aerospace systems the United States Air Force considers the human component in terms of the personnel subsystem (PSS); this concept integrates all the system development processes and products which have to do with man in the system; the concept also enables the Air Force to pursue a development and test program for the human component similar to that for the hardware components. A PSS figure-of-merit is being sought which will then be incorporated into mathematical models of system reliability and effectiveness. The PSS concept and the figure-of-merit emphasize the development of human performance. Consequently, human reliability can be compared to hardware reliability in the system reliability program. A short discussion of the factors affecting human reliability in the Air Force is given.

REVIEW: This is an excellent account of the United States Air Force personnel subsystem concept. The paper is well worth reading as an example of what can be done to make an apparently dry subject come alive; at the same time no relevant facts are omitted and the information density is considerably higher than in most papers of this type. One is left with the feeling that the Air Force, and this author in particular, know exactly what they are doing in the difficult field of human reliability.

This author is one of the few in this field who should be encouraged to write more papers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The prediction and measurement of human reliability

AUTHOR: D. Meister, Head, Human Reliability Requirements Group, General Dynamics/Astronautics, San Diego, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 205-212, April, 1962

PURPOSE: To propose a method for the measurement and prediction of human reliability.

ABSTRACT: Only tentative efforts have been made to predict and measure the reliability of personnel performance which is an essential component of, and input to, overall system reliability. It has been stated that as much as 50% of equipment failures may result from human error. Hence reliability engineers have been forced to conclude that "human reliability" (HR) must be considered in addition to equipment reliability. HR is defined as the probability that a job operation will be successfully performed by personnel at any required stage in system operation within a criterion time period (if one exists). The definition of successful job performance is performance without an operator error resulting in failure to complete the job. A simplified version of a possible method for measuring HR is presented, which is based on the equation $HR = 1 - E/P$, where E is the number of occurrences (errors or excessive time performances) leading to job non-completion, and P is the number of times that the particular job operation was performed.

The problem of the definition of error is discussed with particular reference to catastrophic errors. The need for a pool of HR data, to enable the reliability engineer to predict human reliability, is noted. Some results of field testing in connection with the installation, checking-out, maintenance, and firing of Atlas E and F missiles are discussed.

REVIEW: This is an exploratory paper on the subject of human-initiated failures. As the author has pointed out, much remains to be done in this field. If the paper stimulates increased interest in the problem of quantifying the evaluation of the reliability of the human element, it will have served a useful purpose. This topic has been discussed elsewhere by the same author (see Abstract and Review Serial Number 240), and by others (see Abstracts and Reviews Serial Numbers 188, 196, 248, and 267). Other studies on human factors as they affect reliability and maintainability were covered by Abstracts and Reviews Serial Numbers 480, 502, 565, 567, 712, 840, 841, 842, 843, 854, 910, and 911. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Bowdlerization

AUTHOR: Bertram J. Smith, Personnel Subsystem Program Scientist, Missile and Space Vehicle Department, General Electric Company

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 220-223, April, 1962

PURPOSE: To discuss the "human factors" papers presented at this symposium.

ABSTRACT: "Bowdlerization" is the deleting of indelicate references from a piece of writing. The foregoing papers are examined for signs of Bowdlerism but bear little evidence that any author Bowdlerized. But several papers refer to studies by Shapero or Cooper which revealed far more human error in missile systems than written reporting procedures would indicate.

However, a critical look at recent missile failure reporting codes makes one wonder if prosaic equipment failures are not still often the disguise under which indelicate human errors hide. One also begins to wonder about what is not said in papers such as Majesty's, where oblique reference is somewhat gingerly made to the facts of failure life.

It is not hard to be convinced that, call it Bowdlerization or what you will, people charged with Reliability analysis are provided no better reports of human error today than those available to them four or five years ago when Alluisi worked with Shapero on missile failure reporting bias.

And the more-than-half-way solution proposed by Cooper, that failure reports include environmental and personal information, is still an excellent start to providing information necessary to identify human error upon analysis. Even though this start is short of the checklist goal of human performance deviation, we must conclude that just about nothing seems to be happening to "de-Bowdlerize" failure reporting. (Author)

REVIEW: This paper is entertaining to read and at the same time is concerned with a serious and important problem in the human factors field. As the author has said "failure analysis .. will feed little back to Personnel Subsystem design, for Human Engineering, procedures or otherwise, until reliability field failure reporting catches up with the rest of Personnel Subsystem state-of-the-art in identification of human factors in weapon system behavior." The author is concerned in this paper with emphasizing the existence of the problem. The big question is: "what can be done about it?" This would seem to be an important area of research for the psychologists (and others) in personnel subsystem programs. ##

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R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

TITLE: Reliability improvement program

AUTHORS: H. E. Frederick and A. H. Richards, Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 224-230, April, 1962

PURPOSE: To present a mathematical model analysis of reliability improvement based upon failure mode detection.

ABSTRACT: Statistical demonstration of contractually specified missile component reliability requirements has not generally proven to be economically feasible. As a consequence, the customer now requires that the achievement of reliability goals be accomplished on the basis of continuous system development through reliability improvement programs.

The probability of detecting modes-of-failure in an equipment of marginal reliability (that is, close to the design objective) is so low that large sample sizes are required to do so with any degree of confidence. Equipment which is most likely to be improved during an improvement program is that which contains the fewest number of modes-of-failure and which has the highest inherent unreliability. The more subtle and infrequent the mode-of-failure, the less likely it is to be experienced and corrected. Correction of a mode-of-failure upon first experience is extremely important. Sample sizes required to attain the same level of reliability are more than doubled if a failure mode is not corrected until after it has been observed a second time. Sample sizes required for attaining reasonable reliability levels are not unrealistic if inherent modes-of-failure occur with relatively high probability, and if there are only a few inherent failure modes present. Sample sizes of the order of 20-40 are sufficient to attain 99 percent reliability if two (2) or less failure modes are present and inherent reliability is less than 90 percent.

Accelerated testing may be used in order to raise the probabilities of failure for the various modes to the point where reasonable numbers of tests can find them. Not all modes are equally accelerated and this can cause some problems, although usually one has little choice but to accept these problems. (Authors in part)

REVIEW: The results in this paper are handy to know. While the mathematics involved is not very complicated in principle, it would be tedious to go through these derivations to get the results and plot the curves. They will probably be used only to give a rough idea of what to expect, but this is very useful in itself. ##

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Serial Number 915
Codes 522;824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability through propellant research and development

AUTHORS: Einard S. Haniuk and Bruce L. Baird, Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 241-251, April, 1962

PURPOSE: To describe a multifactor experiment for determining the performance of a solid propellant as a function of many dependent variables.

ABSTRACT: One link in the assurance of missile reliability is the full knowledge of the limits to which the composition of the propellant can change and still meet ballistic requirements... A modified central composite design was adapted by Thiokol Chemical Corporation to investigate the effects of variations in all components of a propellant in a single study. Multiple variable equations were computed from collected data to express the performance of dependent variables, such as density, stress, strain, modulus, and burning rate, as functions of the independent parameters, i.e., percentages of polymer, curing agent, oxidizer, and high energy additives.

Propellant performance requirements can be imposed on the multiple variable equations for the appropriate parameters. These equations are in turn superimposed on a space-oriented model which depicts the over-all composition limits. This method allows conventional sigma limits to be established, or permits replacement of conventionally expressed limits by more comprehensive multifactor limits based on the entire set of performance equations. Propellant which would have been rejected on the basis of conventional sigma limits is determined to be usable because of our increased knowledge of variation effects. This paper details the methods used to set up the program, the computation of the performance equations, and subsequent interpretation of the equations by mathematical and graphical means. The use of the equations in setting acceptance limits and supporting the reliability program is also demonstrated. (Authors)

REVIEW: This paper has little to do with reliability per se, but does describe one step in learning about the behavior of solid fuel so that its performance can be predicted more accurately. It is useful as an example of the application of a response surface approach in analyzing a reliability problem. The approach is discussed in a fair amount of detail; numerical results and illustrative figures are given. Adequate references are cited for the assistance of those who may desire more details on the statistical analysis. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability tradeoff: circuit redundancy vs circuit checkout

AUTHOR: Weldon E. Ihrig, Systems Analysis Group, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Electronic Design, vol. 11, May 10, 1963, pp. 74-77

PURPOSE: To show that periodic checkout and maintenance can greatly reduce the failure rate of a redundant system.

ABSTRACT: If a system has (logically) parallel redundancy--operating all the time--the reliability is improved over the non-redundant system. The improvement in MTBF is not too great, however. If the system is periodically checked and defective parts are replaced, the system MTBF can be tremendously improved. As an example: an indicator lamp has an MTBF of 80 khr. If two are used in parallel, the new MTBF is 120 khr. If there is inspection with necessary replacement every 0.168 khr (weekly), the new MTBF is 40,000 khr. The improvement due to maintenance is a factor of over 300.

REVIEW: The principle involved here is a good one under circumstances where the mathematical model is adequate. The reviewer's main criticism is the lack of clear definition of terms, and the considerable amount of interpretation required. For example:

1. It is not at all easy to see what Figure 1 means.
2. It is not clear from the text what is meant by Equation (4). In fact, the T_{ave} quoted there is the mean time from one repair, scheduled or unscheduled, to the next.
3. The derivation given for Equation (5) is unnecessary and misleading, since the system lifetime distribution (in contrast with that of the components) is not exponential. The quantity m_T is properly defined as the mean time until system failure under the given maintenance policy. This fact is easily proved rigorously using the stated assumptions. The explanation following Equation (6) is not very clear.
4. In example (1), Equation (8) and the preceding formulae are incorrect. Equation (9) is given correctly, however. There are also various misprints. For example, Equation (2) has a "d" with no obvious meaning.

Properly interpreted, the idea of the paper is good, particularly in its application to the examples quoted, where the assumptions are likely to be valid. It should perhaps be noted that the exponential assumptions for the failure distributions of the components enter in an essential way, in order to effectively "return the time to zero" at each repair or maintenance instant.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: American approach to reliability

AUTHOR: M. C. Wooley, Bell Telephone Laboratories, Incorporated

SOURCE: Radio & Electronic Components, vol. 4, pp. 410-414, May, 1963

PURPOSE: To present the Bell System approach to reliability.

ABSTRACT: The Bell System has recognized the need for high reliability in electronics for over 50 years. American industry can now produce "Minuteman" components with a failure rate of 0.0004%/1000 hr. The Bell System philosophy for submarine cable has been:

1. Use only those types, materials and physical constructions which have proven, by field performance, that they are capable of reliable operation.
2. Engineer for the specific application and environment with special attention being given to those factors which experience has shown are the usual causes of failure.
3. Manufacture in such a manner as to produce a product as nearly perfect as possible, i.e., rigidly control raw materials, processes and the end product.
4. Thoroughly screen the finished product to eliminate all individuals which may be deficient in any way as a result of some defect not detectable by inspection or short-time tests.

(The author then elaborates briefly on each topic.)

When the reliability of any device has been improved by the removal of all systematic or deteriorative mechanisms, the remaining causes of premature failure are most likely to be the result of rare mishaps in construction or use. These can be so diverse in nature that their complete elimination is most unlikely. It has been shown, however, that for established types of passive components, systematic and common types of failures can be eliminated and only the accumulation of much more field experience will tell what failure rates have actually been achieved. (Author in part)

REVIEW: This is a general, informative article on the implementation of reliability objectives for electronic systems. It presents a broad picture--not specific information. It will probably be of little interest to the informed American designer. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Proceedings of the Relay Conversazione at the Royal Radar Establishment

AUTHOR: (Editorial Matter)

SOURCE: Electronic Components (incorporating Radio & Electronic Components), vol. 4, pp. 587-592, June, 1963

PURPOSE: To summarize the papers presented at the conference.

ABSTRACT: Four papers and the subsequent discussion are summarized here. The first two papers dealt with relay problems and relays vs semiconductors. The conclusions were that many applications are suitable for relays, although many are not. The discussion dealt with methods of testing relays and with weeding out the infant failures beforehand. The next two papers were on relay requirements for modern circuits and contact theory/research. The discussion involved contact lubrication, contact wipe, plug-in relays, etc. The full proceedings may be obtained from Mr. N. E. Hyde, Royal Radar Establishment, Malvern, Worcestershire, England.

REVIEW: This summary is too brief to enable adequate comment. There were some differences of opinion about reliability factors among the discussants. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The importance of telecommunications reliability

AUTHOR: (Editorial Matter)

SOURCE: Electronic Components (incorporating Radio & Electronic Components), vol. 4, pp. 598-599, June, 1963 (taken from Dr. G. Sarkzy article in Winter Edition of Hungarian Heavy Industries)

PURPOSE: To discuss ways of improving the reliability of equipment.

ABSTRACT: There is a period in the life of equipment when its relative (conditional) failure rate (P-factor) is constant. Main causes of failures are chemical or electrochemical processes. The performance parameters of electronic tubes can deteriorate so badly as to constitute a failure (examples are given). The period of constant P-factor begins after about 1000 hours. After this time the exponential failure law holds. The P-factors of parts vary among themselves and with operating conditions. Modern equipment requires very small P-factors. Trouble-shooting is important; standby equipment can often be of considerable value.

REVIEW: It is not known whether this article is the original paper referred to or just a condensation thereof. It is short and general, and repeats the usual introductory remarks about reliability, but adds nothing else. It will be of little value to anyone but the layman. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor versus relay

AUTHOR: R. E. Stoffels, Automatic Electric Laboratories, Inc., Northlake, Illinois

SOURCE: Electrical Design News, vol. 8, February, 1963, pp. 60-71

PURPOSE: To discuss the relative advantages and disadvantages of transistors and relays in control circuits.

ABSTRACT: Electrical control circuit design usually follows one of two distinct approaches: (1) electromagnetic relays or (2) transistors. A company having no knowledge of transistors must follow a relay approach; a company having no manufacturing capability in the relay line may prefer to use transistors. The optimum approach is to be familiar with both devices and to secure the best features of each. A comparison of the characteristics of both devices is made under the following headings: speed, reliability, simplicity of power supply, power consumption, variety of power types, cost, resistance to heat, isolation and amplification, contact resistance, contact bounce, resistance to shock, and size.

In discussing reliability it is important to consider the total system reliability since transistors and relays cannot directly replace each other. An example is given involving an aircraft application in which relays were definitely predicted to be more reliable and were used; they proved to be satisfactory.

REVIEW: This is an interesting paper which should be read by all electronics engineers. The theme is that both relays and transistors have their place and the designer should know where to use each or a combination of each to the best advantage. The section on reliability is quite brief, but is interesting because of the particular examples quoted. ##

Serial Number 921
Code 835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability data for integrated circuits

AUTHOR: Jay L. Farley, Fairchild Semiconductor, Mountain View, California

SOURCE: Electrical Design News, vol. 8, June, 1963, pp. 64-67

PURPOSE: To prove that integrated circuits are very reliable.

ABSTRACT: Mass produced micro-integrated circuits are available for use in circuit designs. They are at least as reliable as circuits built of conventional items. The manufacturing techniques are the same as those for diffused planar transistors; it would therefore be expected that these integrated circuits would have the same failure mechanisms. There are considerably fewer external connections than in conventional circuits and this is a big source of reliability improvement. The failure rate of all devices has been computed (from tests) to be 0.044%/1000 hr. In a private communication the author has stated that "This failure rate is for the total circuit and I believe that it should be pointed out that the 0.044% failure rate is stated at the 90% confidence level ... the actual observed failure rate was approximately 0.02%." The major failure mechanism has since been eliminated by an optical microscope inspection. Designers are encouraged to use these devices with confidence.

REVIEW: This is a positively written, very enthusiastic article about integrated microcircuits. The author deals only with catastrophic failures--not drift failures. In a private communication the author has stated that "Since we evaluate micrologic circuits as black boxes with input and output characteristics, any real drift failures on the part of the components under test would have caused total circuit failures. Therefore ... any drift failures which occurred are already included in the failure rate stated." Initial tolerance can be a problem with many of these circuits. It is recommended that designers become fully aware of the capabilities of these devices and use them whenever satisfactory properties (including reliability) have been adequately demonstrated. Advertising exuberance should not be mistaken for sound design and performance data. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transformers

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, January/February, 1963, pp. 8-12

PURPOSE: To discuss the status of reliability in the transformer industry.

ABSTRACT: The EIA has issued a Transformer Task Force Proposal, EIA ER-T-27, as a high-reliability specification for transformers. The big problem in any proposal for reliability specifications is that transformers are usually sold in small lots of 10 to 100 and this does not allow much room for hiding testing costs. Four types of failure are described: open circuits, short circuits, insulation breakdown, and output voltage degradation. Improvements have been made in transformer insulation and potting, but money has been lacking for extensive testing and development programs.

REVIEW: Interestingly enough, at one time transformers were regarded as extremely reliable and some advertisements for magnetic amplifiers implied that 100% reliability had been achieved. The manufacturers and consumers face very real problems of cost vs. reliability assurance which will not be solved until both are willing to face the problems squarely. Part of the responsibility for military transformers must be assumed by the DOD for not being willing to insist on reliability and then paying the price in standardization and testing programs, etc.

This article is a general discussion of industry views on this subject; no recommendations are made. The reader interested in this topic should see also a letter to the editor (Evaluation Engineering, vol. 2, March/April, 1963, p. 2) in which it is indicated that a revised draft of ER-T-27 will be issued shortly. Some minor additions/corrections are also given. Among these is a statement to the effect that the EIA program is not intended to specify high reliability at present, but rather to first establish the reliability of products now being purchased under the existing MIL specification. This corresponds to a statement in the article to the effect that ER-T-27 is a check on the state of art in transformers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some "plain talk" about confidence and sample size, Parts I and II (reliability mathematics corner)

AUTHORS: D. Earles, J. Massa, and R. Sirull, Reliability Analysis Section, Avco Research and Advanced Development

SOURCE: Evaluation Engineering, vol. 2, January/February, 1963, pp. 14-15 (Part I), March/April, 1963, pp. 26-27 (Part II), and May/June, 1963, pp. 2,32 (letter to editor regarding Part I)

PURPOSE: To discuss the statistical concept of confidence.

ABSTRACT: A point estimate of reliability can be obtained from a sample, but it is unlikely that one will hit on the true value. It is better to estimate an interval instead of a point. We obtain an interval regarding which we may say, for example, that we are 90% confident that the interval includes the true value of the reliability. This means that on the average our statement will be correct 90% of the time, and incorrect 10% of the time. The 90% is called the confidence level and the specified interval is called a confidence interval. When only the lower (or upper) confidence limit is of interest, we apply the procedure of one-sided confidence intervals. Two-sided confidence intervals are usually (but not necessarily) symmetrical (i.e., an 80% confidence interval is usually so placed that the chances are 10% that the true value lies below the lower limit and 10% that it lies above the upper limit).

In Part II a table is given for calculating a lower 90% confidence limit on reliability in the go/no go (binomial) case. It is based on the relationship

$$R = 1/[1+(r+1)F/(n-r)],$$

where R is the lower confidence estimate of reliability, r is the number of failures observed, n is the number of trials, and F is the appropriate percentage point of the F distribution. A second table, based on the same relationship gives the number of tests without a failure in terms of reliability and confidence.

REVIEW: This is a good discussion of confidence, given in a down-to-earth fashion; the words "plain talk" in the title are quite appropriate. The material is correct and adequate for the purpose. It could be added, however, that in the formula for R the degrees of freedom for F are 2(r+1) and 2(n-r) for the numerator and denominator respectively. This information will enable the reader to spot check the values in the tables, if he so desires, and also to calculate values which are not given in the tables. It should also be pointed out that the confidence levels given in the tables are actually lower bounds on the degree of confidence. That is, for example, the statement accompanying the lower 90% confidence estimate of reliability should be "The degree of confidence is at least 90% that the true value of the reliability is R or higher." The reader may be interested in noting that the first table presents the same results as are given in chart form in Figure A.3, p. 500 in [1]. Also, the second table is a more extensive presentation of the same material as in Table A.1, p. 487 in [1].

As a minor point in connection with Part I, the term "best" used in referring to the statistic (n-r)/n used to estimate reliability should perhaps have been qualified or explained. While the statistic does possess the many good properties pointed out in the letter to the editor (see SOURCE), the sense in which "best" is meant should be stated.

REFERENCE: [1] Reliability: Management, Methods, and Mathematics, David K. Lloyd and Myron Lipow, Prentice-Hall, Inc., 1962 ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability Engineering at Honeywell: The Corporate Reliability Committee

AUTHOR: Marion P. Smith, Manager of Reliability, Honeywell Aeronautical Division, St. Petersburg, Florida

SOURCE: Evaluation Engineering, vol. 2, March/April, 1963, pp. 8-11

PURPOSE: To describe Honeywell's Corporate Reliability Committee.

ABSTRACT: This committee was organized in 1959 to coordinate, but not to govern, the reliability activities of the divisions in the Military Products Group of the Minneapolis-Honeywell Regulator Company. Other divisions of Honeywell participate--particularly some of the non-military groups. The meetings include discussion of techniques, and the carrying out of some corporate projects, and serve to put the attendees on a "first name" basis so that they are not reluctant to consult with each other between meetings. Reliability problems can be discussed more frankly than if outsiders were present. An internal Reliability Handbook for designers has been published and an external Reliability Capability Brochure was prepared. There is a Honeywell Data Exchange that participates in IDEP and circulates both those findings and Honeywell's more private internal findings among the various groups.

REVIEW: This is a brief discussion of a corporate undertaking for informal reliability awareness and improvement. In a large multi-product, multi-division corporation a group such as this can serve the very useful purposes indicated in this article. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Selected reliability films -- 1963 enlarged listings--Parts I, II, and III

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, March/April, 1963, p. 12; May/June, 1963, p. 29; and July/August, 1963, pp. 28-29

PURPOSE: To list available films on reliability.

ABSTRACT: Forty-five films are listed in the three parts of this series. The listing gives a one-sentence description, the source, the running time, and the types of groups that will probably be interested.

REVIEW: This listing serves a very worthwhile purpose in bringing these films to the attention of those who would otherwise perhaps not know of their existence. Most of the films undoubtedly are useful as instructional or indoctrinational material, even if they just let the viewer know what others are doing.

The middle half of the running times of the listed films is between 18 and 30 minutes. Four of the films are listed as confidential. None of the films, per se, have been covered by RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS, but the brochures accompanying five of the Navy films have been covered by Abstracts and Reviews Serial Numbers 284, 285, 479, and 833. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: IDEP--A current report

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, March/April, 1963, pp. 16-18

PURPOSE: To give a brief review of the goals and progress of IDEP.

ABSTRACT: IDEP's (Interservice Data Exchange Program) purpose is to improve the utilization of government funds expended on parts testing by reduction of duplicate efforts. In the process, it also aims to encourage manufacture of parts with improved performance and reliability, assist the contractor in selection of optimum available parts, and to feed data into applicable standardization activities.

IDEP was designed to alleviate some of the problems resulting from the rapid increase in environmental performance and reliability requirements asked from our ballistic missile and space systems. These increasingly stringent requirements, coupled with the greater complexity and smaller production lots of such systems, have greatly increased the parts testing cost per delivered unit.

IDEP's specific objectives are:

1. To speed up new projects by avoiding duplication and repetition of R&D or qualification tests.
2. To increase product reliability by providing advance indication of possible failure modes, and by yielding maximum data for each test dollar.
3. To encourage standardization of test methods, levels, reporting and specifying by providing visibility into others' techniques.
4. To facilitate voluntary intercontractor preplanning of complementing test programs, and to assist contracting officers in decisions to authorize parts test expenditures.
5. To establish direct lines of communication for intercontractor contacts between technical personnel working on related problems.
6. By assisting in the Parts Application Engineering functions with data from other contractors (or other branches of their own firms) and with organized data retrieval procedures, to indirectly increase their stature and authority to monitor designs.

About 120 contractors are qualified to participate in the program. Careful cataloguing allows prompt retrieval of desired documents and many contractors credit the program with both high direct savings and very high indirect benefits. Weaknesses of parts and test programs become evident without costly repetition. Future tests can be designed to emphasize weak areas. While quality is being improved and coverage will be somewhat increased, no vast

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RELIABILITY ABSTRACTS
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expansion of the program is contemplated. (Author in part)

REVIEW: This is a general, enthusiastic report on IDEP. As such it will be of interest to those who are not already aware of the existence and value of this program. Other descriptive articles on IDEP were covered by Abstracts and Reviews Serial Numbers 901 and 905; IDEP and three other data exchange programs were described in the paper covered by Abstract and Review Serial Number 877. ##

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Codes 782;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Heat transfer and resistor reliability

AUTHOR: Clarence Jahnke, Sr., Missile & Space Division, Raytheon Company

SOURCE: Evaluation Engineering, vol. 2, March/April, 1963, pp. 19-21

PURPOSE: To present some of the elements of heat transfer to the non-technical person.

ABSTRACT: Power or heat can be dissipated by conduction, convection (natural or forced), and radiation. The heat conductivity of any substance can be measured and used to calculate the amount of heat transferred in that way. Specific heat and viscosity are also defined. An example of a chassis-mounted resistor is given. Heat is intended to be conducted to the chassis and then convected away. If anything interferes with either process the resistor temperature will rise until the heat can be dissipated. This temperature rise will usually shorten the resistor's life. Tables are given of emissivities and thermal conductivities of some common materials.

REVIEW: This is a very elementary and brief presentation of heat transfer. It can serve best to give an appreciation of heat transfer problems to the non-technical person. Unfortunately, this may include some electronics designers. The author in a private communication has indicated that instances of misapplication lead to the conclusion that some designers are not aware of the finer points on the application of chassis-mounted resistors.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The three ages of reliability

AUTHOR: Howard A. Van Dine, Jr., Senior Reliability Development Engineer, Missile and Armament Department, General Electric Company

SOURCE: Evaluation Engineering, vol. 2, May/June, 1963, pp. 16, 18, 19

PURPOSE: To provide a description of a good approach to reliability.

ABSTRACT: The following table (abbreviated) is given to depict the three ages of reliability.

1. SPECIFY AND PRODUCE--AGE 1
   Specification analysis
   Design analysis
   Personnel reliability education
   Human factors
   Vendor selection and control

2. MEASURE--AGE 2
   Mathematical models
   Demonstration methods
   Designed experiments
   Measurement data accumulation
   Calculation of probability

3. CONTROL--AGE 3
   Failure analysis
   Fabrication process techniques
   Factory personnel training
   Maintenance methods
   Usage methods
   Field personnel training
   Feedback and corrective action

A reliability group should assume aggressive authority for performing the work, should use the best inside and outside talents for advice and to produce results, and should theorize and develop further sophistications based upon experience for future use.

Failure analysis and corrective action are essential to success in the three age reliability analysis.

An example of the application of this system is given for the Thor re-entry vehicle program. (Author in part)

REVIEW: This is a management-type article and gives a broad picture of a program without going into detail. It can be helpful in lending perspective to one's own program. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Shortcuts to redundant design reliability

AUTHOR: Marvin H. Walker, Jr., Project Reliability and Quality Control Engineer, Electro-Mechanical Research, Inc.

SOURCE: Evaluation Engineering, vol. 2, May/June, 1963, p. 25

PURPOSE: To present a simplification scheme for the complex probability equations used to describe the reliability of redundant designs.

ABSTRACT: When reliability is high (the case which is usually of interest) approximations in the calculations can be made. They are based on the series expansion $e^{x} = 1 - x + \ldots$ where higher terms can be ignored. If $R = e^{-\lambda t}$, $1 - R \doteq \lambda t$; this substitution will usually simplify the equations for calculating the reliability when redundancy is involved.

REVIEW: For those who are not aware of the series expansion approximation of the exponential, this paper will be useful; otherwise its contribution is small. Only two examples are given. It should be noted that one sometimes must include higher order terms in the exponential expansion due to the presence of other "cancelling" terms. In general, one can make useful approximations, but the situations in which they are used should be treated individually on their own merits. As a matter of principle, one should always know at least the order of magnitude of the contribution to the calculated value which would be made by any terms which are ignored. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability at General Dynamics

AUTHOR: J. Y. McClure, Director of Reliability and Quality Control, General Dynamics Corporation

SOURCE: Evaluation Engineering, vol. 2, May/June, 1963, pp. 26-27

PURPOSE: To describe General Dynamics' Panel on Reliability.

ABSTRACT: Effective corporation-wide coordination of reliability and quality programs is provided by the General Dynamics Panel on Reliability. Under the direction of the Director of Reliability and Quality Control, the Panel was established to spearhead the corporate reliability effort.

The Panel is made up of the directors and managers responsible for reliability and quality control in 11 divisions. The Panel meets three times a year for two days, with each division acting as host in turn. These Panel meetings are usually followed by simultaneous one-day meetings of a Reliability Technical Panel and a Quality Control Panel for specialized discussions.

Agenda items are referred between the Panels as necessary. A news letter keeps Panel members current between meetings.

A Corporate Reliability Resources Manual has been compiled which states corporate policy and resources. The reliability policy of each division is delineated. Variations between divisions are, of course, necessary due to the different product lines. (Author)

REVIEW: This is a very short description of the information interchange portion of the corporate reliability effort of General Dynamics. It will be of most interest to those concerned with similar undertakings in their own companies. ##.

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Serial Number 931
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic versus mechanical product reliability

AUTHOR: R. R. Landers, Chief of Tapco Reliability Office, Thompson Ramo Wooldridge

SOURCE: Evaluation Engineering, vol. 2, July/August, 1963, pp. 6, 7, 9-11

PURPOSE: To compare electronic and mechanical reliability techniques.

ABSTRACT: Reliability engineering as a discipline started in the electronics industry because of the unreliability of military electronic equipment. Now reliability techniques are spreading to the mechanical fields. All electronic products are at least partly mechanical; many products are a combination of electronic and mechanical parts. The similarities of the products of the two fields lead to similarities in design techniques for reliability in external environments, in basic physics of failure, and in storage and handling. Some reliability methods are also similar e.g., quantitative techniques of measurement and administrative methods. There are differences in such aspects as degree of complexity, degree of standardization, internal environments, failure distributions and modes, design and manufacturing methods, and maintenance.

Electronics people need to realize that they did not invent nor do they have a monopoly on reliability. Reliability groups are becoming assurance oriented and emphasis on the difference between electronic and mechanical factors in their practice is disappearing.

REVIEW: This is a rather general, essentially philosophical paper. There is little to argue about except in the discussion of differences. Answers to such questions as which field is the more complicated, or which is the more standardized depends more on viewpoint than on anything else.

Certainly modern design engineers and reliability engineers should be familiar with the mechanical, electrical, and electronics fields, although inevitably every engineer will have some specialization.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Q & A on the reliability of integrated circuits

AUHTOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, July/August, 1963, pp. 12-13

PURPOSE: To present a few questions and answers on the reliability of integrated circuits.

ABSTRACT: The number of interconnections determines the relative failure proneness of conventional vs integrated circuits. The latter have much less of them and should be more reliable. There are no hard figures yet, but there should be some by the end of 1963. The problem is that it takes time to prove high reliability. The physics of failure approach is used to predict the higher reliability of integrated circuits. These units are as radiation-resistant as any transistors and as shock-and vibration-resistant. Most missile and space vehicles have integrated circuits designed into them now.

REVIEW: This is a general article designed to instill confidence in microelectronic integrated circuits. Since the answers to the questions are all provided by representatives of Signetics Corporation, this is not surprising. The conclusions seem generally to be valid insofar as one can predict without extensive experience. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Self-evaluation needed for reliability engineers?

AUTHOR: G. H. Beckhart, Manager, Engineering Product Assurance, Radio Corporation of America

SOURCE: Evaluation Engineering, vol. 2, July/August, 1963, pp. 14-15

PURPOSE: To collect data on the effectiveness of reliability groups.

ABSTRACT: Panelists at the National Electronics Conference last year suggested that we were not getting our money's worth from reliability. (See Abstracts and Reviews Serial Numbers 557 and 683.) If this is so, our profession is in a bad way. A self-rating chart is included to be filled out and mailed to this magazine. The results will be published if enough returns are received.

REVIEW: The self-rating chart is a good idea if done honestly; but the article on Bowdlerism (See Abstract and Review Serial Number 913) should be read if the possibilities of bias are not fully appreciated. Extra copies of the chart can undoubtedly be obtained from the magazine. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability data now on microfilm

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, July/August, 1963, p. 20

PURPOSE: To publicize a purchasable service which promises to fill the reliability information gap between vendor and contractor.

ABSTRACT: The Visual Search Microfilm File (VSMF) now has vendor data on product reliability available in its Microfilm Catalog File. Details on the program are included in a new microfilm which was released July 10, 1963.

REVIEW: Insofar as vendor data on reliability are trustworthy, this purchasable service will be of interest to designers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Of mold and missiles

AUTHOR: Editorial abstract of a paper presented at the Fourth Annual Symposium of SAMPE (Society of Aerospace Materials and Process Engineers), Hollywood, California, November, 1962, by Roger Kirk, Chrysler Corporation, Missile Division, Detroit, Michigan)

SOURCE: Machine Design, vol. 35, July 18, 1963, pp. 146-150

PURPOSE: To present a review of microbiological contamination in missile systems and an approach to its control.

ABSTRACT: During World War II many military materials were damaged by molds and other microbiological life. Some countermeasures have been instituted, such as the use of fungus resisting chemicals. There are 400-500 fungicides on the market--mostly directed toward agricultural problems. The choice of industrial fungicide depends on the following factors: (1) toxicity to the microorganisms, (2) compatibility with the materials in the equipment, (3) stability under severe environments, (4) life expectancy as a potent fungitoxin under normal storage conditions, and (5) personnel handling qualities.

Parts should be kept clean and dry to keep down growth conditions. Getting rid of mold, once it gets established, is not an easy problem. Washing with ethyl alcohol is sometimes effective and can be repeated if necessary.

An example is given of some tests on the Jupiter missile.

REVIEW: This is not an intensive article, as might be inferred from the fact that it is an editorial abstract. However, the author of the original paper has indicated that considerable information on the fungus and humidity susceptibility of materials, components, assemblies, and systems, and material deterioration due to microbiological attack is to be found in the following Technical Memoranda produced by the Chrysler Corporation Missile Division: MT-M70J, MT-M71J, and EER-151. The first two reports are based on work done for the Army, the third on work done for the Air Force. All three list pertinent references. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Heat-sinking techniques for power transistors in a space environment

AUTHORS: J. E. A. John, Department of Mechanical Engineering, University of Maryland, College Park, Maryland and J. J. Hilliard, Department of Electrical Engineering, Catholic University, Washington, D. C.

SOURCE: IEEE Transactions on Space Electronics and Telemetry (formerly IRE Transactions on Space Electronics and Telemetry), vol. SET-9, pp. 45-51, June, 1963

PURPOSE: To show how best to mount power transistors for use in a high-vacuum environment.

ABSTRACT: An investigation was made of the cooling of power transistors in a space environment, where the only available mode of heat transfer is that of conduction to a heat sink and radiation from the heat sink to space. An attempt was made to minimize the thermal resistance between transistor case and heat sink, allowing the transistor to dissipate as much power as possible while maintaining its temperature within the maximum tolerable level to prevent thermal runaway. Further, it was necessary to electrically insulate the transistor from the heat sink. The use of beryllium oxide washers provided electrical insulation, while adding very little to the thermal resistance between case and sink, the BeO being a good heat conductor. However, the problem of contact thermal resistance at each interface arose, especially in vacuum --this contact resistance providing practically all the thermal resistance between case and sink. The effect on the contact resistance of surface pressure, insertion of foils, and soldering was examined. It was concluded that, for most efficient heat sinking, indium foil should be inserted at each interface, the indium foil having the effect of reducing the contact resistance in vacuum by a factor of 8. (Authors)

This method of mounting proved to be better than using an insulated transistor in one case (2N1724 as compared to 2N1724/I). The heat transferred through the stud, nut, and washer combination was negligible compared to that through the other end.

REVIEW: This is a very good article. Its conclusions will be of direct benefit to design engineers, even in non-vacuum conditions, since the recommended simple mounting method gives better heat transfer than the normal method at atmospheric pressures. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Views on the assurance of value, quality-reliability, standards

AUTHOR: Captain Jonathan A. Barker, USN, Director, Assurance Systems, Engineering Division, Bureau of Ships, Department of the Navy (current affiliation: Lockheed Missiles & Space Company, Sunnyvale, California)

SOURCE: the magazine of standards, vol. 34, pp. 175-176, June, 1963

PURPOSE: To give some views on value, quality-reliability, and standards.

ABSTRACT: These three aspects: value, quality-reliability, and standards are inseparably interlocked. (The paper defines the three terms.) The cost relative to the demands is a function of the quality-reliability; there is an optimum value of the latter to give a minimum cost, i.e. good value. Before a quantified optimization can be made, the level of quality-reliability must be characterized by definition in terms of standards.

To provide confidence that adequate standards have been used to achieve good value in the necessary quality-reliability, it is necessary to assure each of these aspects through planned management programs.

The Bureau of Ships has combined the management of policy and planning for Quality-Reliability Assurance, Value Assurance, and Standardization Assurance in the Assurance Systems Engineering Division. Systems for "making sure" cost money, even though they may well save more than they cost. Good direction, good planning, and strong coordination can make the price of confidence reasonable. Recognition of the interdependence of quality-reliability, value, and standards for a product, and recognition of the need to assure that each of these aspects is properly proportioned in the product, is essential in any program of direction, planning, and coordination for confidence. (Author in part)

REVIEW: This is a short general article which discusses the philosophy of the title in an enlightening and interesting manner. It will make good casual reading for those involved in reliability. ##

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Codes 820;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Critical look at failure-rate approach to reliability

AUTHOR: (adapted from remarks of Arch Cooke, Lockheed Missiles & Space Company, Van Nuys, California, by E. W. Schrader, West Coast Editor for Design News)

SOURCE: Design News, vol. 18, July 24, 1963, p. 6

PURPOSE: To demonstrate that reliability mathematics should be made to agree with the physical facts.

ABSTRACT: Reliability engineering attempts to substitute mathematical double talk for engineering experience. The constant failure rate myth should be discarded and along with it all the expensive tests for estimating it. Especially, this myth should not be forced on mechanical engineers. Reliability is the system efficiency and is the fraction of components surviving at time T. $R = \exp(-\int_0^T \lambda\, dt)$, where λ is the conditional failure rate. If λ is constant, the mathematics is much simpler and the length of operating time has no bearing on the failure rate of such a component. Obviously this equation is wrong for failure caused by fatigue, wear, corrosion, and almost every other possible failure mechanism. Reliability engineers should concentrate on supplying facts as to how and why components fail instead of lengthy calculations based upon unrealistic mathematics and unreliable test data; then they will be true professionals.

REVIEW: There is much valid criticism in this "essay" but the author has taken a rather narrow view. Many data in the electronics industry are such that any hypothesis more complicated than the simple constant hazard (conditional failure rate) is unjustified. To quote from [1]: "Jaynes' principle tells us that if we wish to work with a single parameter distribution and we have no other data, that we should use a Poisson distribution to describe the system." Also it should be noted that when a large number of components are taken, each with a different response to stress, it is not inconceivable that the failures over a reasonable period of time can be adequately described by a Poisson process, which leads to an exponential distribution of times to failure (constant λ). There is a misprint in the equation for hazard (λ). No reason is given for introducing an efficiency and then equating it to reliability. The physics of failure approach is important and should be encouraged, but designers still need numbers.

REFERENCE: [1] Recent Developments in Information and Decision Processes, edited by Machol and Gray, Macmillan Company, New York, 1962, "The use of the maximum entropy estimate in reliability" by Myron Tribus, p. 102 ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relays: least understood, least standardized, most abused

AUTHOR: M. M. Perugini

SOURCE: Electronic Equipment Engineering, vol. 11, June, 1963, pp. 44-53

PURPOSE: To help the circuit designer acquire some basics that will help him in specifying relays.

ABSTRACT: Under "least understood," the general information on contacts, environmental effects, loading effects and specification aids is geared to help the non-specialist in relays better understand this component. "Least standardized" details the progress made, or not made, in classification, reliability and testing of relays. In "most abused," a few circuit misapplications are cited, and suggestions on how to become a "relay specialist" are outlined. (Author)

REFERENCES: NARM publications available from National Association of Relay Manufacturers, Box 1, Bellerose 26, Long Island, New York

REVIEW: This article does not quite cover the intended purpose. It is largely a collection of summaries of papers and opinions; there is no real coordinated exposition of the subject. If one is already somewhat conversant with relay problems, this article can broaden his knowledge. The considerable controversy in the field is well brought out. The cited references are good sources of material on relays. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Product reliability through integrated packaging and handling

AUTHOR: Bronson B. Baker, Lockheed Missiles & Space Company, Sunnyvale, California

SOURCE: IEEE Transactions on Product Engineering and Production, vol. PEP-7, July, 1963, pp. 1-11

This paper is identical to the one covered by Abstract and Review Serial Number 725, although no mention is made of the fact that it was presented at the Sixth National Conference on Product Engineering and Production, San Francisco, California, in November, 1962. ##

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Codes 762;775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Infrared inspection promises to assure production reliability

AUTHOR: (Editorial Matter)

SOURCE: Electronics, vol. 36, June 14, 1963, pp. 62-66

PURPOSE: To show how infrared inspection can aid in uncovering potential early failures.

ABSTRACT: Exploratory work at Raytheon continues to develop applications for infrared inspection. This technique uses the emission from a part to infer its temperature. Some of the things it can check are components during manufacture or inspection, and circuits and assemblies in process; it can locate failure causes during production tests and troubleshooting. An example is given of power transistors that tested as good, but had different infrared patterns. The early failures were explained in terms of the patterns. Another example is checking many transistors in a circuit at once; if one is hotter than it should be, the trouble can be fixed before the circuit is put into service.

REVIEW: This seems to be an excellent technique for assisting in failure analysis and prevention. The many problems inherent in its use should not deter further development of infrared detailed inspection. An earlier report on this technique was covered by Abstract and Review Serial Number 626. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Inspection and quality of solder joints

AUTHOR: Howard H. Manko, Alpha Metals, Incorporated, Jersey City, New Jersey

SOURCE: Electronic/Electromechanical Production, vol. 3, May-June, 1963, pp. 20-23

PURPOSE: To give the basic steps required to make a solder joint suitable for visual inspection, and to indicate the criteria for reliable joints.

ABSTRACT: One of the main advantages of soldering is that a visual inspection can give information about the quality of the joint. Cleanliness and potential corrosivity are also important, in addition to the appearance. The joint should be made from properly solderable materials; it should have adequate current-carrying capacity and be mechanically strong. The solder fillet should have a small contact angle, be well feathered and the contours of the wire and terminal should be visible. Too much solder renders a joint uninspectable and thus unacceptable. Some joints are cold soldered and have a frosty appearance; they are faulty.

REVIEW: This is a short summary directed towards the quality control department. For those not already familiar with the information, it is recommended reading. An earlier paper on reliability in soldered connections was covered by Abstract and Review Serial Number 724.

The author in a private communication has called attention to two of his papers entitled "How to choose the right solder flux" and "How to choose the right soft solder alloy." These appeared in PRODUCT ENGINEERING, June 13, 1960, p. 43 and March 6, 1961, p. 39 respectively. They contain more detail on the subject of reliable solder joints than is contained in the present paper. Reprints are available from the author. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Memos on reliability and quality assurance: reliability costs

AUTHOR: Chester Gadzinski, Staff Columnist

SOURCE: Electronic/Electromechanical Production, vol. 3, May-June, 1963, pp. 36-37

PURPOSE: To discuss the measurement techniques available for determining and evaluating the costs of controls in manufacturing and the cost of maintenance in ownership.

ABSTRACT: Two cost centers that must be considered in the discussion of the economics of achieving and maintaining quality and reliability are the cost of producing a product and the cost of owning it. The cost of producing a product includes not only those costs involved with upgrading raw and semi-finished materials, but also the cost of verifying or controlling the upgrading process. Control of the upgrading process is a function of the size and complexity of the organization, and the cost of ownership includes not only the cost of acquisition but also of maintenance.

In the defense business billions of taxpayers dollars can be saved by:

An early evaluation of the reliability potential of a weapon system.

Selection of suppliers based upon past performance rather than initial procurement cost or glamour of sales presentation.

Closer liaison between the agencies procuring hardware and the agencies maintaining hardware. Although the emphasis is changing, there is still more consideration given to initial cost of procurement than to the long range cost of equipment.

A requirement that Quality Costs be accumulated, reported, and controlled. (Author)

REVIEW: This is a rather brief general article on the subject. It will make interesting reading for those not acquainted with the field.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electromagnetic relays - 11th annual conference

AUTHORS: Alfred J. Ferretti and H. G. Buchbinder, Electromechanical Design, Brookline 46, Massachusetts

SOURCE: Electromechanical Design, vol. 7, June, 1963, pp. 36-59

PURPOSE: To report on the eleventh annual National Relay Conference held at Oklahoma State University, Stillwater, Oklahoma, in April, 1963.

ABSTRACT: This is a summary of some of the papers presented at the conference, the ensuing floor discussion, and interviews with attendees. There was heavy emphasis on reliability.

REVIEW: This summary is quite extensive and useful to read. The appropriate papers will be individually abstracted and reviewed when the proceedings become available. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Wide range low temperature fatigue testing apparatus

AUTHORS: K. D. Shimmin and J. A. Roberson, Strength and Materials Branch, USAF, Aeronautical Systems Division

SOURCE: The Journal of Environmental Sciences, vol. 6, June, 1963, pp. 24-25

PURPOSE: To describe apparatus and experimental procedure for conducting fatigue tests at low and cryogenic temperatures.

ABSTRACT: Equipment has been developed for conducting fatigue tests at low and cryogenic temperatures. The equipment operates over a wide range of temperatures without the necessity of submerging specimens in liquid refrigerant. Fatigue stresses are applied by an axial load fatigue test machine. A description of the apparatus and details of experimental procedure are given. (Authors)

The fatigue tester is an axial load, 300 kg Schenck machine. Liquid nitrogen is used as the coolant; the temperature generally is kept constant within $\pm$ 1°K.

REVIEW: This is a rather brief description of the temperature controlling system; there is probably enough information so that one who is acquainted with the field could construct a similar device. There is definitely a need for low temperature fatigue testing.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fatigue of metals (a set of three articles)

SUBTITLES AND AUTHORS: Part 1--The mechanism of fatigue, G. R. Gohn, Mechanical Testing Laboratory, Bell Telephone Laboratories, Inc., New York, New York
Part 2--Crack propagation and final failure, H. F. Hardrath, Langley Research Center, National Aeronautics and Space Administration, Hampton, Virginia
Part 3--Engineering and design aspects, R. E. Peterson, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania

SOURCE: Materials Research & Standards, vol. 3, pp. 105-139, February, 1963 (Part 3 was ASTM 1962 Edgar Marburg Lecture, presented at the 65th Annual Meeting of the Society, New York, New York, June 17, 1962)

PURPOSE: To explore and summarize the present knowledge on fatigue.

ABSTRACT: Part 1--Fatigue is a cataclysmic result of cyclic, repeated, or spectral stressing. It has been of direct interest to mechanical engineers since 1829. For a long time it was thought that metals crystallized and then failed in fatigue, but now it is known that all metals are crystalline and that the difference is more one of a brittle-like failure for fatigue vs (sometimes) ductile failure in tension. There have been many theories about fatigue--including the denial of its existence--and none are completely satisfactory. The one developed by Wood appears to fit the observed phenomena. Fatigue is considered to result from the accumulation of coarse and/or fine slip bands. These slip bands have been observed by optical and electron microscopy. "Pure fatigue" is characterized by uninhibited fine slip; it gradually intensifies and develops into a crack. The crack then propagates across the section until the remaining area is too small to carry the load; failure then occurs. (There is a detailed summary of the historical background and various theories of fatigue. Some 44 specific and several general references are cited.)

Part 2--The progress of a fatigue crack can be qualitatively understood by observing the "oyster shell" or "beach" markings of a failed part. A series of waves seem to emanate from a central point--the start of the crack. The crash of the Comet jet aircraft in 1954 gave considerable impetus to the quantitative study of crack propagation and residual static strength. Most structures have stress concentrations and the more realistic studies are done on some kind of "notched" specimen. The crack propagation occurs during more than half the fatigue life and can be observed microscopically. The science of fracture mechanics is being developed to study the failure of cracked parts. Another approach is to estimate the effective radius at the crack tip and use it

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

with the Neuber technical stress concentration factor to get the stress concentration factor at the crack tip. This method is widely used even though there are some objections to it. Several formulas have been proposed which relate the crack growth rate to the stress; they all contain empirical coefficients. If nonconstant stress amplitudes are used, crack growth can be rather peculiar. A big problem, in any event, is to define the end of the formation period and the beginning of the growth period. At present the analytical methods for fatigue design are inadequate to provide an efficient structure which is safe from fatigue. Extensive assembly testing must be done; inspection in service can find partially failed parts which can then be replaced. The notion of a fail-safe or redundant feature is used to prevent a part failure from causing a catastrophe. (The topics are discussed at some length and 26 references are given.)

Part 3--Wöhler's work in the late 1800's on fatigue of railway car axles was among the first comprehensive studies of fatigue failure. This early work was almost all of a problem-solving nature--as is usually the case. Fatigue failures occur in ship propulsion, railways, automobiles, aircraft, power machinery, etc. The Comet I failure was one of the most thoroughly investigated cases. It was apparently caused by pressure cycling between ground and high altitude. There are two general forms of fatigue problems: load (stress) cycling and deformation (strain) cycling. Both of these occur in practical cases. While stress/cycle curves are the most common, much useful and fundamental knowledge can be obtained from strain/cycle curves; especially at the low cycle (plastic strain) end. (A considerable discussion is given of this problem.) Stress concentrations are important, although in the plastic range the stress-strain relationship is not simple; nor is the reduction in fatigue strength equal to the concentration factor. (Much general design information is given here.) Cumulative damage caused by varying amplitude stressing and the effects of processing variables are mentioned only in summary. (An appendix--derivation of a new fatigue life formula--and 61 specific references are included.)

REVIEW: This is an excellent series of papers, and reprints (75¢) are available from ASTM, 1916 Race St. Philadelphia, Pennsylvania. All three authors are well known in this field. Most electronics designers are not as familiar with fatigue as they should be and these three articles can be of considerable assistance in providing a basic understanding of the subject. Some topics, such as cumulative damage, are barely mentioned and information on them will have to be obtained from other sources. The reference below will be of some assistance.

REFERENCE: Sines and Waisman, Metal Fatigue, McGraw-Hill, 1959. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effect of seven-year marine exposure on organic materials

AUTHOR: R. A. Connolly, Bell Telephone Laboratories, Murray Hill, New Jersey

SOURCE: Materials Research & Standards, vol. 3, pp. 193-201, March, 1963

PURPOSE: To report marine exposure tests of organic materials for potential cable use.

ABSTRACT: Over 600 specimens of organic materials have been exposed in the ocean at Wrightsville Beach, N. C., and Daytona Beach, Fla., for up to seven years. They have been classified in four different categories according to deterioration. This deterioration is confined primarily to mechanical damage caused by marine borers. Chemically, there have been few changes in the materials.

Most of the plastic specimens have shown no signs of degradation by either borers or microorganisms. The general exception is poly(vinyl chloride), with over half of the compounds exposed exhibiting pholad penetrations. Two of the four nylon materials showed pholad damage within a 12-month period.

The rubbers in general are performing well. The natural rubber and SBR jackets have shown no signs of deterioration. Abortive pholad attempts have been made on two of the rubbers, while silicone rubber was penetrated to an appreciable depth in one instance. Surface-cracking on the silicone, SBR jacket, and butyl jackets has also been observed after four to six years.

Cellulose acetate and triacetate fibers have lasted from one to four years, although microbiological deterioration was detected earlier than this. Cellulose triacetate performed the best, lasting four years before it was destroyed. Natural fibers of untreated jute were destroyed after only six months due to both borer and microbial activity. Of the treated or modified jute specimens, the anthracene oil plus coal tar pitch, road tar 9 (coal tar) plus creosote with copper naphthenate, and cyanoethylation offered the greatest degree of protection.

These tests will be continued and new materials of interest added when appropriate. (Author)

REVIEW: This is an excellent article on the problems of fouling and degradation of organic materials of potential interest for ocean cables. It contains much for the beginner to learn on the subject of marine organisms, and most electronics designers fall in this category. Interest in the ocean environment is expected to expand in the coming years. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A simple environmental chamber for rotating-beam fatigue testing machines

AUTHOR: J. A. Bennett, Engineering Metallurgy Section, National Bureau of Standards

SOURCE: Materials Research & Standards, vol. 3, pp. 480-482, June, 1963

PURPOSE: To show the need for and to describe a humidity control chamber for a rotating beam machine and to show the effects of humidity on fatigue life.

ABSTRACT: Several authors have correlated differences in fatigue life with changes in the humidity of the atmosphere. In order to explore this effect, a simple chamber was designed and built for use on an R.R. Moore fatigue machine. The chamber can maintain from less than 5% up to more than 90% relative humidity; a sensor is included to monitor the humidity.

Humidity control reduces the scatter in fatigue life. High humidity on AZ61A magnesium alloy and on 2024-T4 aluminum alloy gives shorter fatigue life than low humidity. There are speed, fretting, and high-low stress effects which may vary widely as a function of humidity, depending on the material.

REVIEW: This is a good short article on the subject. Enough details are given of the chamber so that it can be adapted to different machines. Reducing the normal scatter and finding sources of variation are an important contribution to fatigue testing. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some materials problems in electrical contacts

AUTHOR: A. G. Keil, Dürrwächter & Company, Pforzheim, Germany (now at Forschungsinstitut für Edelmetalle und Metallchemie, Schwäbisch Gmünd, Germany)

SOURCE: Materials Research & Standards, vol. 3, pp. 489-491, June, 1963

PURPOSE: To discuss some aspects of contact failure.

ABSTRACT: From a chance observation of crystalline growth on a well-used relay contact, the author began an experimental program, preliminary results of which indicate that more attention needs to be paid to the physical construction of electrical contacts. In an environment known to contain sulfur (from a rubber packing ring), silver sulfide crystals formed on a silver relay contact. Similar growths were produced easily and rapidly in the laboratory. In the presence of adjacent gold, the sulfide crept over the gold surface. Particularly undesirable from this creeping point of view, is a porous layer of gold over the silver. Copper is to be preferred as a base for gold plating.

Arcing causes deformation of electrical contacts which carry heavy currents. An experimental program showed that, as with similar deformation in welds, the amount of deformation is a function of the hardness of the contact material. Annealed metals suffered more deformation than hard metals, and deformation was greater for metals with lower thermal conductivity. It appears that contact deformation is the natural result of uneven heating of the material; therefore remedies must be sought in better mechanical design rather than in contact material.

When a very heavy arc occurs, contact material may be evaporated and condensed on adjacent insulators. If electrical conductivity of the condensed material is great enough, breakdown of the insulation is possible. However, evaporation of contact material at relatively low temperatures in the laboratory produced condensation products having no conductivity, even from pure silver electrodes. It seems that the primary products are oxides and that the higher temperatures resulting from heavy arcs reduce the oxide to metal which causes trouble. A remedy may be to alloy precious metal contacts with non-precious metals, which form stable oxides at high temperatures.

REVIEW: The author has started on an experimental program which may be of great value and contribute important information on failure mechanisms. While some of the data presented are preliminary, the tentative conclusions based on these data seem to be valid. There may be alternatives to his diffusion postulates, too, but his observations are none-the-less valid. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mistakes, misunderstandings and frustrations in QC and Reliability emerge

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol.3, May, 1963, pp. 1, 6, 8

PURPOSE: To summarize the discussions and presentations at the all-day session on better quality and reliability of the Long Island Section of ASQC.

ABSTRACT: The amount of aggressiveness that a quality control group should display was debated as well as the usefulness of some of its more complex methods. The goals should always be based on a realistic view of company policy.

In many areas the basic principles of reliability, known for some years, are sufficient to solve most of the problems. The "slower" companies must put their management behind this effort. If reliability testing were really understood and wanted, we could have avoided some of our costly missile failures. Discontent by suppliers was expressed with high confidence, high reliability sampling plans. The use of microelectronics is being encouraged by the Navy (BUWEPS) through its MEETAT program of gradual introduction in present equipment. Eventually the systems would be fully integrated with microelectronics.

REVIEW: This article is a potpourri of ideas generated at the meeting. It makes interesting reading, but has no reference value. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How reliable are relays?

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, May, 1963, pp. 1, 32, 33

PURPOSE: To report on the 11th National Conference on Electromagnetic Relays held at Oklahoma State University in April, 1963.

ABSTRACT: This is a news item covering the annual conference on electromagnetic relays. The main topics discussed were: methods of supplying design engineers with relays having greatly improved reliability, the Relay Association's recently announced high reliability specifications, and the plans to issue a military specification on relays. An extensive Navy reliability testing program on relays was described in detail. Other papers covered a new screening technique for reliability, testing procedures, contact ratings, and the proper application of relays. There was one paper on power switching with sealed relays in spacecraft systems.

REVIEW: Detailed reviews of the individual reliability papers presented at the conference will be made when the proceedings of the conference are available. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: This month's product marketplace

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, June, 1963, pp. 12-16

PURPOSE: To describe new product developments.

ABSTRACT: Several of the reported developments had to do with reliability.

1. A resistor meeting MIL-R-55182 specifications has been introduced. An acceleration factor of 20.3 for 0.5 rated power vs. 2.5 rated power was documented. Over 36 million component test hours have been gathered.

2. Almost 6 years of continuous life testing on tin oxide resistors has been done. Failure rates of less than 0.0015%/1000 hr at 1.4 rated power (60% confidence) were achieved.

3. RF molded coils were tested at several temperatures up to 125°C and a failure rate of 0.165%/1000 hr (90% confidence) at 125°C was obtained. Those with powdered iron forms were good only up to 95°C.

4. Polycarbonate capacitors may be better than Mylar or polystyrene ones. Life tests on Mylar capacitors were completed and showed a failure rate of 0.076%/1000 hr (90% confidence) at rated voltage and 125°C.

Several of these developments were presented at the 1963 Electronic Components Conference.

REVIEW: This column contains information which should be of use to those concerned with the selection of components. The particular items summarized above contained data on aspects pertaining to reliability.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Buying high reliability parts--1963

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol.3, July, 1963, pp. 1, 4-6

PURPOSE: To show the problems and contradictions involved in buying high-reliability parts.

ABSTRACT: There is much confusion and contradiction in reliability today--buyers feel they know more than vendors; reliability engineers do not talk costs to bosses; bosses do not support reliability; reliability estimates are sometimes off by 20:1. Very few people have attempted to measure the costs of a reliability effort and the resulting benefits in terms of dollars. These measurements are necessary if management is to get really behind the reliability effort. At least one such set of data showed a 5:1 payoff for reliability expenses. These figures are very difficult to determine. The emergence of Cost-Plus-Incentive-Fee (CPIF) contracts has made this knowledge all the more necessary. Also the incentives and penalties must be well thought out by both sides.

Traditionally, a contract specifies only the product attributes that can be measured, such as delivery, cost, and quality. This is no longer satisfactory since the buyer cannot afford the time loss if he rejects the item. A new system called "input contracting" is being developed. Its essentials are:

(1) Buyer and seller can identify the item to be controlled.
(2) The contracting methods are perfected and understood.
(3) The buyer must be assured that the controls are actually applied.
(4) An audit may have to be applied to this phase.

A list of the activities to be specified is given (environmental studies, reliability apportionment and indoctrination, design review, vendor monitoring, etc.). The object of input contracting is to be sure that the manufacturer knows what he is doing and that he does it right. Present procurement practices tend to be cumbersome because they have grown from the old way in a patchy fashion.

The next big effort is due on electromechanical parts. Not that all the electronics problems are solved, but a start has been made and the techniques are available. The buyer is largely at fault if he uses inadequate or poor reliability specifications.

REVIEW: This article contains many worthwhile points which should be read and considered by all who are concerned with the procurement of high-reliability parts. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Planning and initiating a reliability program

AUTHOR: Thomas E. Shahanazarian, Burndy Corporation, Richards Avenue, Norwalk, Connecticut

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, July, 1963, pp. 8-9

PURPOSE: To outline the complexity and magnitude of what is needed to guarantee product reliability.

ABSTRACT: No longer are the historical methods of reliability development adequate. The large safety factors and long field development programs are not possible with today's requirements. Reliability extends quality control by insisting that a component continue to function for a given time and under given conditions. The following seven steps are basic for high reliability: customer analysis, sales analysis, product design and evaluation, reliability plan, manufacturing plan, initiating a quality control and reliability program, and corrective action. (Each of these is detailed.)

REVIEW: This is a management paper; it is quite brief and will be of use as an introduction or review only. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How reliability consultants fit in

AUTHOR: S. R. Calabro, President, Aerospace Technology Corporation

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, July, 1963, p. 12

PURPOSE: To list the services that reliability consultants can perform.

ABSTRACT: Both small and large companies have at least occasional need for consultants to supplement their existing staffs. This may be because of a temporary work load or to provide higher skills and knowledge than are available in house. Typical services of consultants are:

1. Preparation of program plans and specifications.
2. Design reviews.
3. Surveillance of facilities, plans, and techniques.
4. Preparation of manuals and handbooks on quality assurance, reliability, and maintainability.
5. Formulation of mathematical models.
6. Preparation of test procedures.
7. Failure reporting systems.
8. Statistical studies and analyses.
9. Review of specifications, manuals, and bulletins for accuracy and content.
10. Training courses.

REVIEW: This is a selling document for reliability consultants. The need for this service is likely to occur in most any company. The biggest problem, and one not touched on here, is how to make sure that your consultant is a good one. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability by design--the Lincoln Continental story

AUTHOR: J. A. Manoogian, Ford Motor Company

SOURCE: 11 pp., presented at the SAE Central Illinois Chapter, April 4, 1962, Society of Automotive Engineers paper S-331

PURPOSE: To describe the design and production philosophy for the Lincoln automobile.

ABSTRACT: Today's car owner demands longer low-maintenance life than he did 10 or 20 years ago. To meet this challenge the company has undertaken to improve the car's reliability. First the objectives were established. This involved product image, design standards, and acceptance specifications; manufacturing specifications for components and systems; and supplier specifications for components and assemblies. Then the engineering programs were developed for prototype body and component design, manufacturing and service feasibility, and laboratory and environmental testing. Next the manufacturing programs were worked out: body build and tool try-out; sample components, inspection and functioning; and pilot model build, preproduction, and production start-up. The product problem control system which is required consists of feedback of problems, problem control and corrective action, and management appraisal of major problems. Finally the reliability program is evaluated for its effectiveness: the program is monitored during production by testing assembly line cars and competitive cars, the product image is checked with actual performance, and the yardsticks for reliability are improved. Customer satisfaction is improving.

REVIEW: This is a very general discussion of the implementation and evaluation of a reliability program. No figures or specific information are given. It may be of general interest to managers, but it is unlikely to be of direct value to designers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Incorporating quantitative reliability requirements into specifications

AUTHOR: Charles J. Brzezinski, Office of the Assistant Secretary of Defense (Installations and Logistics)

SOURCE: 6 pp., presented at the Automotive Engineering Congress, Detroit, Michigan, January 14-18, 1963, Society of Automotive Engineers paper 625A

PURPOSE: To examine the problem of selecting a quantitative reliability requirement and incorporating it into a part specification.

ABSTRACT: The problem of incorporating a quantitative reliability requirement into a part specification involves a radical departure from the traditional two-part specification provision consisting of a clearly defined technical requirement and an inspection procedure by which conformance to the requirement is to be determined. Reliability, by contrast, involves the specification of a requirement that cannot be defined except in terms of the performance of a product rather than a unit of product. But the testing procedure for this unusual requirement must be quite specific and so specified that its stringency will be consistent with whatever level of reliability the current state of the art can meet.

The choice of a multilevel reliability requirement for part specifications was dictated by both the unusual nature of the reliability characteristic and the inherent inflexibility of specifications. It is also the only kind of reliability requirement that can be adjusted to whatever new reliability level a product can meet, as the state of the art advances, without revising the specifications. It is also the only kind of reliability requirement that does not require a supplier to embark on a costly testing program only to find after it is completed that his product is not as reliable as he hoped it might be. (Author)

An example of the application to a pressure switch is given in three appendices.

REVIEW: This is an informative summary of this approach to reliability specification. While not everyone agrees that this is the best solution to the problem, it does represent a reasonable compromise. Two other papers by the same author on this subject were covered by Abstracts and Reviews Serial Numbers 207 and 260. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Turbine engine reliability--Stage II

AUTHOR: W. C. Lawrence, American Airlines Inc.

SOURCE: 4 pp., presented at the Automotive Engineering Congress, Detroit, Michigan, January 14-18, 1963, Society of Automotive Engineers paper 639A (summarized in SAE Journal, vol. 71, June, 1963, pp. 42-43)

PURPOSE: To show what must be done to achieve the potentially high reliability of turbine engines for aircraft.

ABSTRACT: The turbine engine offered promise of high reliability and safety when it was first introduced. These levels, especially of reliability, have not been fully achieved, largely because of management and engineering practices. A proper analysis of costs of ownership would have shown the need for spending money on life improvement and the need for trade-offs between weight/performance and life. Most inadequacies in present engines have been overcome by the application of sound engineering--no breakthroughs were needed. This shows that good engineering could have been used in the first place and the troubles would have been avoided. Higher reliability has advantages such as lower risk of groundings, lower failure rates, reduced overhaul frequency, enhanced safety assurance, and possibly reduced development costs.

REVIEW: This is an indictment of and an exhortation to the aircraft industry with regard to fulfilling the potential of turbine engine reliability. The comments can be applied equally validly to many other industries. The topic is treated in a general way, and no specific details or reliability figures are given. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Overhaul life development and early failure detection of gas turbine engines

AUTHOR: J. J. Eden, Trans-Canada Air Lines

SOURCE: 16 pp., presented at the Automotive Engineering Congress, Detroit, Michigan, January 14-18, 1963, Society of Automotive Engineers paper 639B

PURPOSE: To present methods for extending the time to overhaul and for early detection of failures of gas turbine aircraft engines.

ABSTRACT: The operation of a gas turbine engine in a safe, reliable, and economic manner can be improved by the application of new procedures in respect to Overhaul Life Development and Early Failure Detection. The facts indicate that component total time is the prime single parameter which requires experience and control. The total time limitations of critical engine components should be determined by cyclic testing at the manufacturers. Operational correlation to such tests and the introduction of total time scatter into an operating fleet can safely be obtained by examining small sample sizes of, for example, two engines every 100 hours initially. After due experience is gained from manufacturers' tests and operating experience in respect to component total time on the particular type of engine, substantial overhaul life time increases can be declared.

The development and application of early failure detection designs and techniques can provide an environment in which arbitrary life limitations can be eliminated. Great improvements in reliability and economy are available to airlines and manufacturers from the application of early failure detection; the achievement of such improvements requires concentrated effort by manufacturers and airlines. Certain methods for detection of incipient failures are examined. These are visual examination, X-ray of flame tubes, oil filter residues, magnetic oil plugs, spectrographic oil analysis, engine vibration monitoring and automatic flight performance recording.

To date the application of the above procedures in respect to Overhaul Life Development and Early Failure Detection has saved a minimum of $6,000,000 during the 3,000,000 gas turbine engine hours accumulated in the operation of 50 Viscounts, 11 DC-8s, and 22 Vanguards in Trans-Canada Air Lines. (Author in part)

REVIEW: This is a good summary of the methods being used to take full advantage of the potential reliability of turbine engines. The search for early detection methods is especially to be commended. (A previous report on this subject was covered by Abstract and Review Serial Number 112.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability management control during rocket engine development programs

AUTHORS: D. K. Lloyd and Myron Lipow, Space Technology Laboratories, Inc.

SOURCE: 11 pp., presented at the National Aero-Nautical Meeting, Washington, D. C., April 8-11, 1963, Society of Automotive Engineers--American Society of Naval Engineers paper 687D (summarized in SAE Journal, vol. 71, June, 1963, p. 79)

PURPOSE: To describe how reliability management control has been exercised and evolved during the period from 1954 to 1962 with respect to rocket propulsion systems.

ABSTRACT: The paper describes reliability management control methods which have been used on both liquid and solid propellant large rocket engines during engineering development programs. The procedures, criteria for applicability, and test result classifications, as well as the statistical techniques for reliability assessment as they have been used on the ballistic missile programs, are described. The applications of these techniques are discussed with respect to their use on propulsion systems for space missions.

The following are listed as important factors:

1. Reliability demonstration.
2. Detailed test declaration intent and engine configuration review.
3. Test evaluation by prespecified criteria.
4. A valid and efficient statistical method of reliability estimation.
5. Design freeze sufficiently early in the test program to preclude reliability degradation due to unnecessary performance improvement.
6. Minimization of human error at assembly and test sites.
7. Maximum use of test data by careful analysis of data and preparation of test programs, including use of statistical design and analysis of experiment techniques where possible. (Authors in part)

REVIEW: As the authors have indicated, the methods described in this paper, while not new, appear to be valid and to have appropriate applications to present and future space systems. The paper should be of interest and value to reliability engineers concerned with engineering development programs. Other aspects of this particular development program have been considered by these authors in the papers covered by Abstracts and Reviews Serial Numbers 526 and 839. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Diagnosing semiconductor device stress response

AUTHOR: Conrad H. Zierdt, Jr., Semiconductor Products Department, General Electric Company, Syracuse, New York

SOURCE: Electronic Products, vol. 6, July, 1963, pp. 28-31

PURPOSE: To define the role of a semiconductor failure analysis program and to illustrate its operation.

ABSTRACT: The purpose of the "Physics of Failure Program" is to identify the modes, mechanisms, and causes of failure of semiconductor products in the hope that corrective action can be both direct and economical. The terms failure mode, failure mechanism, and failure cause are defined and illustrated, and then discussed with respect to the failure analysis of grown-diffused silicon n-p-n transistors. A stress-observe-stress-observe diagnostic cycle is applied to defective units while they are still encapsulated. Only after intensive examination are the units opened to the atmosphere. The diagnostic cycle can then continue on the unencapsulated unit if necessary. By judicious choice of stress and proper interpretation of the observations, skilled observers can deduce the failure mode with practically 100% accuracy. Only six failure modes and eleven failure mechanisms were found to exist on these particular units over a three-year study period.

REVIEW: This is an excellent paper on the physics of semiconductor failures and in particular on the failure modes of an n-p-n transistor. The description of the various surface-related failure modes is exceptionally clear and informative. The emphasis upon the thorough testing of a device prior to opening it to the atmosphere is well placed.

While the author claims that only six failure modes have been found to exist in the n-p-n grown-diffused silicon transistors which he examined, he does not enumerate them. Probably they are (1) n-inversion, (2) p-inversion, (3) intrinsic surface, (4) open connection, (5) shorted internal connection, and (6) ionic conduction. A similar listing of the eleven failure mechanisms which he cites is not possible from the information presented.

The distinction between a failure mode and a failure mechanism is not clear from the definitions and examples. The terms "discrepancy" and "phenomenon", used to distinguish a failure mode from a failure mechanism, are not mutually exclusive so that classifying, for example, a poor weld as a phenomenon rather than a discrepancy seems arbitrary rather than rigorous.

The diagnostic sequence, sketchily outlined in Figure 3, probably

RELIABILITY ABSTRACTS
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represents as detailed a description of a failure analysis program as can be found in the literature. While the success of this program does rely heavily on skilled personnel, a less well organized program would be even more dependent on them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Choice of fluids for cooling electronic equipment

AUTHOR: Alex. F. Knights, Kidde Aero-Space Division, Walter Kidde & Co., Inc., Belleville, New Jersey

SOURCE: Electro-Technology, vol. 71, June, 1963, pp. 57-63

PURPOSE: To present factors affecting coolant selection for a closed-loop, forced convection system.

ABSTRACT: Physical propeties of coolant fluids and their effects on cooling design are discussed under the headings: Toxicity, Flammability, Flash Point, Vapor Pressure, Pour Point, Thermal Decomposition, Electric Strength (Breakdown), Effects of Moisture, Compatibility, and Surface Tension. For eight gases and eight liquids two comparative-performance indices are developed: the heat-transfer/pumping-power index, γ, and the ducting-weight index, ϕ (for circular ducts). These are shown in graphs for many fluids.

REVIEW: The author's presentation of the subject matter is good and the paper is quite informative. However it contains a number of statements which need further explanation. In Figure 1 it is not clear what the author means by "heat flow by compartment pressurization." Also in Figure 1 the phrase in parentheses after Major heat flow should read: (conduction plus forced convection).

In the paragraph discussing the vapor pressure of coolants it might be pointed out that boiling heat transfer is an effective method of cooling a surface provided the peak heat flux at the burnout point is not exceeded. Note also that the statement relating operating system pressure and minimum coolant saturation pressure in a gas-cooled system is true only if the coolant is a single chemical specie.

In Figures 2,3,4, and 5 the author should point out that R_e is the Reynolds Number, give its definition, and hence define the characteristic lengths and velocities on which R_e is based for the different flow geometries considered.

In figures 4,5, and 6 water would probably be a better reference fluid than air since results for liquids are being compared.

In the appendix the definition of hydraulic radius should be given; the numerical designation of Equation (1) is not shown. Finally Equation (16) is incorrect; it should show α as equivalent to the first factor on the right side of Equation (15).

In a private communication the author has furnished the following

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additional information.

1. Figure 1: In the upper sketch the notation "Heat flow by gaseous forced convection, and compartment pressurization" was made to indicate that the coolant performed the two functions of convective cooling and compartment pressurization. The comma after "convection" was left out in the article.

2. Vapor pressure discussion: As pointed out in the introductory paragraphs, the article is concerned with single-phase forced convection cooling schemes; the reader is directed to references which discuss other methods of cooling. The discussion of two-phase flow was to indicate problems this regime will cause in a system designed for single-phase operation.

3. Reynolds Number is defined as the dimensionless term ($4r_h G/\mu$), where the symbols in parentheses are defined in the article. The hydraulic radius r_h and the mass velocity, G, may be defined in a number of ways. In developing the data for Figures 2-5 the correlations, and hence definitions, of Kays and London (reference 20) were used. In this reference, the hydraulic radius equals the minimum free-flow area times the flow length divided by the total heat transfer area. The mass velocity, G, is the mass flow rate divided by the minimum free-flow area.

4. Since air is so very widely used as a coolant for electronic equipment, indices for both gases and liquids were normalized with respect to air. The relative advantage of using liquids as opposed to gases, as far as the indices are concerned, is obvious, and even clearer, when all fluids are compared on a common basis. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of the field-effect transistor

AUTHOR: Phil Holden, Semiconductor-Components Division, Texas Instruments Incorporated, Dallas, Texas

SOURCE: Electro-Technology, vol. 72, July, 1963, pp. 58-61

PURPOSE: To compare the operation and the reliability of a field-effect transistor with that of a bipolar transistor.

ABSTRACT: The advantages of a field-effect transistor (FET) over a conventional bipolar transistor are stated to be (1) higher input impedance, (2) better input-output signal isolation, and (3) higher frequency capability. The disadvantages are (1) higher operating voltages, (2) increased sensitivity to temperature, and (3) higher cost.

The reliability of an FET is discussed with respect to environmental and operating stresses. Since the materials, size, and processing of FET's are similar to those of bipolar transistors, the environmental reliability of the two structures should be comparable. Under operating stresses, however, the catastrophic type of failure should be less frequent for the FET because it has only one p-n junction. Operational parameter degradation is expected to be the same for the two structures, although a drift in the junction leakage of the FET is probably more detrimental to the operation of an FET circuit than a similar drift is to the operation of a bipolar circuit. The FET may also be vulnerable to operating conditions which cause the gate-channel junction to be forward biased.

When a surface of the semiconductor is used to define the boundary of the channel, the stability of the surface is reflected in the device performance. Life test data taken on both germanium and silicon FET structures whose channels are so defined show a parameter drift quite similar to that of bipolar transistors.

REVIEW: Many of the conclusions of this article are restricted by the FET structure considered, in which at least one side of the channel region terminates at a surface. Contrary to the author's opinion FET structures can be manufactured which avoid this undesirable feature and such FET's are commercially available (Amelco FG37, for example). Either a planar double diffused or a planar epitaxial type of structure results in a channel which is completely bounded by silicon. From the discussion of the article such a structure should avoid a major source of parameter degradation--the surface. However, two junctions are needed to fabricate this structure so that the superior resistance to catastrophic failure claimed for the one-junction structure is no longer applicable.

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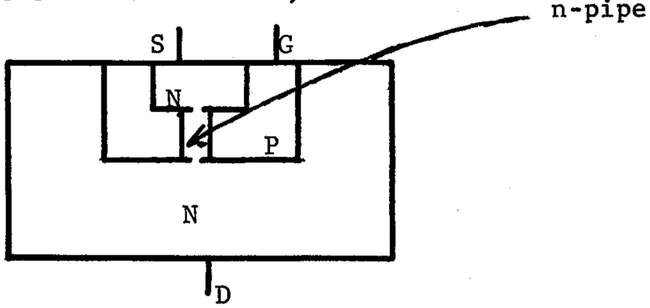
RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

The statement that the frequency capability of an FET is higher than that of a bipolar transistor neglects to add that this capability is seldom realized, generally because the path which the carrier must traverse is much longer in the typical FET channel than in the typical bipolar base region. To build an FET with channel length comparable to the base width of a bipolar transistor one has merely to introduce an n-type pipe between the emitter and collector of a conventional bipolar transistor and operate it as follows (nomenclature same as author's):



The gate voltage needed to pinch off an n-type channel is negative with respect to the source so that the gate voltage shown pinching off the conduction of the n-type channel in Fig. 3 should be written $V_{GS} = - V_{PO}$. ##

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Serial Number 964
Codes 711;782;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: "Stress analysis" of switching-circuit reliability

AUTHOR: H. F. Najjar, Telecommunications Engineering Department, Stromberg-Carlson, A Division of General Dynamics, Rochester, New York

SOURCE: Electro-Technology, vol. 72, July, 1963, pp. 68-70

PURPOSE: To present charts showing how the failure rates of certain components are affected by voltage, power, and other pertinent stresses.

ABSTRACT: Three tables and corresponding figures show the indicated stress vs failure rate relationship for capacitors (voltage); resistors, coils, and transformers (power); and transistors, diodes (junction temperature). If failure of any component causes system failure and if all failure distributions are exponential, then the system failure rate is the sum of the failure rates of the components. Use of the tables/figures yields the desired answers.

REVIEW: This article uses the very simple exponential distribution, series system assumptions, which are not new. It uses charts which show that failure rates are functions of stresses, which are not new either. Thus the contribution of the article lies only in presenting standard material in a concise way for use by designers.

The use of the same failure rate, regardless of manufacturer, for all mylar capacitors, or for all germanium n-p-n transistors, is not justified except for obtaining "ballpark" estimates of system failure rate. The criteria for failure are not given, which renders the application of the results difficult. The use of three or four significant figures in the data suggests an accuracy much better than is in fact there. One would be fortunate, under the circumstances, to predict an individual failure rate within a factor of two.

The limitations of this approach should be fully understood before it is used. ##

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Serial Number 965
Codes 720;810

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability trends in space electronics

AUTHOR: Donal B. Duncan, Aeronutronic Division, Ford Motor Company, Newport Beach, California

SOURCE: Electronic Industries, vol. 22, June, 1963, pp. I-2--I-4

PURPOSE: To point out that the most critical parameter in designing "spaceware" now is reliability.

ABSTRACT: The ordinary performance parameters required of electronic systems can be obtained without pushing the state of the art too far. The one parameter now most in need of improvement is reliability, especially for critical space missions. To achieve this in small-quantity production, each part and system must be made under controlled conditions. The conditions must be both rigid and flexible enough so that unless changes are explicitly ordered, none are made, but when changes are ordered, they should be readily and accurately assimilated. This requires strong management support and direction.

REVIEW: This is a good short qualitative article on the need for high reliability. It is primarily designed for the layman in this field. ##

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Serial Number 966
Codes 782;835;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Controlling stress increases reliability

AUTHORS: Robert E. Hovda and William J. West, Armament Control Advanced Engineering Department, Autonetics Division, North American Aviation, Inc.

SOURCE: Electronic Industries, vol. 22, June, 1963, pp. I-5--I-9

PURPOSE: To give a picture of how "space" circuits should be designed.

ABSTRACT: The most important requirement for space electronics is reliability. The stress vs. strength relationship and its statistical nature must be taken into account for all components. The failure rate of a component should be low during its constant phase. The onset of wearout should be beyond the needed life if maintenance is not allowed. Redundancy, usually at the subsystem level, can be used where absolutely necessary. The failure rates of parts can be adjusted by controlling the various stresses. The failure rate of a circuit can be estimated by knowing the equivalent circuit equations and substituting in them the appropriate behaviors and tolerances of the parts (including drift).

Microminiature electronics are predicted to have very high circuit reliability and they will probably find much use in hybrid applications.

REVIEW: This is a rather general article on circuit reliability in space systems. It has little specific information for the design engineer, but does provide good reading for one not versed in the field. The section on environment considerations may have suffered in editing, e.g. "A conclusion to draw from environment factors is that environment has only a small effect on stresses associated with reliability," and "The hostile environment of space does not materially degrade the reliability of the system." Undoubtedly there are qualifications for these statements. ##

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720;775;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Manufacturing components with clean electrical contacts

AUTHOR: Edgar Freudiger, Metals and Controls, Inc., A Division of Texas Instruments, Inc. (currently with IMEASA, Neuchatel, Switzerland)

SOURCE: Electronic/Electromechanical Production, vol. 3, January-February, 1963, pp. 10-16

PURPOSE: To discuss the factors affecting the cleanliness of electrical contacts.

ABSTRACT: The performance of a pair of electrical contacts is changed fundamentally by the presence of foreign matter on the surfaces. Contamination affects contact resistance, reliability, contact adhesion, and emission properties. Changes in adhesion are reflected in variations in the wear and noise level on sliding contacts, and the presence of contaminants changes the conditions under which dielectric breakdown of the contact gap occurs; this in turn results in a different erosion mechanism. Troubles from contact contamination can usually be eliminated by: (1) identification of the contaminants, (2) determination of the source of these contaminants, (3) elimination of the source, or if not feasible, introduction of a properly controlled cleaning process or a change in contact material. Proper handling during the manufacturing cycle has as much to do with contact performance as proper design and correct choice of materials. Contamination may result from such operations as rolling, swaging, or drawing; from chips of metal embedded during coining or welding operations, or from the lubricants used during the finishing processes. Contamination may also occur during storage when the contact materials react with the ambient atmosphere. Dust is always a problem and should be guarded against during all stages of the manufacturing process. In the finished assembly, contact reliability can be increased by providing wiping action and using multiple contacts. The contact arrangement should be such that the surfaces are parallel to the direction of gravity thus preventing the collection of dust particles on the contacts. (24 references are cited.)

REVIEW: A large amount of available material has been well condensed into a very readable six-page article that can be read with profit by both the layman interested in the effect of cleanliness upon contact reliability and the expert already familiar with the field. One point of criticism is that the author is in error when he states that thin adsorbed films do not form in a vacuum. This might possibly be true in a perfect vacuum, but in those attainable in industrial processes adsorbed films are formed quite readily. For a detailed discussion of this topic the reader may refer to "Scientific Foundations of Vacuum Technique" by Saul Dushman (Wiley and Sons, New York, 1961). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effect of stress on the radiation stability of ASTM A 302 grade B pressure-vessel steel

AUTHOR: M. B. Reynolds, Vallecitos Atomic Laboratory, Pleasanton, California

SOURCE: Materials Research & Standards, vol. 3, pp. 644-645, August, 1963

PURPOSE: To determine the interaction of stress and fast neutron irradiation of steel with impact transition temperature.

ABSTRACT: In view of the current concern over the increase in impact transition temperature of reactor pressure vessel steels under irradiation, it seemed advisable to determine if this effect is altered by simultaneous application of stress.

Specimens were cut from a plate of the same heat of ASTM A 302 grade B steel used in fabrication of the Dresden Nuclear Power Station reactor pressure vessel. Mechanical properties were: yield strength, 71,000 psi; ultimate strength, 92,000 psi; elongation, 23 per cent; and reduction of area, 60 per cent. Whenever the reactor was in operation, the 1000-psi reactor coolant pressure put a tensile stress of approximately 13,500 psi on the specimen. An unstressed control specimen of equivalent length was installed parallel to the stressed specimen.

During the irradiation period of approximately 7 months, the specimen was stressed and unloaded at least 30 times owing to reactor shutdowns and "scrams," each of which resulted in loss of coolant pressure. The post-irradiation impact strength of the stressed material was greater than that of the unstressed material in spite of the somewhat lower exposure on the unstressed bar.

It is too early to speculate on the mechanism of this effect, but it would appear that stress aids the growth of vacancy clusters beyond the size and spacing at which the maximum effect on mechanical properties occurs.

It is planned to repeat this experiment at an early date using stressed and control bars of 0.5 by 1.0 cm cross-section to double the stress level. Also, it is planned to study the effect of stress as a function of exposure in order to explore further the analogy between radiation phenomena and aging. (Author)

REVIEW: The interactions between nuclear radiation and other environments may be quite important. It is encouraging to see work being done in this field. The article is short and will be worth reading for those directly concerned. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Self-repairing machines (Part One)

AUTHOR: Earl J. Kletsky, Department of Electrical Engineering, Syracuse University, Syracuse, New York

SOURCE: 89 pp., Syracuse University Research Institute, College of Engineering, Electrical Engineering Department, Report No. EE759-614F1, Final Report, Part One of Two, RADC-TR-61-91A, April, 1961, sponsored by Rome Air Development Center, Contract No. AF30(602)-2234 (ASTIA Document No. 263957)

PURPOSE: To establish theoretical upper limits on mean lifetime of various self-repairing systems.

ABSTRACT: The mean life is determined for a closed binomial system model, assuming identical elements with independent exponential failure rates. Perfect switching of failed elements is assumed. Failure rates of standby elements and operating elements are not constrained to be identical. For standby failure rates approaching that of operating elements, a system mean life of three to four times the element life is a practical upper limit.

A class of switching mechanisms suitable for selecting and interconnecting the working elements is investigated. This mechanism consists of one or more switching masks or shorting plugs, movable on an array of element terminals. The position of the masks on the terminal matrix determines the elements being utilized. In case of failure, one or more masks are moved until operation is restored. Such a system offers a degree of self-diagnosis. Of the special cases studied, best reliability obtained is equal to that of wired-in redundant systems having the same number of elements. Sacrifice of system reliability is shown to improve diagnostic ability and reduce switching complexity.

A study of open systems--in which element replacement is possible--is based on the model used for closed systems. For a sufficiently large constant replacement rate, system reliability is shown to be increased by orders of magnitude. Periodic replacement of operating units with standby units is considered for various degrees of repair of the standby units. An upper bound on reliability of such a system is established.

The preceding conclusions form the basis for a discussion of system design philosophy. In essence, diagnostic and switching hardware should be minimized in on-line equipment.

REVIEW: This paper provides a thorough analysis of various redundancy and repair techniques, based on a highly idealized model. The derivations and conclusions appear sound. Graphical results and

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

examples illustrate the major conclusions and provide rapid references. This is a good theoretical framework for one approach to the reliability problem.

The final discussion and conclusions are weak, with many of the points being "obvious". The author's assumptions are standard for studies of this nature. References cited in the paper provide considerable additional information.

The paper covered by Abstract and Review Serial Number 772 is based on parts of this report. ##

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Serial Number 970
Codes 720;813;815;
851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: New departure in resistor reliability

AUTHOR: --

SOURCE: Special Report on Electronics (published quarterly by Chariot Publishing Company, 65 Broad Street, Stamford, Connecticut), March, 1963, pp. 28-31

PURPOSE: To describe the military specification MIL-R-55182 for resistors and to illustrate its implementation.

ABSTRACT: The new military specification MIL-R-55182 covers hermetic seal, fixed film resistors and details reliability and performance requirements. The failure rate levels M,P,R, and S correspond to 1.0%, 0.1%, 0.01%, and 0.001% failures/1000 hrs, respectively. A schedule for testing is set up so that a resistor can progressively qualify for better levels as more experience is accumulated (these are listed). The confidence level is fixed at 60%, a compromise based on consumer desires, testing expense, and time. The resistors are also 100% checked for accuracy. Both carbon film and metal film resistors are made; they have different accuracies and temperature coefficients. The components of the resistor and hermetic seal are carefully selected and exactingly assembled. Attention to minute detail is very important. As time goes by, the resistors are expected to have even lower failure rates.

REVIEW: The emphasis here is on reliability and testing; the article seems to be directed toward resistor users, which would include designers, and contains general information. It will make interesting reading for those not familiar with the subject. (It should be noted that in a testing procedure where the random variable is discrete, such as an integer, the confidence level on the estimated interval cannot be given exactly; the statement of confidence in the paper should read, e.g., at least 60% confidence.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: In-use failure rates of component parts

AUTHOR: --

SOURCE: Special Report on Electronics (published quarterly by Chariot Publishing Company, 65 Broad Street, Stamford, Connecticut), June, 1963, pp. 46-47

PURPOSE: To show that failure rates of parts are strongly influenced by the application and environments.

ABSTRACT: A generous variety of changing factors--basic design, application, systems manufacture, environment, even shipping and handling--frustrates standardization of in-use reliability information.

A thought-provoking study by the EIA's Ad Hoc Group on Component Parts Failure Data illuminates the variability of parts failure under different operating conditions. The data, which include the failure rate charts shown in the paper, document close to an estimated 100-billion component hours of operating time. Data were derived from field-reported information by 28 major military, industrial and electronic research organizations.

Chronologically, data do not point toward a particular trend for better or for worse during the period from 1954 to 1960. Not surprising is the display of higher component failure rates for airborne applications, whereas for use in shipboard, ground, and laboratory environments they are lower (in the order indicated).

Data were also compiled, at the system level, for cycling versus continuously-on performance. Results are conclusive that component parts fail more frequently when cycled than when used continuously-on. (Author in part)

REVIEW: These are interesting charts and they point out the applicability of the term "ballpark" for system failure rate estimates. They also implicitly emphasize the pointlessness of using more than two significant figures for expressing failure rates. ##

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TITLE: Designing for the military--the new disciplines move in

AUTHOR: Alan Corneretto, News Editor

SOURCE: Electronic Design, vol. 11, July 19, 1963, pp. 40-65

PURPOSE: To show the important changes which are coming for designers of military electronic equipment.

ABSTRACT: The military is tightening its procurement rules so that reliability, maintainability, human factors design, and proper interference environment control are adequately considered. The trend is to put numbers, which must be met, in the specifications. The object of all this is to get the lowest costs over the life of the system.

Designers now are encouraged to (1) use technologies such as integrated circuits that promise very high reliability, (2) use parts and circuits of documented reliability, and (3) design to numerically specified reliability. The services are becoming increasingly concerned with the slow progress in the reliability areas and are specifying reliability goals in more detail. BuWeps has a four-part program to introduce integrated circuits into its equipment.

A Reliability Center has been set up at Rome Air Development Center to collect, analyze, and summarize parts reliability data. Their reports will deal with failure distributions, differences in failure reports from various sources, failure modes, etc. A book on reliability design is being published by BuWeps (GPO) and the military is sponsoring R&D in reliability prediction, self-repair, accelerated testing, small-lot reliability acceptance, etc. (A chart of applicable reliability specifications is given and the above book is described.)

Maintainability is also being required as a necessary part of availability. Specific numerical requirements for this may be generated in the future. Adding it after design is too late; designers must prepare for it effectively. (A selected list is given of maintainability specifications and other documents.) The Air Force hopes to supply designers with more detailed use data and goals. The maintainability of the equipment will have to be demonstrated by tests to show compliance.

Human engineering is important; much work has been done in some areas, but the field is wide open now that the subject is well accepted. Value engineering is being required more and more, and is even being written into contracts. The control of Radio Frequency Interference (RFI) is very important to systems reliability, as more

and more equipment uses electronics. This problem has not yet achieved universal recognition and this state hampers the development of a technology to cope with it. (A list of applicable documents is given.)

(About fifty sources of specialized information on these subjects are listed.)

REVIEW: This is a good survey article on military problems. While it does not treat any subject in complete depth, it can give designers and others a good idea of some of the changes to expect. It is perhaps worth noting that design engineers have traditionally been concerned with all these factors; the degree of concern is changing as required by management--but management has always had this responsibility. The degree of concern of engineers is being increased so much that they need new tools and background to adequately cope with the situation. Articles such as this are a help. ##

Serial Number 973
Code 832

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Human error and "goof proofing"

AUTHOR: George A. Peters, Santa Monica, California (no affiliation given)

SOURCE: 10 pp., presented at the Product Assurance Symposium, American Society for Quality Control, San Fernando Valley Section, Glendale, California, October 20, 1962

PURPOSE: To explore the question of how to identify and control sources of human error which might affect the design, development, fabrication, test, and operational reliability of complex systems.

ABSTRACT: Information is presented on the current need to reduce human error, some recent contractual requirements for this activity, a description of some techniques for the implementation of a human error program, some empirically derived generalizations regarding this effort, and a few of the current problems in this area. (Author in part)

REVIEW: This is a discussion and review paper directed to the layman in the field. The paper is interesting and well organized. The author has devoted much thought to setting forth in a simple manner the general principles and major generalizations of his field. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Method of using parameter confidence limits in circuit design

AUTHOR: Louis J. Ragonese, Electronics Laboratory, General Electric Company, Electronics Park, Syracuse, New York

SOURCE: 11 pp., digest of paper presented at the 1963 International Solid State Circuits Conference, Philadelphia, Pennsylvania, February, 1963

PURPOSE: To outline briefly a method of microelectronic circuit design that yields a circuit with the maximum probability of drift-free operation.

ABSTRACT: This method of design presumes a microelectronic digital circuit application involving (1) a fixed number of building blocks of any particular topology; (2) a maximum required frequency of operation; (3) a specified fan-in fan-out requirement; (4) a fixed thermal packaging scheme; (5) the use of components whose relevant parameter distributions are known; and (6) the existence of a minimum power dissipation worst-case design procedure for the particular topology. The design method consists of three independent steps: mapping the circuit "realizability plane", establishing the physical system thermal characteristic, and combining the first two steps to produce an optimum design.

The "realizability plane" consists of number of worst-case, minimum power dissipation values plotted on different confidence level curves. The worst-case limits are obtained by fixing a confidence level (e.g. 99.99%) and a reference temperature (e.g. 20°C). Then the lower limit for the worst-case analysis is the lower bound of the confidence interval at the reference temperature. The upper limit for the worst-case study is the upper bound of the confidence interval for a selected maximum temperature (e.g. 40°C). Several maximum temperatures are selected and the power dissipations are used to form a curve for the specified confidence level. A second confidence level is chosen, and holding the reference temperature fixed, a second curve is plotted as before. This is done for as many confidence levels as are desired and then the curve of system maximum temperature as a function of per-circuit power dissipation is superimposed on the realizability plane. The intersection of this curve with the realizability plane permits the selection of the circuit design whose design limits have a greater confidence than any other design for the given thermal system.

REVIEW: This is a digest of a paper and should be judged as such. The development is rather sketchy and the optimality of the procedure is not rigorously demonstrated. The relevancy of Figure 6 is not clear, since no reference is made to it in the discussion. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Forecasting fatigue life of peened parts

AUTHOR: H. O. Fuchs, Department of Engineering, University of California and Vice President, Metal Improvement Company, Los Angeles, California

SOURCE: Metal Progress, vol. 83, May, 1963, pp. 75-78, 116, 118, 120

PURPOSE: To present ways of estimating fatigue strength and life improvement due to shot peening.

ABSTRACT: Recent research on fatigue crack propagation now permits quantitative estimates of the endurance of shot peened parts based on tests involving more fundamental properties of steel.

The quantitative analysis refines qualitative rules of thumb which are:

Parts with section changes or other stress raisers can benefit more by shot peening than parts that are smooth.

Parts with skins that are prone to fatigue damage (decarburization, corrosion attack, chromium plate) can gain far more than parts without such skins.

Potential gains in fatigue life increase with the hardness of the steel, regardless of alloy content. At equal hardness levels, various steel alloys gain about equally.

If failures occur at less than 1000 cycles, shot peening is not likely to help. If they occur at more than 100,000 cycles, shot peening is likely to increase the life by a large factor.

Large and small parts can gain equally by peening.

Fatigue failures almost always start at the surface.

These qualitative rules, substantiated by long and varied experience with shot peened parts, seem to contradict some older theories of metal fatigue. However, they check with quantitative fatigue analysis which considers three separate criteria of failure: yielding, crack initiation, and crack propagation. In such an analysis, load stresses and internally balanced residual stresses must be considered together, keeping in mind that a grain of steel knows only the stresses and deformations imposed upon it, not their source. (Author)

REVIEW: This is an interesting summary of empirical knowledge about shot peening vs fatigue. The rules of thumb should be helpful to design engineers (although, of course, due caution should be applied in their use). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability physics (the physics of failure)

AUTHORS: D. R. Earles* and M. F. Eddins*, General Electric Company, Daytona Beach, Florida (*Work performed while with the Avco Corporation, Research and Advanced Development Division, Wilmington, Massachusetts)

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 43-57

PURPOSE: To present an outline of the basis, objective, and scope of reliability physics.

ABSTRACT: Mathematically, reliability engineering is born of variability. In the definition of reliability there are two major elements, the job to be done - the environment or load (stress) - and the product's ability to withstand the environment or load (strength). If both strength and stress were exactly known, there would be no great problem in obtaining reliability. However, both strength and stress are always variables.

The physics of reliability deals with the relation of strength to stress. It is defined as the science that treats the phenomena associated with failure related to matter in general, especially the relations to energy and the laws governing these phenomena.

This paper presents an outline of the physics of reliability proposed for use in an initial reliability engineering technology. It attempts to organize the basis, objective, and scope of reliability physics available for today's state-of-the-art. (Authors)

REVIEW: The stated purpose of the paper is highly commendable. Its invocation of mathematics and physics through the constant use of associated terms invites the serious attention of engineers. The same authors have published quite similar material before (see Abstracts and Reviews Serial Numbers 329, 330, 331, 332). Thus it is reasonable to expect more than an initial effort. The definitions and concepts introduced in this paper should not contradict well established ones nor should they be internally inconsistent. Instead, they should extend the conventional concepts into the area of reliability. They should be related clearly and correctly to the problems of failure.

A general criticism of the paper is that many of the statements seem at first glance to be important, but a careful analysis results in the reader's being unable to find a clear meaning. This vagueness, or "almost-rightness" makes the paper difficult to evaluate. There is some useful information here and there, but the presentation does not make it easily available. Simple orderly

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R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

concepts have been by-passed for tortuous unrewarding ones that eventually wind up short of the goal. Some examples of the ways in which this paper falls short are given below.

1. "...the consequence of a function may be described by the existence of a stress level (or a combination thereof) and an associated level of strength which, if exceeded, will result in a failure with respect to the function." It is not obvious how this applies, for example, to corrosion processes, surface leakage effects in semiconductor junctions or to mechanical fatigue.

2. "An object is defined as a sample of material, a piece-part or an assembly which has a strength related to the fact that it can store energy. This energy that the object must store is its stress." Energy is definitely not stress (mechanical stress is, however, energy per unit volume); in addition, the statement is not at all clear. There is a theory of failure of ductile materials which involves distortion energy, but its application is limited.

3. "The law of conservation of energy states that energy is stored among the various possible energy storage mechanisms of an object.

$$E_i = \sum_{j=i}^{j=n} K_i^j e_j ,$$

where E_i = Input energy of form 1,2, ..., e_j = Stored energy of form a,b, ..., K_i = Storage factor." The law of conservation of energy does not say the above. Furthermore, the equation is quite without meaning in regard to energy conservation unless $K_i = 1$. (It is not clear whether the superscript j on K_i^j is omitted in the definition or whether it is an exponent.) Why the sum begins at i is also not clear. Work is not considered to be stored unless it can be retrieved virtually intact. This does not include processes for which there is an entropy increase.

4. "Experience has shown that a given law of energy (storage) always ceases to be valid at some value of load or stress. This was formulated by Beltrami into a formal definition of failure as follows: A failure in an object occurs when the energy stored by a given mechanism exceeds a critical value." The first sentence applies only to inadequately formed laws as far as energy storage (work) is concerned. Its application to generalized stresses is not at all clear. The postulate quoted is either a definition of some of the terms contained in it or it is a theorem which must be proved before it can be accepted. How it would apply, for example, to a resistor failing by corrosion is not obvious.

5. "In any object with a large number of flaws the strength is determined by the size of the largest flaw." If geometric size of mechanical flaws is referred to, the statement is false, since the nominal stress distribution, the stress concentration, and the

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

cause of failure (e.g. fatigue or tensile) are important factors. The statement could be considered a definition of "largest flaw", although it is a poor choice of words for that purpose.

6. "The strength of an object is not necessarily constant, likewise, the criteria of failure is not necessarily associated with one point of energy acceptance nor one point in time." The meaning is not at all clear.

7. "$\log_e S = \log_e S_o - Kte^{-Q/E}$ where S = Strength, S_o= Initial Strength, K = Linear function of material concentration, Q = Activation energy, E = True level." While this equation is analogous to a chemical equation, there is no assurance that many, if any, parts have this strength vs. time law. Unfortunately, the text gives the impression that this is <u>the</u> reliability equation. Creep-rupture mechanics, for example, is far from a solved problem.

8. "A stress is interpreted as any design parameter, environmental factor or other phenomenon, physical or chemical, that exists prematurely or temporarily as a result of the requirement that a design feature function be performed. The operating stress is the value or level of stress that will exist during functional performance as intended in the design criteria." These definitions of stress certainly are different--both from the earlier ones in this paper and from established ones. The words "prematurely or temporarily" and "as intended in the design criteria" are novel modifications of which the utility is, at best, questionable.

9. Stress is divided into two categories: those due to application and those due to environment. The definitions for these are not mutually exclusive.

10. "It should be noted that a difference exists between a stress and a failure stress. The failure stress cannot be defined until it is known to approach the design limit." The meaning of this statement is not at all clear.

11. "By definition of failure, any study of the mechanisms of failure must be a study of the dynamics of energy storage mechanisms. These dynamics consider two types of agents, chemical and physical..since the strength of an object is related to the fact that it can store energy, then the mode of failure can be further defined as the manner in which the stress (energy that an object must accept) exceeds strength." This is an oversimplification of the problem. It should again be mentioned that energy is dissipated (entropy increases), not stored, in many failure mechanisms. Consider, for example, friction (wear) and corrosion.

12. "Another consideration of failure mechanisms is the effect of cycling. The concept of things in motion versus things at rest, or the dynamic state versus the static state must be considered in the discussion of failure mechanisms." The first sentence is quite true. The second has little to do with the first and its meaning is not obvious.

13. "The 'generic' failure rate is defined as the number

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of failures per unit of time or cycles that occur under ideal internal and external stress conditions." The concept of an ideal stress condition is hard to grasp, unless it be at stress = 0, in which case failure may not occur at all. Perhaps "ideal" is supposed to mean "standard use" or something similar.

14. "The largest flaw changes with time and operating stress based on Dakin and Malmlow's postulate and this may or may not be described by many distributions such as the Weibull, Normal, Log-Normal, Gamma, Gompertz-Makeham, etc. These distributions are superimposed on the exponential failure rate to form the failure rate life characteristic." The manner in which these distributions are superimposed is not clear. Nor is it obvious why they should be superimposed on the exponential distribution.

15. In a physics paper it would be better not to use the term "force of mortality" (although the term is used by some statisticians) to describe a probability density. The concept already has at least two names that are used in the reliability and statistical literature: hazard function and conditional failure rate.

16. "If the assumptions are made that the failure force exhibits an exponential function, observed failures are based on a constant criteria ...." One can only guess what the authors mean here. Perhaps what is meant is: when the hazard function is a constant, the reliability function is a negative exponential.

The tabulation of failure rates for use in preparing "ballpark" estimates of system failure rate is quite worthwhile, although the limitations of this approach (which are many) should be kept firmly in mind by the users. (It would have been helpful if the exact meanings of the headings--lower and upper limits and mean--had been given in this paper.)

A good paper on the basic concepts in physics-of-failure is needed and an effort to produce one should be commended. This paper is still a first step and there is a long way to go. ##

Serial Number 977
Codes 874;884

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Bureau of Ships maintainability specification

AUTHORS: G. Margulies and J. Sacks, System Effectiveness Section, Bureau of Ships

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 84-92

PURPOSE: To describe the development of a maintainability index procedure for electronic equipments.

ABSTRACT: This report describes the steps taken by the Navy in developing a maintainability index procedure which could be used as a specification requirement. The report contains various tables which give the average times for maintenance actions based on fleet studies of maintenance functions on radar, sonar, and a communication transmitter used aboard destroyers. The proposed solution to a maintainability index requirement was validated by later studies on additional units of equipment and other units of the fleet.

REVIEW: This is an excellent utilization of industrial engineering technology. The authors report on the use of statistical time study techniques (based mainly on the log-normal distribution) and record-keeping on data flow. Articles of this type should be encouraged, preferably when the performing organization and project manager receives just credit for the work. ##

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Serial Number 978
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An easy allotment method achieving maximum system reliability

AUTHOR: Masafume Sasaki, Electrical Engineering Department, Defense Academy, Yokosuka, Kanagawa, Japan

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 109-124

PURPOSE: To discuss a computation method for determining the optimum types and quantities of components that should be used in order to make a system as reliable as possible, subject to given constraints on cost, weight, and size.

ABSTRACT: This is a continuation of an earlier paper (see Abstract and Review Serial Number 496) in which the author presented a method of computing the highest reliability of an electronic system obtainable through the use of an optimum number and configuration of redundant components. The method is based on theorems for which derivations were given in the paper. Constraints on cost, size, and weight were taken into account. In the earlier paper sensing and switching devices were considered to have perfect reliability whereas in this paper they are considered to have reliability less than 1.

REVIEW: A major part of this paper is devoted to proofs of theorems related to systems employing redundancy. As in the earlier paper (see Abstract and Review Serial Number 496), the statements of the theorems and the proofs are, in general, very difficult to follow. The lack of clarity in the presentation makes it very difficult to assess the validity and/or usefulness of the underlying ideas. ##

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Serial Number 979
Codes 824;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A realistic measure of spacecraft reliability

AUTHORS: G. R. Grainger, W. E. Faragher and L. L. Philipson, Planning Research Corporation, Los Angeles 24, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 125-131

PURPOSE: To present a realistic measure of spacecraft success.

ABSTRACT: The conventional definition of reliability is not satisfactory where partial mission performance can be tolerated. The difficulty with it is that it dichotomizes performance into good and bad, whereas most space systems have intermediate states. Define a figure of merit V(t) as

$$V(t) = \sum_{\substack{\text{All}\\ \text{States}}} P(S_i, t)\, V(S_i, t),$$

where $V(S_i, t)$ is the value of state S_i at the time t, and $P(S_i, t)$ is the probability of S_i at t. A suitable definition of $V(S_i, t)$ is the ratio of the number of experiments that can be serviced by the spacecraft to the number that are desired (ratio is a function of time). An example is given to illustrate the procedure. It is shown that the method reduces to the standard definition under certain conditions.

REVIEW: As the authors mention, this type of approach is not unique. A similar approach has sometimes been given the name system "effectiveness." All of these are worthwhile extensions of the reliability concept. Enough work has now been done so that some sort of standardization on the concept would be beneficial. ##

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Serial Number 980
Codes 835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability factors in microwave equipment design

AUTHOR: George N. Kaposhilin, Airborne Instruments Laboratory, A Division of Cutler-Hammer, Inc., Deer Park, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 132-137

PURPOSE: To review the various factors affecting the reliability of high-frequency and microwave components and systems.

ABSTRACT: Up to about 30 Mc, parts have a dominant property such as resistance or capacitance and the "stray" properties are not considered. From 30 Mc to 1 Gc the stray properties are very important; they may be either helpful or not. Above 1 Gc parts do not have a dominant property and circuits are usually analyzed in terms of electromagnetic fields. For high reliability these stray properties must be well known and controlled. They will usually age differently from the main property and will respond differently to various stresses. The microwave components must be discussed individually and are treated here under the headings: coaxial, waveguide, and strip transmission line structures; part interconnection; and system packaging. In all of these, mechanical and electrical design are inseparable. Connectors are a problem not really solved--especially coaxial connectors.

REVIEW: This is a discussion of "well known" factors involved in high frequency/microwave circuit design. The main reliability problems seem to stem from not caring rather than from not knowing. It is almost inconceivable that any good microwave engineer would not know the proper methods if queried about them. Apparently the biggest challenges lie in getting him to care enough about reliability to use the knowledge he has, and in being sure that the constraints on cost and time allow him to do so. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component parts reliability programs in USAERDL

AUTHOR: John W. Gruol, U. S. Army Electronics Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 138-143

PURPOSE: To describe the current component parts program at USAERDL in the area of reliability.

ABSTRACT: The concepts and techniques of reliability at USAERDL are diffused throughout the organization and its programs. Some examples of the efforts of this group are:

1. Long-life electromagnetic relays: Capacity and size are deemphasized to allow more concentration on long life, e.g., a failure rate goal of less than 0.01%/10,000 operations for 10^6 operations minimum.
2. Miniature dry reed switching capsule: At 20% rated current (50ma) as many as 5×10^6 operations before 1% failure.
3. Unimite relay: A comprehensive factorial experiment will test the effect on failure rate of operating voltage, operating rate, temperature, and contact voltage and current.
4. Electron tubes: The analysis of tube factors related to reliability has been going on since 1953. A three-year life tube is now under development; the progress is made less by breakthroughs than by painstaking attention to details.
5. 70 mc 3 watt transistor: This unit was developed and reliability vs. power information is being accumulated.
6. Step-stress and screening procedures for semiconductors are being developed.
7. Micro-module reliability has been extensively pursued.
8. Cordwood modules are also being investigated. The solder joints appear to be quite reliable.

Crystals, capacitors, batteries, etc. are also touched upon.

REVIEW: This is a good look at some of the components work which is being supported by USAERDL. The comments on solder joints are interesting in view of the weld/solder controversy. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The development of a selective degradation screen for detecting potentially unreliable silicon transistors

AUTHORS: Albert Fox and C. H. Zierdt, Jr., General Electric Company, Syracuse, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 144-165

PURPOSE: To describe the techniques developed and utilized in the development of a selective degradation screening sequence for detecting potentially unreliable silicon transistors.

ABSTRACT: Use of a stress screen of high ambient temperature with back-bias collector voltage applied to Minuteman 703 transistors contributed substantially towards the achievement of the two-order-of-magnitude reduction in failure rate in the Minuteman High-Reliability Component Program. This is borne out by the testing of almost 10,000 transistors from 5000 to 8000 hours at the user's stress levels.

The highlight results of these investigations are:

1. Stress screening is estimated to have contributed to the average failure rate objective of 0.001% per 1000 hours over a period of 3 years demonstrated at the 60% confidence level in the large reliability estimation experiment.

2. The effectiveness of stress screening could not be demonstrated at user's power level in the sample size-limited screen experiment, even with tightened definitions of failure, simply due to the absence of failures.

3. Performance at higher power level tests clearly demonstrated the effectiveness of stress screening; the higher the reliability level of the product, the higher the power level of the test required to distinguish stress-screened from non-stress-screened product.

4. While a 200°C. temperature with 45-volt collector voltage stress was both effective and efficient at power level tests below the maximum rated (500 milliwatts), this effectiveness would be severely lowered at higher than maximum rated power level tests; however, resorting to a higher temperature (250°C.) with equivalent voltage stress proved to be very effective but much less efficient.

5. Utilizing short-term (2 weeks) burn-in power operating tests as a screen was not nearly as effective as the high temperature plus back-bias voltage tests; further, burning in at power levels higher than the cycled 650 mw. condition accelerates failures on a life test of cycled 650 milliwatts.

6. Efforts expended towards arriving at the failure mechanisms and modes (reject analysis) is very important in developing a screening experiment by eliminating the many needless stresses

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

that might otherwise be designed in.

7. The experimental designs, as well as the electrical and computer techniques in the screening procedure developed here can be readily applied to other component types.

All of the tests were conducted and analyzed on a statistical basis. The experiments are described in the paper. (Authors in part)

REVIEW: This appears to be a rather comprehensive discussion of a series of well planned and well executed experiments. To perform tests such as these requires competent engineering and statistical talent. ##

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Serial Number 983
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Separation of accelerated failure modes in semiconductors

AUTHOR: W. D. Rowe, Sylvania Electronic Systems, Needham Heights 94, Massachusetts

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 166-172

PURPOSE: To demonstrate that the use of a central value for junction temperature is a valid criterion for determining the contribution to failure of the storage temperature failure mechanism, and thus allows the remaining failure mechanisms to be studied.

ABSTRACT: The failure rate for many semiconductors is $\lambda = A \exp(-B/T_j)$, where A and B are parameters and T_j is the absolute temperature of the junction. If all devices have the same ambient temperature they will have different junction temperatures because of their differing thermal resistances. The mean failure rate is obtained by integrating λ times the probability of T_j over all T_j. In practice this is complicated. It is shown that the mean failure rate is closely approximated by the failure rate corresponding to the mean T_j. Some of the types of failure modes that are separable are illustrated in a graph by means of hypothetical examples. The value of and need for accelerated tests is discussed in an appendix.

REVIEW: The purpose of the paper is not achieved, largely because of errors in interpreting the parameters A and B in the formula for λ (see ABSTRACT). They are incorrectly identified as the initial failure rate at standard temperatures and a factor to double the failure rate, respectively; neither definition is even close to the proper one. (Equation (6) for $\bar{\lambda}$ is also incorrect.) The value of B used in the "proof" of the validity of using the failure rate at the mean temperature for the mean failure rate is seriously in error--apparently because of the incorrect definitions. The value used would correspond to an activation energy of the failure mechanism of less than 10^{-3} ev, which is ridiculously low for a device operable at room temperature where kT_j is about 1/40 ev. (k is Boltzmann's Constant.) If a more reasonable value had been used, corresponding to an activation energy much greater than $kT_j = 1/40$ ev, the correct result would have been obtained--namely that the hoped-for approximation is not valid for the example. Figure 6, the example graph and its explanation, for showing various failure modes, is difficult to interpret--partly due to poor reproduction. While some of the basic ideas in the paper may be useful, their development is entirely inadequate. ##

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Serial Number 984
Codes 810;832

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The impact of reliability on manufacturing

AUTHOR: Joseph D. Fernbach, International Business Machines Corporation, Space Guidance Center, Owego, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 173-183

PURPOSE: To discuss the interrelationship of the manufacture of electronic equipment in the space age and reliability.

ABSTRACT: There are ten conditions that the space age has forced on manufacturing: reduced size, weight, and power requirements; new environmental aspects; lack of firm specifications; higher accuracies; more reliability; lower costs; quicker delivery; and less maintenance. When assemblies were first tested under the more severe environments, it was found that the techniques of assembly then in use were seriously inadequate (several examples are given). Reliability requirements are extremely high compared to previous practice. Manufacturing needs to learn how to do it right the first time and how to improve reliability without corresponding cost increases. Failure analysis is sometimes done right on the floor. Human factors groups have made recommendations in five areas: training, motivation, performance aids, work situation, and management aids (several examples are shown).

REVIEW: The points in this paper are well made, although they are not new. Apparently they need constant repetition so that organizations which are new to high reliability will have the exhortations and information at hand. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Human reliability production audit

AUTHOR: D. Meister, Head, Human Factors and Maintainability - Space Launch Vehicles, General Dynamics/Astronautics, San Diego, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 184-192

PURPOSE: To develop the theme that the production process is a man-machine system and is therefore amenable to human factors evaluation.

ABSTRACT: The production process is a man-machine system, i.e., a functional organization of men and machines designed to respond to certain input stimuli with certain required outputs. As such, it includes equipment, personnel, communications, technical data, logistics, and organization. In combination, these elements perform the following functions:

1. To plan for and provide information to production.
2. To fabricate and assemble components, subsystems and systems.
3. To check and inspect manufactured articles.
4. To receive, handle and transport these articles.
5. To organize and manage the entire process.

Since people are involved in each of these functions, each is subject to human error. It is these errors which human factors production evaluation seeks to analyze.

The discussion is organized under the headings: Workmanship and Process Errors, Production Evaluation Standards, Indices of Production Evaluation, and Human Factors Production Evaluation Techniques. The latter include Failure Report Analysis, Discrepancy Report Analysis, Information Flow Analysis, Search Analysis, Process-Flow Observation, Interviews, Group Discussion, and Critical Incident Reporting. (Author in part)

REVIEW: This is a fairly comprehensive discussion of human factors related to the production process. These factors clearly have an important effect on the production of reliable equipment. Other studies on human factors as they affect reliability and maintainability were covered by Abstracts and Reviews Serial Numbers 188, 196, 240, 248, 267, 480, 502, 565, 567, 712, 840, 841, 842, 843, 854, 910, 911, and 912. ##

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Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of in-plant component failure

AUTHORS: R. P. Caldarone, M. L. Wolf, and J. W. Dziamanski, Westinghouse Electric Corporation, Air Arm Division, Baltimore, Maryland

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 193-203

PURPOSE: To examine failure data generated during the manufacture and assembly of typical electronic equipment.

ABSTRACT: A study has been made of the types and causes of in-plant component failure of two military data processing systems. Nearly 1,000 electronic parts were suspected of failure and removed from the systems, and in each of these instances, no part could be replaced without surrender of the failed part and filling out of a form description of the failure. Failure modes, comparison of failures between the systems, and causes of failure are discussed in this paper. A new approach to the problem of semiconductor device failure was derived to explain the experimental results of this analysis. The following are the main conclusions.

1. A balanced reliability improvement program will be most effective for systems reliability in the long run. There is simply no panacea for reliability improvement and growth.

2. Education for improvements of transistor manufacture, design application, handling, assembly into the system, and testing is clearly needed and economically justified. Too many transistors are removed from the system at no fault of the transistor. The aura of suspicion and confusion concerning transistors is reflected primarily on (a) a tendency to blame system failure on transistors if no other failure is immediately apparent, and (b) additional system requirements on transistor operation over and above those normally specified in transistor procurement.

3. Apparently, the fabrication and design application of diodes is being taken for granted and loose habits seem to have been permitted to develop. This is a mutual problem of the system manufacturer and diode fabricator.

4. In general, capacitor and resistor failures occur at lower rates than the semiconductor device failures, are usually human induced, are less likely to be due to mechanisms of failure, and, as such, pose a less serious obstacle to the goal of system reliability than the semiconductor devices.

5. During systems assembly and test (a) the greatest cause of failure in the transistors, diodes, and capacitors included in the present study was shorts either existing in them or occurring during the initial few hours of operation; (b) under even tight control of manufacturing, assembly, and test procedures, a significant portion of failures is due to human errors; (c) the overall failure rate of the four electronic component parts studied de-

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creases in the order: transistor, diode, capacitor, and resistor.

A model of failure for components is hypothesized in which the different failure modes due to leads, surface, junction, etc. are listed separately. Each has a failure probability independent of the part in which it is found. These separate failure probabilities are affected differently by various stresses. (Authors in part)

REVIEW: The report of this experiment is useful, in terms both of the actual results and of the further hypothesizing about the make-up of gross failure rates. The results will be of use to those doing design and manufacture as well as to those interested in the fundamentals of failure. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Criteria for soldered interconnections - metallurgical completeness

AUTHOR: J. D. Keller, Advanced Manufacturing Technology, The Martin Company, Orlando, Florida

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 204-210

PURPOSE: To cover the elements essential for the formation of proper solder joints.

ABSTRACT: Findings have been based on solder flow tests, and the correlation of the flow to an area of spread as a function of an angle of wetting. Results were studied in the light of metallurgical requirements, discontinuities, mechanical versus metallurgical joints or adhesions, dewetting, porosity and grain size.

The validity of the soldering operation was first studied on a specimen level. Spread tests on copper coupons disclosed discontinuities, grain size, dihedral angle of wetting and other metallurgical bonding requirements. Interface areas were examined by photo-micrographs to determine the nature of given intermetallic formations. By correlating the metallurgical excellence with mechanical pull tests, reliability conditions were explained. This information was transposed into actual configurations, and the importance of wetting, solder quantity, solder flow and dihedral angle was noted on various printed circuit connections.

Identical fundamentals were then explained in configurations of vast differences, such as printed circuit connections versus lugs. In all cases, however, the all-important dihedral angle of wetting principle was used to predict the integrity of the metallurgical attachments. It is possible, therefore, to set forth this correlation from a microscopic level to a level of actual hardware configuration, and acquire firm standards for visual joint acceptance with minimum inspector training. This meant the acceptance of soldering operations based on engineering logic rather than individual opinion. (Author)

REVIEW: This is a reasonably complete discussion of some phases of the soldering operation. There is no mention of how the surfaces were cleaned or of the flux problem. (It is presumed that a metallurgically sound joint will have long life, i.e. be reliable.) Other papers on reliability in soldered connections were covered by Abstracts and Reviews Serial Numbers 724 and 942. See also Abstract and Review Serial Number 988. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Experimental evaluation of reliable soldering processes

AUTHORS: G. V. Browning and M. H. Bester, Autonetics, A Division of North American Aviation, Inc., Downey, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 211-221

PURPOSE: To describe experiments for determining some optimum parameters in the soldering process.

ABSTRACT: Laboratory tests to select optimum parameters for reliable soldering were conducted with emphasis on flux types, cleanliness, component lead and board material, soldering time and temperature, and mechanical factors.

To assess flux effectiveness, approximately 13,000 test joints were examined. Use of a glutamic acid hydrochloride flux resulted in six percent imperfect joints compared to ten percent for an activated rosin flux and 47 percent for water-white rosin. Failure to remove fluxes resulted in corrosion during humidity tests. Corrosion was proportional to flux activity. Feasibility of suitable flux removal procedures was demonstrated by humidity tests and the use of radioactive tracers.

Component lead cleanliness was shown to be increasingly significant with less active fluxes. Tests with as-received leads resulted in 27 percent imperfect joints compared to 14 percent with cleaned leads. Vapor blast cleaning proved to be superior to detergent cleaning. A lead solderability screening test was devised to develop acceptance standards. Lead materials exerted considerable effect on solderability, particularly after accelerated aging at elevated temperatures. Solder and tin coated leads and gold-plated leads were good; however, leads required adequate plating thickness. Lead orientation in holes and diametral clearance exerted a marked effect on the incidence of imperfect solder joints.

Plating thickness in through-plated holes significantly influenced solder joint quality with thicker plating being most beneficial.

A wave and a dip soldering machine were assessed, and comparison of machine results versus hand dip soldering illustrated machine superiority. Use of hydrogen as a gas flux was evaluated thermodynamically and then tested experimentally with negative results at the temperatures employed. However, satisfactory results were obtained with a hydrogen flame. (Authors)

REVIEW: This is a good discussion of some phases of the soldering operation.

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A N D   T E C H N I C A L   R E V I E W S

The criteria for good/bad joints are not given and were apparently more severe than in practice since all tests contained some bad joints. (It is also apparently presumed that a metallurgically sound joint will have long life.) Other papers on reliability in soldered connections were covered by Abstracts and Reviews Serial Numbers 724, 942, and 987. ##

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Serial Number 989
Codes 835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of printed wiring cordwood modules

AUTHORS: T. S. Gore and W. V. Lane, U. S. Army Electronics Research & Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 222-227

PURPOSE: To determine the suitability of a cordwood design for meeting military requirements.

ABSTRACT: When cordwood assemblies were made with straight leads and potted in silica-filled epoxy, the thermal strains caused part failures. The leads were then kinked and the parts and leads were coated with a silicone compound to allow for thermal expansion mismatch. This proved effective. Nine module types were selected for reliability test; they were subjected to several extreme environments. All tests were performed in series; there were no combined environments. The table shows the test results:

Analysis of Operational Life Test

Component Type	Quantity in Sample	Failures in Sample	Total Unit Hours	Calculated Max Failure Rate (At 75% Confidence)
Transistors	408	0	1.53×10^6	$0.090\%/10^3$ hrs
Diodes	1558	0	5.84×10^6	$0.024\%/10^3$ hrs
Resistors	1400	0	5.25×10^6	$0.026\%/10^3$ hrs
Capacitors	492	1	1.77×10^6	$0.153\%/10^3$ hrs
Printed Wiring Solder Joints	11,802	0	44.25×10^6	$0.0031\%/10^5$ hrs

It is concluded from the test results that the use of military-standard components in encapsulated printed wiring cordwood modules using the construction technique described in this paper can result in component reliability levels at least equal to the levels reported for similar components in a free-air environment. (Authors in part)

REVIEW: This is a description of an experimental program. The cordwood concept in general seems now to be fairly well established as one of the "reliable" miniaturizing methods. ##

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Serial Number 990
Codes 835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure analysis of potted electronic modules

AUTHOR: Burton S. Levin, General Electric Company, Reentry Systems Department, Philadelphia 4, Pennsylvania

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 228-231

PURPOSE: To describe some of the diagnostic techniques used to determine the cause of failure of potted electronic modules.

ABSTRACT: Potted (epoxy) cordwood modules are tested (input vs. output) to determine their quality (good or bad). All modules pass the test before potting. The modules are X-rayed to reveal such defects as wiring shorts. The epoxy is then dissolved from the ends to reveal the welded nickel ribbons. If necessary, parts are removed from the stack. While many of the part examinations are done in-house, the vendor is kept informed and requested to examine some of the parts. There is feedback to the production system so that failure causes can be eliminated.

This program reduces costs, improves quality, and increases reliability.

REVIEW: This is a brief description of a failure analysis program, which seems to be working well. In the context of failure analysis it is doubtful if any failure should be considered "random," i.e., without cause. ##

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Serial Number 991
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Human factors in high density electronic packaging

AUTHORS: M. Freitag and H. G. Frankland, Ryan Electronics/Ryan Aeronautical Company, San Diego, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 232-239

PURPOSE: To describe some of the safeguards developed for ensuring reliable design and fabrication of high-density packaging for space applications.

ABSTRACT: Electronic packaging technology is presently undergoing far-reaching change under the impetus of space and missile system requirements. The constant pressure to minimize equipment space and weight on these programs is manifest in the trend toward component miniaturization. The availability of these new and smaller components has both enabled and forced the development of new packaging techniques utilizing 3D or wafer-type construction. By use of these methods, inter-component spacing and interconnections are minimized, thereby making maximum use of available space with minimum weight. Modules constructed in this manner can be encapsulated or potted for added reliability thus reducing environmental degradation effects.

Promised increases in reliability are not obtained until the procedures, materials, handling and interaction effects are debugged and proven. Departing from the older, more familiar methods should be done gradually with the precautions, retraining and retooling necessary to provide a smooth transition period. Initially the module rejection rate will be high. If the necessary precautionary program is instituted, a low rejection rate will result. This initial reliability decrement has been attributed primarily to the human factors problems caused by the very advantages of dense packaging. These initial problems can be minimized if the necessary safeguards and precautions are taken in design, fabrication and material handling and if personnel are properly indoctrinated and trained in the new methods.

The paper deals with (1) handling of parts and materials, (2) conflict of packaging design with the requirements of maintenance and producibility, (3) integration of packaging and circuit design, (4) changes in design methods, (5) economics, and (6) selection of assembly personnel. (Authors in part)

REVIEW: This is a good discussion of the human problems involved in high-density packaging of electronic circuits. The specific points are well and briefly made; the overall paper is general enough to be of use to a great variety of people. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Manufacturing reliability

AUTHOR: B. L. Lubelsky, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 240-243

PURPOSE: To point out the factors which are needed to insure the manufacture of high-reliability assemblies.

ABSTRACT: A discussion is given of the checks and balances required to minimize the degradation of design reliability during the manufacturing-inspection-use-cycle. The paper identifies and explores the relationship of the basic areas which primarily contribute to degradation of reliability in the cycle and the checks and balances as provided by Product Assurance functions to cope with these considerations in the Polaris Program. It delineates principal Product Assurance functions required prior to manufacture and correlates these with the check and balance functions which have been found necessary during the production phases. It relates the historical trend of the inspection functions, and the recognition for the need to reverse this trend in terms of modern day "state-of-the-art" production programs. It summarizes the organizational reorientation of the Product Assurance functions at Lockheed Missile Systems Division providing for re-establishment of the role of the "Chief Inspector" as a serious intent to train inspectors and create the awareness of the importance of inspection for those workmanship characteristics which are not susceptible to measure, but which must be considered in a decision as to acceptability of product.

Several itemized lists of the functions of a Product Assurance group are given. (Author in part)

REVIEW: The key to the whole program is the "painstaking attention to details" mentioned by the author. The purpose of all the checks and balances and the associated check lists is to assure the consideration of every detail, however "insignificant," which might affect reliability. Engineers in the normal course of events are familiar with some of these, but it is important to have attention called to all of them.

In passing, it might be worth noting that manufacturing people sometimes have <u>good</u> ideas which should be incorporated in the design to <u>improve</u> it. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Infrared techniques enhance electronic reliability

AUTHOR: Riccardo Vanzetti, Communications & Data Processing Operation, Equipment Division, Raytheon Company

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 244-256

PURPOSE: To describe the determination of power dissipation and current flow by means of the measurement of the infrared radiation emitted by energized electronic parts.

ABSTRACT: This paper describes a new approach to the determination of power dissipation and current flow in electronic circuitry. The approach involves the measurement of the infrared radiation emitted by energized electronic parts. It has the effect of substituting the use of radiometers for wattmeters and ammeters. Its main advantages are the following:

1. No loading of the circuitry nor upsetting of the electrical or thermal equilibrium of operating components, because these are not in physical contact with the measuring equipment.
2. Fast and complete performance measurement for each and every component part is possible, instead of the standard way of testing a limited number of electrical data at a limited number of test points.
3. Disclosure of thermal characteristics, normally undetected with the use of conventional methods, might supply the key to early failure prediction.
4. Comparison of infrared recordings taken at different intervals of working time could point out those component parts whose performance is drifting towards a future catastrophic failure.
5. In preventive maintenance, comparison of infrared recordings could disclose whether the new unit is really better than the one being replaced.

The main areas of application of these techniques are (1) engineering design evaluation for better reliability, and (2) quality control at the component-part and assembly levels, with good possibilities of yielding fully automated operation. Results which could be derived by the full implementation of the techniques include (1) improvement in equipment design, (2) improvement in reliability through improved inspection and testing, (3) improvement of maintenance techniques, and (4) use of the infrared techniques as the natural solution for the difficulties encountered in measuring current flow in microminiaturized and thin-film circuitry.

Some typical results are shown in pictures and recordings.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Current areas of investigation are summarized. (Author in part)

REVIEW: This is a description of a new non-destructive testing technique which appears to have considerable potential usefulness in dealing with electronic components and circuitry. The account given is clear and well presented. ##

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R E L I A B I L I T Y   A B S T R A C T S
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TITLE: Sequential 3-way classification of lot quality

AUTHORS: James A. Lechner and Herbert Ginsburg, Westinghouse Research Laboratories, Pittsburgh 35, Pennsylvania

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 257-269

PURPOSE: To describe a method for classifying lots into one of three quality grades.

ABSTRACT: Current lot acceptance procedures generally allow only two alternative decisions, conveniently labeled "Accept" and "Reject". However, within the class of acceptable items, higher quality will generally result in lower maintainability costs. If, through better discrimination in lot quality grade, the selling price could be tied to lot quality, this procedure could be mutually advantageous to consumer and supplier.

In this paper, a method for classifying lots into one of three quality grades is described. Numerical examples are presented for the case where the measure of quality is mean time to failure, and the distribution of time to failure is assumed to be exponential. (The definition of failure is assumed given and unambiguous.) (Authors)

REVIEW: The procedure outlined in this paper constitutes an addition to the available plans for use in acceptance sampling when the underlying distribution is assumed to be exponential. As the authors have indicated, there are certain as yet unanswered questions as to the robustness of the procedure (i.e. its sensitivity to failure of the assumption of an exponential distribution), its efficiency relative to other existing procedures, and the effects on it of various kinds of truncation. Investigation of these and other questions is under way. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weibull tables for bio-assaying and fatigue testing

AUTHORS: Henry P. Goode and John H.K. Kao, Department of Industrial and Engineering Administration, Cornell University, Ithaca, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 270-286 (also ASTIA Document No. 286035 and in "Sampling Procedures and Tables for Life and Reliability Testing based on the Weibull Distribution(Reliable Life Criterion)", Quality Control and Reliability Technical Report TR6, Office of the Assistant Secretary of Defense (Installations and Logistics), U. S. Government Printing Office, 1963, price 45 cents)

PURPOSE: To present an acceptance sampling procedure and tables of related sampling inspection plans for the evaluation of the reliable life of a lot.

ABSTRACT: This report presents an acceptance sampling procedure and tables of related sampling inspection plans for the evaluation of lot quality in terms of reliable life (or its complement, quantile life.) The Weibull distribution (including the exponential distribution as a special case of the Weibull) is assumed as a statistical model for item lifelength. The evaluation of sample items is by attributes with life testing being truncated at the end of a specified period of time. Tables of factors are also provided from which other sampling inspection plans of desired form can be designed and for use in evaluating the operating characteristics of other specified sampling inspection plans in terms of item reliable life.

The Weibull distribution has three parameters, viz. (1) the scale or characteristic life parameter, which need not be known, (2) the shape parameter β, which must be assumed known, and (3) the location parameter, which is assumed to be zero, but for which correction can easily be made if it is not zero. Six examples of the use of the tables are given. In addition to the material in the paper, the report TR6 (see SOURCE) contains a section on life testing time requirements to assure required reliable life, together with associated tables and illustrative examples. (Authors in part)

REVIEW: These tables supplement the others of the authors for the Weibull distribution. (See Abstracts and Reviews Serial Numbers 46, 202, 208, and 756.) They are, of course, useful in other fields besides these listed in the title of this paper. One good use is in seeing how critical the assumption of a particular value of β is, by comparing the results for several values which are close together. This is especially true around $\beta = 1$, the exponential assumption so often made. ##

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Serial Number 996
Codes 424;612;824;
831;837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Using transfer functions in reliability prediction

AUTHORS: Irving Bosinoff and Richard M. Jacobs, Sylvania Electronic Systems, A Division of Sylvania Electric Products, Inc., 100 First Avenue - Waltham 54, Massachusetts

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 455-469

PURPOSE: To show how network equations are used in reliability prediction.

ABSTRACT: A transfer function can be defined as response function/excitation function. Laplace transforms simplify the application of transfer functions.

A collection of network equations may be represented by a matrix equation. Inversion of the matrix (when possible) then solves for the network voltages (or currents). The system component parameters appear in one matrix. The values of these parameters can be given random values corresponding to their actual distributions. The effect on important operating voltages (currents) can then be determined. If desired, the probability distribution of the operating voltages (currents) can be determined. For any but the simplest networks, a computer will be necessary for performing the arithmetic. Two examples are given.

REVIEW: The transfer functions mentioned in the title, and discussed only briefly, are not the same as the network equations which are actually used in the paper. The use of matrices in the solution of the network equations is quite standard; the Monte Carlo method of assigning values to the component parameters for determining the distribution of operating voltages (currents) is well covered in the literature. The explanation of this process given here is brief but good. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Exact truncated sequential tests for the exponential density function

AUTHOR: Leo A. Aroian, Space Technology Laboratories, Redondo Beach, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 470-486

PURPOSE: To derive formulas for exact truncated sequential tests based on the exponential density function.

ABSTRACT: Formulas are derived for the exact truncated sequential tests when the density function is the exponential. The operating characteristic function and the average time to termination of the test are given. The method depends on identifying truncated sequential tests with a random walk governed by a Poisson stochastic process which itself is a Markov chain. The method is perfectly general and may be applied to other density functions. (Author)

REVIEW: This is a mathematical paper which makes a worthwhile contribution to the methodology of sequential life testing. An earlier paper on the truncation of sequential life tests was covered by Abstract and Review Serial Number 200. By contrast with the present work, the results in the earlier paper were obtained by Monte Carlo procedures. The present paper includes a comparison of the approximate and exact results. Twelve pertinent references are cited. ##

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Serial Number 998
Codes 612;824;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Monte Carlo: Reliability tool for design engineers

AUTHOR: Peter J. Myers, Member of the Technical Staff, Product Effectiveness Laboratories, Hughes Aircraft Company, Culver City, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 487-492

PURPOSE: To describe the Monte Carlo technique as a tool for reliability engineers.

ABSTRACT: Monte Carlo is a method for solving complicated technical problems which cannot be solved directly without risky approximations. In a Monte Carlo solution, the given problem is replaced by a mathematical model which can be solved numerically. This model is called a simulation. The parameters of the problem are, in general, variables. In the simulation, variable parameters are represented by specific frequency distributions. Then a value is specified for each parameter by choosing a number at random from its corresponding distribution. Each set of values determines an answer to the problem. This constitutes one trial. Accurate answers can be obtained by averaging a large number of trials with the aid of a computer.

This paper contains a description of the areas in which Monte Carlo may be applied and an explanation of the basic steps involved in a Monte Carlo solution. Two examples of the solution technique are included. (Author in part)

REVIEW: This is a brief description of the Monte Carlo technique as it may be applied by reliability engineers. As such, it will be of most interest to those who are as yet unfamiliar with the technique, and require a brief description, with illustrations. No references are cited. See also the paper covered by Abstract and Review Serial Number 996. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability models in space systems planning and decision making

AUTHOR: Gerald H. Sandler, Radio Corporation of America, Major Systems Division, Moorestown, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 493-498

PURPOSE: To consider the reliability and relative cost problems connected with the choice of a single direct shot versus a multiple-shot orbital docking operation for a soft lunar landing vehicle.

ABSTRACT: A major problem facing the space systems engineer is the lack of prior knowledge to use when comparing alternate system approaches and designs for accomplishing particular missions. For this reason, mathematical models provide a powerful tool for system decision-making under uncertainty. If these models can indicate reasonably adequately the consequences of alternate decisions, and compare them over a range of contingencies that may arise, the decision-maker may have a fairly high degree of confidence in the policy chosen.

This paper is concerned with the reliability and relative cost problems associated with the choice of a single direct shot versus a multiple-shot orbital docking operation for a 2000-lb. soft lunar landing vehicle. For the direct-shot approach, the probability distribution of the number of launchings until the first success is derived by developing a system of difference equations describing the transitions between the states of success and failure, and solving them by means of generating functions. A similar approach is followed in the multiple-shot case. Comparison of the alternative approaches is made through the use of the derived probability distributions, in terms of the number of shots required for a certain assurance of success in each approach and various booster and docking reliabilities.

REVIEW: This is a worthwhile mathematical study, of which the principles should have applicability to missions other than the one considered. The practical value of this approach depends very much on the adequacy with which the models represent the consequences of alternate decisions, and on the validity of the input data from which the necessary probabilities are obtained. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design review--a philosophy, survey, and policy

AUTHORS: J. Y. McClure and E. S. Winlund, General Dynamics Corporation, San Diego, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 287-300

PURPOSE: To discuss and justify on the basis of a mail survey the values of a design review program.

ABSTRACT: This paper outlines the current need for formal design review in complex product design, and the underlying philosophy. It analyzes the problem areas, presents relevant results of two surveys, and recommends a policy for each principal consideration. These policies can be used as a basis around which to develop specific policy and procedure irrespective of organization structure.

The authors believe that design review, when justified by product complexity, can be made to pay off very handsomely in early product maturity and overall cost reduction. (Authors)

These conclusions are based upon the results of an industry survey limited to members of the Aerospace Industries Association. Topics include definition, objectives, cost, scheduling, organization, forms and procedures, and an indication of the results which are expected.

REVIEW: The Aerospace Industries Association is to be commended for undertaking such a thorough survey and having it reported upon for all industry to use. The survey would have been more representative of the over-all aerospace industry if the sample had included some of those aerospace industrial organizations which are not members of AIA. The reference list could have been more complete --particularly in a study of this kind. Other papers on design reviews have been covered by Abstracts and Reviews Serial Numbers 25, 26, 29, 125, 183, 190, 193, 245,273,275,382, 493, 621, 638, 744, and 750. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System design for reliability

AUTHOR: Henry S. Katzenstein, Solid State Radiations, Inc., Los Angeles, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 499-501

PURPOSE: To philosophize about design for system reliability.

ABSTRACT: While almost everyone is convinced that reliability is important, it is necessary to get rid of the illusion that it can be added to a completed product like so many coats of paint. The margin between operating stress levels and gross-failure stress levels are quite small and the systems designer is caught in the middle. Redundancy is a possible solution to the reliability problem but not necessarily the best one for a given set of constraints (e.g. cost, size, and weight). Adaptive mechanisms are an exciting possibility.

While the use of advanced concepts such as optimum redundancy or adaptive systems are becoming mandatory for complex systems, these developments must not obscure the basic professional responsibility of the system engineer to make reliability a cornerstone of his design process. (Author in part)

REVIEW: This is a short general philosophical paper. The message is good but not new. ##

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Serial Number 1002
Codes 813;836

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability assurance for custom testers

AUTHORS: B. O. Allen and W. W. Westman, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 315-325

PURPOSE: To describe the development, implementation, and administration of a reliability improvement program involving a short delivery time, a small number of design review personnel, and a product required in small quantities.

ABSTRACT: This paper describes a program which was developed to support, with a minimum number of reliability personnel, a requirement for a large variety of manual, semi-automated, or fully automated production acceptance and quality evaluation system testers (normally in quantities of 1 to 4). It is built basically around an early independent design review requiring highly competent, experienced personnel. The program, to be effective, must receive full support from management, must gain the confidence of the designers, must not stifle engineering progress, and must be effective in the initial design stage. As a result of this program, it has been demonstrated that reliable custom test equipment can be developed with a small design review supporting organization by a combination of a well planned reliability program and the determination of design personnel and management to increase tester reliability.

The program follows a pattern of management engineering which first finds the problem, defines it in measurable terms, establishes the various efforts which will achieve the objective, and develops a method of evaluating the results. The prime elements consist of design review, data feedback, analysis and the human problem of dealing with designers and reliability personnel who approve/reject the designs. Sample forms, specifications, design guides, and policy directives are included. (Authors in part)

REVIEW: Reliability management personnel should read this paper in the interest of learning how a small product line can achieve reliability improvements without large expenditures. General management would do well to evaluate the principles presented after tailoring the effort to their own product. ##

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Serial Number 1003
Codes 824;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability evaluations by computer simulation

AUTHORS: Edward W. Veitch and George Ashendorf, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 326-334

PURPOSE: To describe a general computer simulation method of evaluating/predicting reliability of electronic systems.

ABSTRACT: A general discussion of the problems facing a systems designer is presented, along with a consideration of the reliability and maintainability parameters which must be considered in the system design. Computer simulation philosophy with advantages and disadvantages are presented. A simple example involving an inverting two-input gate is given.

REVIEW: This paper is likely to be useful to very few readers, as it falls short in both the mathematical and the management areas. No references are cited, leading the reader to infer that no effort was made to correlate this work with that of others in the field. This is an important weakness in an area in which approaches and opinions differ. See, for example, the papers covered by Abstracts and Reviews Serial Numbers 996 and 998. The paper covered by Abstract and Review Serial Number 191 contains a useful bibliography for those interested in this topic. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: "Run-in" or "burn-in" of electronic parts -- a comprehensive, quantitative basis for choice of temperature, stresses, and duration

AUTHOR: R. Hosmer Norris, General Engineering Laboratory, General Electric Company, Schenectady, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 335-357

PURPOSE: To present a discussion of a comprehensive run-in procedure.

ABSTRACT: The "run-in" procedure here proposed is a much extended, and quantitatively refined, form of the conventional "run-in" procedure. It is designed to yield as low a failure rate (in subsequent service of the surviving population) as is possible from the test evidence practically obtainable from any given lot of moderate size (e.g. 1000 specimens). The three general features of the proposed procedure are as follows. (1) The "run-in" should consist of a comprehensive set of conditions - to catch specimens which would be short-lived with respect to not just one, but each stress or mode of failure likely to be a significant hazard. (For example, temperature cycling, and vibration, as well as steady temperature). (2) "Truncation screening" should be utilized, namely, removal of all specimens for which any characteristics (such as I_{cbo} and internal thermal resistance of transistors) deviate abnormally from the usual range, either initially, or by drift during the "run-in" procedure. (3) A logical, quantitative, procedure (here specified in principle) is proposed for choice of the duration and the value of each stress (and temperature), of the "run-in" as well as to choose limits of stress and of temperature for service. These limits will of course be lower, the lower the allowable risk of failure. (Author)

REVIEW: This is a long and involved general paper. It deals with no specific situation; many contingencies are mentioned, but not in detail. However, some examples of test results on actual hardware are presented to illustrate the quantitative considerations advocated in the paper. For those who are considering run-in tests, it may be valuable reading since so many points are covered. It is in no sense a handbook for run-in tests because it is so general. If the complete programs mentioned here were implemented, the cost in time and money would be very large and impracticable except for high production components where the need exists (as in spacecraft applications) for reducing the failure rate to a very low level. Individual parts of the proposed run-in procedure, however, and particularly the quantitative approach here advocated for the choice of run-in duration, may well prove useful even where the complete program is not economically justifiable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability takes part in a vendor-rating program

AUTHORS: Marvin R. Carpenter and Leonard G. Rado, General Precision, Inc. Librascope Division, Glendale 1, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 367-371

PURPOSE: To present a summary of a vendor-rating program.

ABSTRACT: A system which provides realistic, up-to-date ratings of vendors of parts and materials has been instituted by General Precision's Librascope Division. The program is unique mainly because the firm's Reliability Department helps Quality Control and Purchasing evaluate vendor qualifications. Reliability's experience in collecting, storing, processing, and retrieving laboratory test data warranted the group's selection as a participant in the program. Results to date reflect substantial savings in time and money and an improvement in the decision-making abilities of company buyers.

The vendor-rating program does not usurp the buyer's right to select sources of supply. His ability to make the right decisions is strengthened by the availability of additional information. The vendor-rating system reduces the secretiveness formerly surrounding reasons why buyers selected particular sources. Vendors who are <u>not</u> selected according to final ratings are revealed when Receiving Inspection checks the list of sources against the one used by the buyer. (Authors)

REVIEW: This is a very brief paper; in fact it is too much so to enable one to judge the merits of the program. On its face, it appears to be reasonable and to avoid the many pitfalls of too little or too much control/advice on the part of the purchasing department. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A cumulative-results plan for small-sample inspection

AUTHORS: A. F. Cone and H. F. Dodge, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 21-30

PURPOSE: To present a plan for use when small samples are taken and the user requires protection against accepting product of poor quality.

ABSTRACT: As a rule, the components, piece-parts, and hardware going into today's complex weapons, spacecraft, and other assemblies are manufactured in relatively small quantities and in limited production runs. Consequently, quality control and quality assurance face a special challenge, for only small-sample inspection data are available for evaluating product quality and controlling processes.

The plan described in this paper is intended for general application in quality assurance and quality control inspections in situations where small samples are necessary or desirable for one reason or another. This problem is encountered in connection with, for example, characteristics involving destructive or costly inspection or tests, items produced in small quantities, audit inspections, and check samples repeatedly taken during production. Under any of these circumstances, the standard lot-by-lot sampling plans and procedures are usually found to be unsatisfactory. The consumer's protection against highly defective product is poor when plans with small sample sizes are used, and the power of such plans to discriminate between good and bad product is inadequate.

Clearly, some additional mechanism is needed. A different and effective approach is offered in this paper in the form of a plan that employs rules of action (including a stopping rule) based on cumulative results and that serves to encourage and induce the supplier to submit product of a desired quality.

The use of cumulative results and of a stopping rule is not new. Cumulative results are used in a number of lot-by-lot sampling plans, such as those designated as "deferred sentencing", "chain sampling", and "skip-lot sampling"; in continuous sampling plans; and in process-control plans. And stopping rules have been included in published plans, as for example, rules for stopping inspection and rules for stopping production. (References are cited.) But what is proposed here is a plan or system, superimposed on the regular acceptance (or process) sampling plan, in which cumulative results are brought into play as necessary and used as a means for (1) detecting when the process level falls significantly below what it should be, and (2) invoking a particular kind of feed-back

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that initiates appropriate action on the process.

The plan is described first in general terms, and then as it has been successfully put into operation in a quality assurance application. (Authors in part)

REVIEW: This is an excellent paper, which should be useful to those who are operating line organizations or conducting acceptance inspections, as the procedure is simple to use and the calculations are easy to perform. It appears reasonable enough that it should not be difficult to sell to the skeptics. Reliability engineers may find some of the symbolism in the paper unfamiliar. For example, RQL (Reference Quality Level) should not be confused with Reliability Quality Level and m (cumulative sample size upper limit) should not be confused with MTBF. ##

Serial Number 1007
Codes 813;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The contribution of design analysis to product assurance

AUTHOR: W. L. Hurd, Jr., Lockheed Missiles & Space Company, Sunnyvale, California

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 51-54

PURPOSE: To present the elements of a total product assurance program and to show the contribution which design analysis can make to product assurance.

ABSTRACT: The major elements in a total product assurance program are:

...Reliability assistance to the design effort.
...Production and field test, and inspection planning.
...Performing all formal testing and inspection.
...Operating the failure reporting and corrective action program.
...Collecting and using design, production, and field data to assess product quality, to identify problem areas, and to assess the effectiveness of corrective action.
...Coordinating all of the aforementioned efforts with both suppliers and using agencies.

These elements are discussed briefly.

REVIEW: This paper emphasizes the fact that a competent design analysis function is essential to the achievement of high inherent reliability in a complex system. However, it is too short to be a significant contribution to the solution of the problem. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Systems engineering--a major new technology

AUTHOR: Donald S. Feigenbaum, International Systems Company

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 71-77

PURPOSE: To review the origins, nature, and work of systems engineering, its relationship to quality control engineering, and the results which can be obtained from its application.

ABSTRACT: Systems engineering is the basic new technology of integrated man-machine-information systems. In earlier years, it was confined to the purely physical hardware aspects of product systems engineering. It is now evolving as the engineering field which deals with the analysis, development, programming, design and installation of the broad total systems which are necessary for the effective introduction of automation in the factory, of computerization in the office and of the planning and control of managerial decision-making.

This technology is a major factor in the design and installation of genuine total quality control systems--the quality planning "software" as well as the test equipment "hardware". Systems engineering may thus become the fundamental design technology of the quality control engineer. It will permit him, also, to integrate --on a far more scientific basis than before--the efforts of the other groups in his company which are related to the creation, building and maintenance of product quality.

The topics discussed in the paper are (1) the origins of systems engineering, (2) the nature and work of systems engineering, (3) the interrelationship between systems engineering and quality control engineering, and (4) the results obtainable from systems engineering applications. (Author in part)

REVIEW: The author defines systems engineering as "that branch of engineering specifically concerned with the application of scientific knowledge to the design and creation of groups of interacting human and/or machine elements, directed by information, which operate on and/or direct material, information, energy, and/or humans to achieve a common specific purpose or objective." It might be thought that the performance records of such man-machine systems as warships, aircraft carriers, and communication networks constitute evidence that attention has been paid in the past to the area described in the above definition. However, the author, in a private communication, has pointed out that the emphasis in the new technology is on the interactions of the elements of systems and on the integration of humans as elements. The paper serves as an introduction to the approach. ##

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Serial Number 1009
Codes 612;640

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The role of PERT in missile and space management

AUTHOR: Willard Fazar, Herner and Company, Washington, D. C. (current affiliation: Executive Office of the President, Bureau of the Budget, Washington 25, D. C.)

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 79-84

PURPOSE: To describe the role of the Program Evaluation and Review Technique (PERT) in missile and space management.

ABSTRACT: Growing numbers of managers and technical administrators are recognizing the need to apply new and advanced management systems in order to cope with the rapidly changing conditions created by space age developments. The exponential growth of new knowledge and new technology in the past decade have greatly increased the complexity of management planning, controlling, and decision-making. Booming research and development effort and unprecedented breakthroughs in science and technology have advanced hardware systems at a much faster pace than management or "software" systems. The capacity of managers is being strained to provide the kind of leadership they have traditionally enjoyed. The creation of new tools for management requires effort quite similar to that employed in developing new hardware systems. Improved management systems result from the same careful, orderly research and development effort that is practiced to develop new hardware systems. The effectiveness and efficiency of tomorrow's managers will depend on the development and application of management systems that provide them with a sounder basis for making decisions to improve the payoff from given resources. PERT (Program Evaluation and Review Technique), designed and developed for POLARIS in 1958, the first system for measuring research and development progress and progress outlook, has won international acclaim as a "management breakthrough" for saving time and resources in the space age.

The basic PERT system is described briefly. Extensions of the basic system to reliability and to costs and resources are indicated. Evidences of the widespread application of the technique are cited. (Author in part)

REVIEW: This is essentially a "selling" document for PERT. As such, it should be worthwhile reading for managers and administrators in the missile and space fields. It does not attempt to describe the specifics or technical details of the technique, but cites nine references in which these may be found. The author inserts a well-taken note of caution against possible misapplications of the system. It might also be pointed out that any system which relies in part on the integrity and judgment of people possesses, ipso facto, an inherent vulnerability. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fads and fallacies of reliability creation

AUTHOR: Gordon H. Beckhart, Radio Corporation of America, Moorestown, New Jersey

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 125-127

PURPOSE: To present seven reliability-creating elements of a research and development program.

ABSTRACT: An example is cited of a reliability organization in a research and development laboratory in which the following features were ignored: reliability predictions, reliability allocations, a reliability program plan, reliability monitoring, planned life tests, factorial tests, and a failure reporting system. It is suggested that the following constitute seven basic elements of reliability engineering which must be applied in a research and development program: systems engineering, human factors engineering, the creation of reliable circuits and mechanisms, the selection of parts and materials, designing the equipment to withstand the mechanical environments of transportation and usage, designing for ease of troubleshooting, and designing for ease of maintenance. These elements are briefly discussed.

REVIEW: This is an attempt to satirize and downgrade certain features which have come to be regarded as standard elements of many reliability programs. The author probably has his own good reasons for making this criticism, but it could have been done more effectively with a more reasoned approach. There is no doubt that the elements proposed as important by the author are very worthwhile, but he has not established the fact that they are incompatible with the features which he apparently proposes to reject. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A case history--the Telstar satellite program

AUTHOR: P. S. Darnell, Bell Telephone Laboratories, Incorporated, Whippany, New Jersey

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 129-139

PURPOSE: To describe the achievement of reliability in the Telstar satellite.

ABSTRACT: Looking at the satellite as a device under life test, it performed all of its intended functions without failure in the actual operating space environment for 0.37 year. If we had attempted to demonstrate a mean time between failures (MTBF) of 0.37 year with a confidence level of 90% by conducting tests on completed satellite models, we find that over 23 satellite months of test with two failures would be required assuming that an exponential distribution of failures applies. Because of the high cost of satellite models, and the length of test time which must elapse, this is not the way to evaluate satellite reliability. There must be some other way, and there is, by following the philosophy applied several years ago in the development, design and manufacture of the transatlantic submerged repeater communication system.

The approach to reliability could be made by one or more of the following:

1. The use of construction and materials which have been proved by long use, particularly in the Bell System.

2. The use of only mechanically and chemically stable materials.

3. The use of extreme precautions to avoid contamination by materials which might promote deterioration.

4. Special care in manufacture to insure freedom from potentially hazardous defects.

It has been necessary to deviate to some extent from submarine cable philosophy on the satellite project. For example, the schedule on the satellite did not permit as long periods of test on some components, as was the case for certain subcable components. Also, the undersea cable parts and electron tubes were all of Bell System manufacture, whereas various parts for the satellite were supplied by outside vendors. Under these circumstances, it has not been feasible to establish as exacting manufacturing controls as when the product is made in-house. However, in spite of such differences, we were able to adhere to submarine cable philosophy in many ways and to approximate it in others.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

The topics discussed include component selection, design qualification tests, screening conditions, and environmental evaluation. (Author in part)

REVIEW: This is an excellent case history with proven success--the type of results which the industry respects. There will be an interest in more details than the author was able to present because of limitations on time and space. For example, such features as very close coordination between circuit designers and component specialists, failure reporting and post-mortem analysis were undoubtedly involved, but are not reported. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Buick's reliability program

AUTHOR: J. R. Gretzinger, Buick Motor Division, Flint, Michigan

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 269-276

PURPOSE: To describe a commercial application of a total reliability effort.

ABSTRACT: The reliability concept originated with military programs a few years ago. It is true that there is very little really new about reliability; but the fact that it is an organized, planned, and scientifically executed program by people who have no other primary responsibility is new. Some of the things that cause military reliability programs to be put into effect are:

1. Quality control organizations are not able to control field failures adequately.
2. Product complexity is increasing.
3. We have a shorter development time for our programs.
4. The customer is demanding higher reliability.
5. The cost of unreliability is increasing.
6. The importance of flight safety.
7. We have no way to test "one-shot" equipment.
8. There was some very unfavorable publicity concerning the reliability of our important weapons systems.

In addition, there are definite advantages in applying a reliability program to an automobile as compared to military products. Some of these are:

1. We have higher volume production, which gives us a larger statistical sample.
2. We normally have more prototypes to test.
3. Our design changes are much less radical than in military equipment.
4. We have more failure data on previous designs and the current design.
5. We have better control of the servicing of our product.
6. We can obtain faster decisions to correct a reliability problem.

The initiation and organization of the Buick Reliability Program are described. The function of the reliability group in general terms is given as:

1. To assist in the establishment of reliability goals.
2. To predict reliability in the following phases of a program:
   I. <u>Design Phase</u>
      1. Design Review
         a. Preliminary design.
         b. Detail design.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

2. Coordination with Engineering.
3. Redesign review.

II. Test Phase
1. Design of test.
2. Prototype testing.
3. Evaluation of test results.
4. Redesign after test.
5. Design review.

III. Production Phase
1. Production tests.
2. Evaluation of production tests.
3. Redesign.
4. Evaluation of design.

IV. Customer Service Phase
1. Evaluation of field failures.
2. Corrective action.
3. Design review of corrective action.

3. To promote corrective action and design change to improve reliability of the product in the phases enumerated in item 2. (Author in part)

REVIEW: The author has done an admirable job of describing a reliability program for a commercial product. However, he quotes no cost or schedule information, nor does he cite any references. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contractor guided corrective action program

AUTHOR: H. D. Greenwood, Aerojet-General Corporation, Sacramento, California

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 301-302

PURPOSE: To review briefly a customer directed corrective action program based on specific malfunctions or deficiencies.

ABSTRACT: To prevent design degradation and functional failure of missile components, the sources of nonconformances during manufacture must be promptly detected and eliminated. The high production capability of today's industry demands that corrective action effort be accomplished with dispatch if recurring nonconformances are to be minimized. Unfortunately experience has demonstrated that many subcontractors are neither staffed nor organized to promptly implement effective corrective action. This situation is most critical with small business suppliers and job shops.

In the preparation of a corrective action request, the subcontractor's past quality performance is reviewed in detail. In addition to specific out-of-control conditions, other associated and borderline deficiencies are marked for the engineer's consideration. As deficiencies in production equipment, tooling and operations can produce similar nonconformances of the same general type, the review must isolate these out-of-control conditions and support them with specific references to nonconforming characteristics on all other affected part configurations. This review initiates a case history file defining a subcontractor's quality performance problems.

The accuracy of predicting the probable cause of the nonconformance has improved with experience in design analysis and the use of the cause and effect charts. The evaluated information permits the supplier to quickly pin-point and eliminate the deficiency. The economic benefits to both the contractor and the subcontractor can be substantial. (Author in part)

REVIEW: This paper is intended for quality assurance personnel, but it has implications which should be of interest also to those concerned with reliability.

It is unfortunate that this paper and some others in the Transactions of the Seventeenth Annual ASQC Convention were merely abstracted and not published in full. Perhaps in such cases the authors can supply copies of the full text to those who may request them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Operation of a quality controlled repair program at depot level

AUTHOR: Frank O. Biehl, International Business Machines Corporation Space Guidance Center, Owego, New York

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 315-316

PURPOSE: To discuss the operation of a depot repair facility.

ABSTRACT: The operation of a repair program at depot level is outlined. Emphasis is placed on the degree of Quality Control exercised throughout the entire operation. This paper deals with components of an aircraft electronic system, hereafter referred to as "units."

Extensive inspection and testing of repaired units has proven worthwhile. Most units involved in the repair program are hermetically sealed and gas filled. When a unit is rejected by a using location, such as an Air Force location, it is sent to the contractor's depot where the department receiving the unit conducts a careful inspection of both shipping container and unit. Any damage noted as received is documented and recorded by photographs. This information is sent back to the responsible location or carrier through normal channels.

The unit is then functionally evaluated by trained technicians, and necessary paper work and documents are initiated. Three prime documents are necessary to conduct the unit through the repair cycle. These are a routing, a trouble report, and a test data record.

The role of each document is described briefly. A flow chart depicts the series of actions taken. (Author in part)

REVIEW: The details of this operation could be of considerable use to engineers planning maintenance functions. It is unfortunate that this paper and some others in the Transactions of the Seventeenth Annual ASQC Convention were merely abstracted and not published in full. In this particular case at least, the author should be encouraged to publish a complete report, including pertinent data.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimation for the Weibull distribution

AUTHOR: John S. White, General Motors Research Laboratories

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, p. 317

PURPOSE: To cite several estimators for the parameters of the Weibull distribution.

ABSTRACT: The two-parameter Weibull distribution function is quoted. Given a sample of n failure times from a population having this distribution, it is desired to estimate the two parameters. Estimators based on the method of moments are cited. It is shown how, through the use of certain logarithmic transformations, the parameters may be estimated graphically. The application of least squares estimation is indicated. The relationship between the Weibull and extreme value distributions is pointed out, and the results of applying the method of moments to the latter distribution are given. The maximum likelihood equations for estimating the Weibull parameters are stated.

REVIEW: This is essentially an abstract, and merely cites the results mentioned. It serves the purpose of providing these equations in a ready-reference form, but those who desire details on their background and derivations will have to look elsewhere. A good reference on these topics is [1].

REFERENCE: [1] Reliability: Management, Methods, and Mathematics, David K. Lloyd and Myron Lipow, Prentice-Hall, Inc., 1962 ##

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Serial Number 1016
Codes 222;770;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Lifetesting time requirements to assure required reliable life

AUTHOR: Henry P. Goode, Cornell University, Ithaca, New York

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 319-324

PURPOSE: To describe a sampling procedure for reliability testing which assures with 95% confidence that the items in the lot will meet specified requirements.

ABSTRACT: This paper describes a sampling procedure for reliability under which one needs only to determine the minimum lifetesting time to employ for sample items. This is done by selecting the appropriate factor from tables provided and using it as a multiple of the specified minimum reliable life or mean life to obtain the minimum testing time. The procedure assures with 95% confidence that the items in the lot will meet the specified requirements. The Weibull distribution (with the exponential as a special case) is used as a statistical model. Inspection is by attributes, the acceptance criterion being that no more than some specified number of items fail before the end of the minimum test time.

Five tables are presented to enable implementation of the procedure. Tables 1, 2, and 3 list in terms of multiples of specified reliable life the minimum lifetesting times required to assure lot compliance. Reliable life is defined as the life beyond which some specified proportion of the items in the lot can be expected to survive. Factors are provided for three reliability indices or proportions: .99, .90, and .50 (median life). Table 4 provides factors for lot evaluation in terms of mean item life. Factors have been supplied for each acceptance number from 0 through 5 and for seven different sample sizes between 10 and 1,000.

The ability of an acceptance plan of this form to discriminate sharply between good and bad lots depends on the size of the acceptance number (and not on the size of the sample as is usually the case); the larger the acceptance number the sharper the discrimination. Guidance in the choice of an acceptance number is provided by the ratios in Table 5, which gives for each of the acceptance numbers and shape parameter values the ratio between the reliable life (or mean life) for which the probability of acceptance is .95 and that for which the probability of acceptance is .05. (The latter is the specified minimum life used in determining minimum lifetesting time.) (Author in part)

REVIEW: This paper is a contribution to the set of sampling procedures available for life testing. Although the text is brief, it describes the procedure adequately. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of a rocket nozzle ablation experiment

AUTHOR: S. Roy Wood, Aerojet-General Corporation, Glendale, California

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 329-332

PURPOSE: To describe an experiment designed to test the theory that certain chemical additives might improve the performance of the nozzle convergent section of certain rockets.

ABSTRACT: Increasing the range of rockets and missiles is the object of much research today throughout the world. Range depends on the thrust generated by the exhaust gases escaping at high velocity from the rocket combustion chamber. During the flight of a rocket, hot gases erode away the nozzle convergent section, the throat diameter increases, the chamber pressure drops, and the velocity of the exhaust gases is lowered, resulting in reduced thrust and a shorter range. Thus, the nozzle convergent section must resist excessive ablation caused by high temperature, high velocity exhaust gases if distance as well as power is to characterize the performance of a rocket.

Plastics, because of their desirable light weight and other properties, were considered by the Structural Materials Division of Aerojet as candidate materials for the convergent section. One material in particular, a reinforced synthetic resin, looked promising in exploratory tests. Theory indicated that certain chemical additives might improve the performance of the nozzle convergent section. An experiment was designed on a statistical basis to test this theory.

The effects of four resin additives were investigated. The experiment was set up as a randomized block design. Tests of significance indicated that the materials did differ, but an apparent improvement over the control (no additive) was judged to be attributable to the chance variation found within the materials. (Author in part)

REVIEW: This is a good case history illustrating an application of a statistically-designed experiment to an industrial problem involving a high-cost, low-volume product. It is unfortunate that this paper and some others in the Transactions of the Seventeenth Annual ASQC Convention were merely abstracted and not published in full. Perhaps in such cases the authors can supply copies of the full text to those who may request them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical design and analysis of qualification test program for a small rocket engine

AUTHORS: S. Roy Wood and Donald E. Hartvigsen, Aerojet-General Corporation, Glendale, California

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 345-348

PURPOSE: To discuss the phase of a qualification test program dealing with the analysis of four key environmental factors.

ABSTRACT: Prior to static test-firing, rocket engines assigned to a qualification test program are subjected to a series of simulated environmental stresses. A common practice is to subject each unit to specified combinations of environmental factors in the environmental sequence encountered during the actual life cycle of the rocket engine. However, if a rocket engine tested in this manner should prove unsatisfactory, it is difficult to pinpoint the specific environmental factor, or combination of environmental-test conditions, which produced the poor results. To overcome the difficulties presented by sequential environmental testing, a statistical plan of testing was adopted which required several different environmental pre-conditioning paths. Rocket engines for the qualification test program were randomly selected from production units. This paper discusses only that phase of the qualification test program dealing with the analysis of four key environmental factors.

The design of the qualification test plan represented a compromise between engineering and statistical requirements. Nevertheless, statistical planning of the qualification test program enabled separate estimation of the effects of each environmental factor. In addition to testing sensitivity to environmental extremes, the statistical test program also permitted appraisal of the ability of the rocket engine to perform as required when the units were subjected sequentially to all environmental test combinations. Of the four factors investigated in this phase of the qualification test program, only the temperature for altitude cycling and firing had a significant effect on the performance of the rocket engine. (Authors in part)

REVIEW: This is a good case history illustrating an application of a full factorial experiment (2x2x2x4) in a qualification test program for a small rocket engine. It is unfortunate that this paper and some others in the Transactions of the Seventeenth Annual ASQC Convention were merely abstracted and not published in full. Perhaps in such cases the authors can supply copies of the full text to those who may request them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System reliability when failure depends upon a parameter that ages

AUTHOR: F. R. VanWagner, IBM General Products Division, Development Laboratory, San Jose, California

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 353-354

PURPOSE: To discuss the estimation of the reliability of a system in which failure depends upon a parameter that ages.

ABSTRACT: The system considered is one in which failure depends upon a parameter, X, which degrades with time. X is visualized as a random variable following some probability law and changing with time. An expression for the system time to failure cumulative distribution function is cited, as well as an expression for the mean time to failure. Reference is made to an example of a linearly aging, normally distributed parameter in a hypothetical electronic circuit.

REVIEW: Like some of the other items in the Transactions of the Seventeenth Annual ASQC Convention, this is just an abstract. However, the complete paper, available from the author, provides a careful development of the mathematical model, an example involving a hypothetical electronic circuit, and a discussion of methods of solving the model equations on computers. The paper will be of most interest to those concerned with mathematical models for parameter degradation. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Parallel step stressing (A method of accelerated life testing)

AUTHORS: Richard E. Loomis and Donald C. Snyder, Western Electric Company, Inc., Laureldale, Pennsylvania

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 357-358

PURPOSE: To describe a method of parallel step stressing, and to indicate its advantages over successive step stressing.

ABSTRACT: The technique of step stressing (see Abstract and Review Serial Number 165) is useful in demonstrating device reliability in a relatively short length of time. The parallel step stress method will satisfy the same objective more rapidly and more economically. The original technique is based on repeatedly subjecting the same sample of devices to successively increasing stress levels for a fixed interval of time until all devices fail. A mean failure temperature and standard deviation is then determined from a plot of the cumulative failure percentages versus temperature (1/T absolute) on standard probability paper.

Parallel step stressing is based on simultaneously subjecting several sub-samples of devices to several equally spaced stress levels. A mean failure temperature and standard deviation is then determined from the cumulative results, percent good and percent failing at each stress level, plotted on "modified" probability versus temperature (1/T absolute) paper. An acceleration curve is generated by repeating this procedure for successively increased intervals of time and by plotting the 1%, 10% and 50% failure temperatures at each interval versus the logarithm of time.

The parallel step stress technique has been simulated using the "Monte Carlo" approach and an IBM 1401 computer. Repeated simulations of the technique indicate that parallel step stressing yields the same results, statistically, for a given sample of devices, as the original step stress procedure. Other advantages of the parallel method are indicated briefly. (Authors in part)

REVIEW: It would appear that this is a worthwhile method of accelerated life testing, but the potential user will require more detail than the authors have given. It is unfortunate that this paper and some others in the Transactions of the Seventeenth Annual ASQC Convention were merely abstracted and not published in full. Perhaps the authors can supply copies of the full text to those who may request them. ##

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Serial Number 1021
Code 836

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design review techniques to overcome administrative problems

AUTHOR: Benjamin W. Marguglio, Fairchild Stratos Corporation

SOURCE: Transactions Seventeenth Annual Convention, American Society for Quality Control, Chicago, Illinois, May, 1963, pp. 359-363

PURPOSE: To explain the technique and to cite the advantages of the progressive design review.

ABSTRACT: Some of the complicating factors which can be encountered in setting up a successful formal reliability program for a missile project are cited. The role of the progressive design review in overcoming these conditions is described. The advantages of the progressive design review over the after-the-fact review are discussed.

REVIEW: This is an abstract of a longer paper, and undoubtedly suffers considerably because of brevity. Much has already been written on design reviews (see Abstracts and Reviews Serial Numbers 25, 26, 29, 125, 183, 190, 193, 245, 273, 275, 382, 493, 621, 638, 744, 750, and 1000), and because of the brevity noted above it is not clear what the author's new contribution (if any) is. However, in a private communication he has indicated that the objectives of the paper are to stress techniques of design review aimed at overcoming unusual administrative problems and to give advice on how to "sell" a review program under unfavorable conditions and to persons who may be unfavorably disposed towards it. This could be a useful message to management. The author has also indicated that the complete paper appears in the September, 1963 issue of Quality Assurance. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contracting for product integrity

AUTHOR: Leslie W. Ball, Director of Reliability, Aero-Space Division, The Boeing Company, Seattle, Washington

SOURCE: 7 pp., Invited presentation to the Bureau of Naval Weapons Material Reliability Conference, October 31, 1962, on the theme "Industry Advises the Chief"

PURPOSE: To discuss the mechanics of contracting for product reliability.

ABSTRACT: Industry is well along in developing the four essential requirements for contracting for product integrity. It is evident, however, that we are still not doing the best we know how. The very impressive paper, "Material Reliability as Related to Aircraft Accidents," prepared by Rear Admiral E. C. Outlaw, Commander of the U. S. Naval Aviation Safety Center, proved this statement. Particularly, it demonstrated that we are so managing our weapon programs that errors that occurred 30 years ago are still being repeated. To help stop this cycle of repetition of unreliability, the Bureau of Naval Weapons needs to:

1. Provide a Bureau-wide program to identify activities that must be brought under formal control.
2. Coordinate and provide funding for research to ensure that all the disciplines necessary to build integrity into Naval weapons are being developed.
3. Develop and use contracting methods based on program plans that will ensure application of available disciplines.
4. Extend the functions of the Inspector of Naval Material to cover Operations Evaluation of input contract requirements.

Ten years ago, the Bureau of Aeronautics made a major contribution to reliability by guiding the publication of Robert Lusser's pioneering reliability papers. One month ago, Robert Lusser keynoted the European Organization for Quality Control Symposium. He concluded by stating that the problem of weapon system unreliability was so severe that either we would conquer it, or it would conquer us. In a like vein, either we learn to contract in ways that will ensure application of all the disciplines essential to product integrity or we will not obtain the level of reliability that the Chief of Naval Operations and the Congress demand. (Author in part)

REVIEW: This is a general management paper, but it does contain important concepts. Many of these have been put forth before, but the need for their constant repetition is obvious. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of electronic switching circuits through stress analysis

AUTHOR: H. F. Najjar, Stromberg-Carlson, A Division of General Dynamics, Rochester, New York

SOURCE: 6 pp., presented at the IEEE Winter General Meeting, New York, New York, January 27 to February 1, 1963, IEEE Conference Paper No. CP 63-515

PURPOSE: To describe a method of evaluating failure rates of components as functions of stresses.

ABSTRACT: The accuracy in determining ... failure rates depends upon the pertinent confidence limits and the precision of design tolerance. Therefore, refined technological methods based on sound scientific principles are of the utmost importance in achieving the ultimate goal of reliability. This can be insured only if: (1) system planning objectives are constantly revised and updated in order to incorporate the state-of-the-art improvements attained by parts manufacturers; (2) the "worst condition" in stress level calculations is considered more carefully and realistically so that a "happy medium" is chosen to prevent the over-all reliability from diverting from the practical result. Therefore, it is not until certain postulates and rules are established to accurately interpret system planning objectives, design tolerance and worst conditions, that these hazards of divergence are completely minimized.

Three charts and three tables are presented which show failure rates for: (1) capacitors in terms of voltage and temperature, (2) resistors, transformers, and coils in terms of power and temperature, and (3) transistors and diodes in terms of junction temperature. (Author in part)

REVIEW: This is a "standard" technique which has been presented before. It is better than using single "ballpark" estimates, but must still be considered in that class. For example, all mylar capacitors are lumped together as are all wire-wound resistors. Many papers and the whole concept behind IDEP are based on the fact that such gross approximation is not always adequate.

While drift and sudden failures are mentioned in the text, the distinction is ignored in the examples. No criteria are given for failure. The fact that many of the failure rates are known rather inexactly is implicitly ignored when combining failure rates (this problem is difficult). The temperature correction given in Equation (2) does not agree with any of the charts or tables. Equation (1) for confidence is incorrect; it should be the sum of several terms and is true only where test time is

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A N D T E C H N I C A L R E V I E W S

fixed and number of failures is the random variable. The method for calculating junction temperature ignores the thermal resistance between the case and the surroundings; this may be appreciable.

Possibly a better term for "random failure rate" would be "Poisson failure rate", since it is more descriptive of the type of randomness assumed.

(The paper covered by Abstract and Review Serial Number 964 is a condensed version of this paper.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A computer reliability program

AUTHOR: S. E. Basara, Radio Corporation of America, Electronic Data Processing Division, Camden, New Jersey

SOURCE: 14 pp., presented at the Fall Radio Meeting, Institute of Radio Engineers and Electronic Industries Association, Toronto, Canada, November, 1962

PURPOSE: To discuss the function of a reliability assurance program associated with the design of a digital computer.

ABSTRACT: This is a non-technical discussion concerning the purpose, organization, and functioning of a specific reliability assurance program. The program is based on conventional methods for forecasting computer reliability. The following four phases of the program are considered.

1. Design review by committee
2. Component specification and selection
3. Testing of feasibility model
4. Field failure reporting

Emphasis is placed on reliability studies conducted concurrently with design and production.

REVIEW: This paper might be of interest to non-technical personnel desiring a brief introduction to the nature of reliability studies. It is neither detailed enough nor general enough to provide useful information on the organization or administration of a reliability program. ##

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Serial Number 1025
Codes 783;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The improvement of Service electronic equipment by environmental testing

AUTHOR: P. W. Baker

SOURCE: RRE Technical Note No. 678, April, 1961, Royal Radar Establishment, Ministry of Aviation, Malvern, Worcestershire, England (ASTIA Document No. 269707)

PURPOSE: To disseminate some of the experience gained during the environmental testing and assessment of newly developed British Service equipment.

ABSTRACT: This Technical Note outlines some practical methods of improving the general standard and reliability of (British) Service electronic equipment. The overall reliability of a piece of equipment is shown to depend on a number of variable factors in addition to the basic reliability of the individual components used. As a result of the intensive development of reliable components, the majority of defects occurring during environmental testing are due to the misapplication of components, design defects, and poor workmanship rather than to inherent defects in the components themselves. A guide is given to the derating of various components in order to improve the overall reliability. The correct application of resistors, capacitors, tubes, and semiconductor devices is also considered. A brief treatment of the important mechanical design considerations is given under the following subheadings: (1) thermal design, (2) construction, (3) selection and treatment of metals, and (4) connections and wiring. Some design defects found in recent environmental tests are listed together with the suggested remedies if the latter are known.

REVIEW: This is a straightforward logical treatment of the subject and may be useful to the American engineer who is interested in learning something about British methods. The paper is well written and uses a minimum of jargon. There are four references, three of which are other RRE papers. ##

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Codes 770;782;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Comparison tests--welded embedded modules and soldered printed circuits

AUTHORS: Staff Engineers, Communication and Information Systems Laboratory, Douglas Aircraft Company, Inc., Testing Division

SOURCE: Douglas Technical Memorandum, No. TM-DSV-IV-E/E-L2867, December 1, 1961 (ASTIA Document No. 273915)

PURPOSE: To describe the results of an investigation to obtain data for comparison of welded embedded modules and soldered printed circuits, with respect to electrical performance and mechanical durability, under conditions of vibration and temperature shock.

ABSTRACT: Five specimens each of the welded embedded modules and soldered printed circuits have been evaluated in the Communication and Information Systems Laboratory to obtain performance and mechanical durability data. Each specimen was subjected to vibration for 5 hours at levels of 5 - 25 "g" and temperature cycling from 194°F to -67°F.

One specimen of the welded modules showed an intermittent internal connection while at a temperature of 194°F. Investigation indicated a faulty connection to the module connector pin. The malfunction did not recur at low temperature (-67°F) or at room conditions. No other failures were observed. (Authors)

REVIEW: The information contained in this paper is of limited value by virtue of the fact that all of the items tested were manufactured by Douglas Aircraft Company and that only five specimens of each type were subjected to test. Complete details of the tests are given in the various appendices to the memorandum. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component part failure rate curve considerations

AUTHOR: Daniel A. Adams, Space Guidance Center, International Business Machines Corporation, Owego, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 301-314

PURPOSE: To discuss factors that affect the accuracy of failure rates for discrete electronic component parts.

ABSTRACT: The generally accepted concept that electrical and thermal stresses are the predominant factors contributing to the unreliability of the component part is questioned. A modified approach which considers additional factors, such as strengths, other stresses and the duration of stress application, is advanced as a method that could yield more accurate system failure rate predictions.

Component part failure rate compilations have been published by ARINC, WADD, Martin Aerospace (IDEP release), and others. Examination of the component part failure rates in these listings shows the extremely wide disparity -- often three orders of magnitude -- in the observed failure rates. These listings also frequently lack the explanations necessary for intelligent use of these data, for generally the component part is not identified beyond a broad component part category. Despite shortcomings, the data can be used as an aid in estimating the probable failure rate of a component part under a particular set of circumstances. Sufficient usage detail is necessary, however.

Realizing the limitations of the conventional approach, a modification has been developed to account for as many of these factors as possible, when they were considered important to the program at hand. Implementation of this approach requires large amounts of well documented and analyzed failure data as well as thorough analysis of all failed component parts.

For ease and consistency in extrapolation, failure rate curves and modifiers are generated. Based on the assumptions generally used, failure curves are generated to express the relationship between failure rate and electrical and thermal stresses. Other stresses can have a marked effect on the component part's failure rate and are accounted for by employing failure rate modifiers. To account for the relative ability of component parts to withstand the applied stresses, a set of strength curves and modifiers is developed showing the effect of minor variations in construction of the component parts, the effect of burn-in, the effect of various levels of screenings, and the effect of protection afforded

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

the component part in packaging and handling. (Author)

REVIEW: The limitations of the ordinary failure rate curves are well expressed. The term "ballpark" is appropriately applied to these estimates of failure rate. The methods proposed here deserve serious consideration, although they do not seem as different from some of the better conventional methods as the author has claimed. In general, the proposed method would include the conventional modifiers due to application severity (aircraft, shipboard, etc.). In addition, it would include modifiers to account for the care exercised in a reliability program, for part screening, handling, particular value, rating, etc. Failure definitions, however, remain a problem. These ideas are worthwhile, although as the author mentions, there would be complications in applying all of them.

The discussion of the stress-strength relationship repeats the erroneous concept of largest flaw. Obviously this cannot be geometric size, especially in mechanical parts. It must be emphasized that the flaw which will cause failure is a function of the local environment as well as of the part; e.g. an externally induced hot spot on a part could be anywhere and it is more likely that a flaw in the hot region will cause failure, even if a flaw located elsewhere were worse.

The use of a constant failure rate is implicit in the whole discussion; this is usually justified by the lack of data to support a more complex hypothesis.

In a private communication the author has stated that much more detailed information on his proposed method is available, but that lack of space precluded its inclusion in the paper. Many of the new features were apparently not emphasized in the published version. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some pitfalls of the Weibull distribution

AUTHORS: Paul Gottfried and Howard R. Roberts, Booz-Allen Applied Research, Inc., Bethesda, Maryland

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 372-379

PURPOSE: To illustrate some of the dangers inherent in blind application of the Weibull distribution.

ABSTRACT: For any given part type, it is common to find several failure mechanisms which contribute to the observed failure rate. In general, these mechanisms respond differently to variations in stress level. Often, the relative importance of their contributions to the gross failure rate varies with the age of the part. Obvious economic and practical limitations on testing make it difficult to isolate the distributions associated with individual failure mechanisms. When the total failure rate of a part type is observed to vary with age (time-in-service for the population), it is natural to seek a mathematical model other than the exponential law to describe such variations. Recently, a number of authors have urged the use of the Weibull distribution to describe observed declining failure rates in semiconductor devices, especially for the purpose of devising acceptance sampling plans.

The two-parameter and three-parameter Weibull distributions lend themselves to excellent fits to survival data. Such fits are obtainable even when the data apply to heterogeneous populations embracing diverse failure mechanisms and a variety of "true" underlying life distributions for the sub-populations. In these circumstances, the Weibull distribution may provide an excellent descriptive model, yet lead to gross errors when extrapolation in the time or stress domain is attempted (and also when changes in production processes occur, since such changes do not necessarily affect all failure mechanisms equally). Various types of population heterogeneity are illustrated, and some of the physical causes of heterogeneity are discussed. Illustrations include actual examples from extended life tests on capacitors. (Authors in part)

REVIEW: The cautions in this paper are very well taken; they should be heeded by everyone involved in the analysis of life test results. (It should be pointed out that the approximation of a heterogeneous distribution by a Weibull is usually satisfactory only over a limited time range. Since tests are usually time-censored, it makes the problem even more critical.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing electronic reliability into commercial automatic pilots

AUTHOR: R. H. Wagner, Sperry Phoenix Company, Division of Sperry Rand Corporation, Phoenix, Arizona

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 502-512

PURPOSE: To discuss the reliability requirements for the design of electronic equipment in an SP-50 Automatic Flight Control System (Boeing 727), and the means found to implement them.

ABSTRACT: Reliability requirements are being contractually specified for some commercial aircraft electronics. In the case described here the allowable unreliability could be only 1/4 of that now being experienced in similar equipment. The obligations are specified in three ways: (1) design requirements specify a minimum MTBF of 700 hours and maintenance periods in excess of 5,000 hours, (2) specific reliability tasks must be performed during the design, production, and in-service phases of the program, and (3) an equipment warranty must be provided covering the first 3,000 hours of actual operation or 18 calendar months. The present major causes of unreliability are inadequate troubleshooting or maintenance at the aircraft level; electrical failure due to inadequate circuit design, random part failures, and improper manufacture; and mechanical weaknesses caused by poor design or faulty manufacture. The airlines feel that size and weight are not as important as cost, ease of maintenance down to the component level, and long life. Redundancy is employed only at the subsystem level or above--not within major components.

The program began in the design phase with the selection of parts with specified reliability. These figures were placed on the drawings. The temperature rise in critical areas was measured to be sure of proper application. Some redundancy was used with manual changeover. Maintainability was improved by electrical and mechanical separation of the roll, pitch, and yaw axes; special attention to packaging; self-contained checking features; and semi-automatic carry-on test sets. The dissipated power was reduced by elimination of vacuum tubes and relays where possible; eliminating or extending the function of instrument servos; better heat conduction paths; etc. The structural design was important to provide protection, to allow ease of servicing, and to prevent deterioration after much servicing.

REVIEW: This is a good case history of improving reliability. It shows what can be done without breakthroughs in the state-of-the-art, and just by using good engineering methods with emphasis on the desired features. (Unfortunately, no final figures are given on the reliability results actually achieved.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An introduction to environmental chamber systems engineering

AUTHOR: Alvin R. Saltzman, U. S. Naval Air Development Center, Johnsville, Pennsylvania

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 513-523

PURPOSE: To present an introduction to Environmental Chamber Systems Engineering.

ABSTRACT: When thermal or other types of environmental cycles are performed in an environmental chamber for evaluating the reliability of an electronic equipment, the equipment, environmental chamber, its controllers and other components form a part of and behave as an environmental chamber process system. Because of the complexity of modern environmental facilities and need for reliable data simulating operational usage of electronic equipment, it is important that the "Environmental Process Control Engineer" obtain as much analytical information as possible on the environmental control capability of the chamber system before performing the actual evaluation.

This paper presents a systems engineering analytical method of evaluating the response of an environmental chamber system to a thermal environment step input.

The advantages and disadvantages of alternatives in using various types of control actions are presented. Emphasis is placed on the effect of the electronic equipment and other components of the system acting as thermal load disturbances to chamber environmental controllers. (Author)

REVIEW: This will be a good paper for those who are already somewhat familiar with the methods of system response analysis and who are concerned with environmental chambers. Obviously, there is no difference in the mathematics, just a difference in the kind of system. It is a review and attention-calling paper (both worthwhile objectives), rather than one which introduces something new. ##

Serial Number 1031
Code 720

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Process control for reliability

AUTHOR: Walter H. Friedlander, Collins Radio Company, Cedar Rapids, Iowa

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 524-529

PURPOSE: To describe an approach to the development of a method for determining weaknesses in man-machine systems and manual assembly operations.

ABSTRACT: System reliability, in addition to sound system design, depends on the ability of manufacturing to reproduce given quality levels. To perform this function, manufacturing must be aware of the inherent weaknesses of production processes and must know the type and extent of controls necessary to obtain reproducibility.

Information pertaining to the weaknesses of a given process is of extreme importance to a manufacturing organization dedicated to shipping quality work on time at a competitive price. It is equally important that this information be relayed to engineering, for the designer has a great deal of influence on reproducibility. Engineering specifications, dimensioning, and tolerance distribution have a major effect on quality levels. It is the responsibility of manufacturing to appraise engineering of production process capabilities. It is the responsibility of engineering to make practical use of this information in design.

The difficulty facing manufacturing is the manner of determining the parameters necessary to measure reproducibility. The work described in this paper constitutes an attempt to find some of the answers to this problem. A method is described that makes use of inspection sign-out data and quality audit information to determine stable patterns of variation among defective lots and substandard equipments coming out of specific manufacturing departments. General conclusions are reached based on the assumption that apparent non-random occurrences among defective lots represent over-all weaknesses that can be controlled. The conclusions concern the effect of lot size on rejection rate, the influence of industrial engineering and inspection techniques, and the effect of engineering overspecification. All of the work reported deals with nonautomatic processes. (Author)

REVIEW: The ideas presented in this paper should be of general interest and use to those concerned with the pin-pointing of weaknesses in production processes. The material is clearly set out and illustrated with graphs and charts. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable systems versus automatic testing

AUTHOR: Alan D. Swain, Reliability Department, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 380-390

PURPOSE: To discuss some of the less obvious disadvantages of automatic check-out equipment.

ABSTRACT: The informal reasons for the trend toward automatic checkout or testing equipment (ATE) are: the trend toward automation, profits, the feeling that more automation improves technology, the fact that designers of prime equipment specify more tests than can be done manually and tend to compare the best ATE with the worst manual situation. None of these reasons are always right and some should be actively resisted. (Examples are given in the text.) The formal factors are: (1) ATE will mean that system maintenance personnel and test equipment maintenance personnel need not be as highly skilled as those who use manual testers, (2) ATE will reduce the overall numbers of personnel, (3) ATE is needed where there are speed or other requirements which cannot be satisfied by human operators, (4) the use of ATE is more valid than manual testing because it avoids human subjectivity, and (5) ATE provides more reliable testing because human inconsistency is avoided. Again, these factors are not always right and some are wrong (examples are given). Three especially pertinent comments are: (1) designers first need to spend some time in designing, or at least thinking about, manual testing methods and systems, (2) they must follow a system in allocating testing functions between man and machine, and (3) even if the decision is to use ATE, key human factors have to be considered to achieve the optimum system. (Author in part)

REVIEW: This field, like soldering vs welding, is very controversial. At first glance the author seems opposed to automatic test equipment, but careful reading suggests that he is trying to counteract the natural trends toward it and thus he necessarily emphasizes the disadvantages. Most of the points seem to be very well taken--they emphasize the need to look at the whole problem, not just a small part of it. Also, it is easy to infer that salesmen's claims should be heavily discounted in the field of automatic test equipment. Anyone who is considering specifying or buying this type of gear can benefit by reading this entire paper and, probably, some of the cited references. See also Abstract and Review Serial Number 1034 for a different outlook. ##

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Serial Number 1033
Codes 413;824;872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Sequential testing of electronic systems

AUTHORS: J. H. Bailey and W. F. Mikhail, Development Laboratories, Data Systems Division, International Business Machines Corporation, Poughkeepsie, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 391-400

PURPOSE: To discuss sequential testing for industrial applications, with particular reference to the testing of system availability.

ABSTRACT: Decision-type sequential tests are becoming important for industrial applications because of the time which they save as compared to non-sequential tests. The most widely applied sequential test is the probability ratio sequential test (PRST), which can attain the same test risks as the current most powerful non-sequential test on the basis of a much smaller expected number of observations (i.e., less time).

A PRST is developed, which employs the method of maximizing the likelihood functions under each of two hypotheses, followed by the assignment of values to the ratio of these maximized functions, which serve as the critical values for decision making. The development is effected through examples rather than through rigorous statistical derivation. Test formats for sequential tests on system availability are obtained, for situations in which the input data come from exponential, gamma, or Weibull populations. The determination of the expected sample size for a PRST when the successive test observations are not independent is demonstrated. Examples are given of specific test plans and the results of applying a PRST to the availability of an electronic equipment.

REVIEW: There is no doubt that sequential testing has important potential industrial applications. This paper will serve a useful purpose in promoting an awareness of this. However, for a proper appreciation of the material presented, the reader will require a knowledge of the fundamentals of sequential testing, found mainly in the work of Wald, which is the principal reference cited in the paper.
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Serial Number 1034
Codes 771;773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A controlled study of automated testing techniques

AUTHORS: Philip R. Oyerly and Dewey C. King, ARINC Research Corporation, Washington 6, D. C.

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 401-414

PURPOSE: To present the results of a controlled study of automated vs. manual testing.

ABSTRACT: Much has been written about automated vs. manual testing, but most of it is engineering hypothesis rather than results of direct observation. These tests, using the RT-178/ARC-27 as a vehicle were explicitly designed to test automated vs. established (and presumably perfected) manual testing techniques. The subsequent MTBF was improved by the use of automated test equipment (ATE). The several groupings of the test procedures and the results after 100 hours of equipment use are summarized in the table. Note that the use of ATE had a lasting effect (group 2). This is the one that would be considered for actual use.

	Test Group 1	2	3	4
Maintenance before installation in aircraft	depot ATE		depot or contractor manual	
Maintenance after installation in aircraft	depot ATE	field manual	depot manual	field manual
Approximate MTBF (hr. of RT ON time) after 100 hours	104	93	84	61

(A complete discussion of the procedure and the results is given in the text.)

REVIEW: This appears to be a well planned and well executed experiment. A generalization of the results is subject to controversy in the manual vs. ATE discussion. The problem as usually presented is "What manual techniques were compared? How much effort was expended in improving them as compared to optimizing the ATE? Would optimized manual procedures be better than ATE? To what extent should manual procedures be considered optimized if they have been in use for a long time?" This review does not attempt to answer these questions, but merely to show that generalizations become difficult. For a discussion of problems that can arise with ATE see Abstract and Review Serial Number 1032. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Limitations of plans designed to demonstrate minimum life with high confidence

AUTHORS: Andrew C. Gorski and Benjamin Epstein, Computers and Data Systems, Autonetics, Anaheim, California

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 415-520

PURPOSE: To show that high levels of confidence are hard to obtain in an MTBF demonstration and to present tables for calculation.

ABSTRACT: It should be noted that specifying a confidence level for demonstration of MTBF precludes the use of sequential sampling.

For any choice of acceptance number, c, there is a truncated total test time, T, that will satisfy the MTBF and confidence requirements (c is the maximum allowable number of failures in T). As c is increased, T becomes greater. The only choices a manufacturer has in order to get more of his product accepted, for a given MTBF and confidence requirement, is to make the true MTBF larger or to make c (and thus T) larger. Neither is usually a very palatable or feasible choice. Tables showing the ratios T/θ^* and θ^*/θ_R, where θ^* is the true MTBF and θ_R is the required MTBF, are given for various confidence levels and values of c.

REVIEW: The concepts presented here are not new, nor are the conclusions, but the material is presented in an easy-to-use form and the tables should be helpful. With more people becoming involved in reliability specifications, it is a good idea to repeat and emphasize the problems involved in proving high reliability.

It should be noted that the main source of confusion lies in the assumption of no a priori knowledge about the MTBF which is implicit in the sampling plans. If this assumption were in fact to be true, then the manufacturer and the buyer are both "consumers" of the output of the production line, and it is meaningless, in a useful physical sense, to speak of the true MTBF. (Even though it exists, it is, by hypothesis, unknowable.) If the assumption of no a priori knowledge of true MTBF is not true, then the sampling plan is unduly pessimistic; if the a priori information were taken into account, high MTBF would not be as difficult to prove. There are both practical and theoretical problems in applying a priori knowledge to sampling plans, and only a start has been made on solving them. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability approach to the spare parts problem

AUTHORS: George H. Ebel and Andrew J. Lang, Fairchild Camera and Instrument Corporation, Defense Products Division, Clifton, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 421-430

PURPOSE: To describe a system whereby unskilled personnel, using simple charts and tables, can select the number of spare parts required to support a given program.

ABSTRACT: A system for selecting the number of spare parts required to support a given program has been developed. The method of programming a digital computer to generate charts and tables for use in the system is presented. Information is generated for various confidence limits, operating times, and failure rates. Typical cases in which the charts and tables may be used include (1) the selection of the minimum number of spares required for a given program, (2) the determination of critical spares after a program has been running for some time (serving as a check on the original failure rate assumptions), and (3) the decision on action to be taken if a spare part is determined to be critical.

Planned future efforts in the reliability approach to the maintenance problem are discussed. These efforts include more parameters than have been considered in this paper. The goal of the next phase of the program is to be able to feed parts lists, operating times, use conditions, etc. into the computer and have the computer print the most economical solution to the spare parts problem. This solution would include such things as the original order for spare parts, the intervals at which various spares should be checked, and the proper action to be taken for the number of spares in stock at the time of the inventory. (Authors in part)

REVIEW: The system described in this paper should be of interest to design engineers working on equipments for which the provision of limited stores of spare parts is feasible, as well as to those concerned with the logistical considerations associated with such stores. The basic assumptions are the usual ones based on an exponential distribution of failure times. An essential input to the system is a value of the failure rate for each component. It must be recognized that uncertainties in these failure rates will be reflected as uncertainties in the indicated numbers of spares.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the proper preventive maintenance

AUTHOR: H. H. Cho, The Laboratory for Electronics, Inc., LFE Electronics Systems Division, Boston, Massachusetts

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 431-438

PURPOSE: To derive a formula for the optimum time to preventive maintenance and to illustrate its use.

ABSTRACT: This paper proposes that preventive maintenance in its proper application is a valuable method of improving an equipment's effectiveness. However, preventive maintenance is only valid when applied to components and equipments which obey a wear-out law of failure which is characterized by increasing failure rate and variability of failure-times smaller than that of exponential distribution.

Probability functions and parameters describing equipment failure, repair, and preventive maintenance are derived. A preventive maintenance objective function is formulated and solutions which maximize equipment availability and operational readiness are indicated with numerical examples. Equipment failure rate is classified into three cases in which it is either increasing, or constant, or decreasing. The significance of each of the three cases is discussed with respect to preventive maintenance technique. (Author)

REVIEW: The formula for optimum time to preventive maintenance action may be quite useful in cases where the assumptions are realized. The derivation appears to be rigorous (although the formula for operational readiness was not checked). A major assumption is unfortunately implied rather than stated explicitly, viz., after each and every maintenance action, preventive or repair, the <u>entire</u> equipment is returned to its $t = 0$ state. The stringency of this basic assumption is not explained in the paper. Every part must be replaced at every maintenance action unless it is known that no degradation has occurred (for example, drift in characteristics), no improvement has occurred (for example, burn-in type of improvement), and that the part has the negative exponential failure distribution. The violation of any of these criteria will negate the assumption made in the derivation. That is why it is so important to state explicitly <u>all</u> assumptions at the beginning of a theoretical derivation.

The author introduces $T_f' = \int_o^\infty F_o(t')\,dt'$ but has already effectively defined $T_f = \int_o^\infty F_o(t)\,dt$. Obviously $T'_f = T_f$ regardless of the definition of t' as compared to t.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

The author states that "... preventive maintenance is worthwhile ... for only those equipments which exhibit f(t) with variability of failure-times less than that of the exponential distribution." (Variance is meant as the measure of variability.) While this statement may be adequate in some particular cases, its generalization is meaningless. Consider the normal (Gaussian) distribution whose mean and variance are obviously independently adjustable.

In Example I, eight units are connected in series--each having the same exponential failure distribution. Ordinarily (assuming independence--not mentioned either way by the author) the system would have an exponential failure distribution with eight times the individual failure rate. The author apparently arrives at the figure 1/8 instead, and gets an Erlang distribution which is quite unlike the exponential. (The symbols k and K seem to be used interchangeably.) The comparison of variances is in error due to some kind of misinterpretation of symbols.

The author correctly points out that with a decreasing failure rate preventive maintenance (of this type) is not desirable. It is also not desirable if the mean time for preventive maintenance is more than that for repair maintenance. In any event, the use of the formula or graph will always give the right answer, including those cases in which the time between preventive maintenance actions is infinite, i.e., no preventive maintenance is indicated.
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Serial Number 1038
Codes 832;872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A practical approach to maintainability prediction

AUTHOR: George T. Harrison, ARINC Research Corporation, Washington 6, D. C.

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 439-447

PURPOSE: To describe a maintainability prediction technique based on the determination of the probabilities of occurrence of certain fundamental activites and the establishment of the distributions of times required to perform these activities.

ABSTRACT: The usual methods of predicting the time required to return a failed system to operating condition are based on the use of system hardware characteristics as predictors. For example, system complexity is positively correlated with required maintenance time; other relevant factors include accessibility, built-in measuring and testing devices, warning lights, and packaging. However, factors related to system hardware do not include all of those which must be considered. Human factors are an important example.

Under an Air Force contract, ARINC Research has developed a new technique for predicting maintainability based on the following principles: (1) the determination of the probabilities of occurrence of certain fundamental maintenance activities, and (2) the establishment of the distribution of times required to perform these activities, and the statistical combination of these (and other) time distributions to obtain an ultimate prediction of system down time. These principles are considered generally applicable to all systems. The specific prediction procedures developed thus far, however, apply only to those electronic systems which are under the operational and maintenance cognizance of the Air Force and for which maintenance at the system level is accomplished predominantly by "black box" replacement.

Elemental maintenance activities are described and illustrated. The considerations involved in their selection are stated. A general expression for obtaining the probability of occurrence of an elemental activity is given. The prediction of maintainability is described and illustrated.

REVIEW: The approach described in this paper should prove to be of interest and value to those concerned with maintainability prediction. The claim that adequate prediction cannot be based entirely on system hardware characteristics seems to be well taken, and the alternative proposed appears sound. In practical situations, the identification of the elemental activities, as defined by the author, will require careful consideration as well as a sound knowledge of the system and of the over-all maintenance activity. ##

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Serial Number 1039
Codes 771;872;874

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A procedure for system maintainability testing

AUTHORS: B. L. Retterer and R. A. Miles

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 448-454

PURPOSE: To outline a testing procedure designed to fulfill the requirements of the Air Force maintainability specification MIL-M-26512B.

ABSTRACT: This paper outlines a testing procedure for the demonstration of achieved mean and maximum down time for electronic systems as specified by MIL-M-26512B. The testing procedure entails the introduction of failed parts or modules into the system to establish a requirement for maintenance. Trained technicians are used to accomplish normal maintenance routines to locate and repair the malfunction. Monitoring of these routines permits time data and other useful information to be derived. Discussions include the test planning phase, the administration of the test program, and the data analysis process necessary to derive the mean and maximum down time measures. (Authors in part)

REVIEW: This paper will be of interest and value to those concerned with the evaluation of system maintainability in the equipment development phase, and with the demonstration of compliance with stated maintainability specifications. For those who desire more detail than is given in the paper, seven references are cited. An earlier paper on the same program by the same authors (but not referenced in the present work) was covered by Abstract and Review Serial Number 481.

Mr. Grafton Griswold of the RCA Service Company, in commenting on the above abstract and review, has indicated that the paper reflects a portion of the work accomplished for a maintainability techniques study performed for the Rome Air Development Center. The study was recently completed and a final report issued, consisting of two volumes, the first of which describes the work performed during the study, while the second presents the maintainability techniques developed. Copies of this report are available from the Defense Documentation Center as document numbers AD 404898 and AD 404899. ##

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Serial Number 1040
Codes 813;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: RCA'S experience with AGREE testing

AUTHOR: Paul Jay Goldin, Radio Corporation of America, Defense Electronic Products, Aerospace Communications and Controls Division, Camden, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 530-538

PURPOSE: To discuss the implementation and follow-up required by RCA to meet AGREE requirements, and to illustrate them using specific RCA equipments and the results of both factory and field testing.

ABSTRACT: The requirements of the military adaptation of the Task Group 3 section of the Advisory Group on the Reliability of Electronic Equipment document (AGREE Report) are outlined briefly. The extreme importance to the contractor of having his equipment pass the initial and monthly reliability tests is noted. The contractor needs to take positive steps prior to the reliability test to assure himself that the finished product will meet the AGREE requirements. In order to implement this, the already tight process control system of RCA was further reinforced. This process control system has three objectives, viz. (a) to push the debugging phase as far back in the assembly and test cycle as possible, (b) to reduce the influences of the human factor, and (c) to assure the customer and RCA that each system, whether it was subjected to the AGREE test or not, would meet the contractual MTBF.

The previous RCA Control is compared with the controls now being used on all AGREE programs. An important step in the new program is the instituting of comprehensive debugging and corrective action cycles to detect problems before they reach the AGREE test. All suppliers who build major assemblies are required to burn-in their units for given periods of time under the same environmental conditions imposed on RCA built units. The forms and procedures used in failure reporting and analysis are outlined. The results of AGREE testing of specific equipment are summarized, and a number of significant observations are listed.

REVIEW: This is an updating of the paper covered by Abstract and Review Serial Number 206, and the principal points are essentially the same as in the earlier paper. It should be of interest and use to those concerned with AGREE reliability testing of electronic equipment. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prelaunch calculation of space system reliability

AUTHOR: Vernon L. Grose, Director of Reliability Technology, Northrop Ventura (1515 Rancho Conejo Boulevard, Newbury Park, California)

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 539-550 (also published in two parts in The Journal of Environmental Sciences, vol. 6, June, 1963, pp. 12-16, and August, 1963, pp. 35-38)

PURPOSE: To discuss some of the factors involved in the prelaunch calculation of the reliability of space systems.

ABSTRACT: Reliability of space systems cannot be calculated prior to launch (at the present stage of technology) primarily because space systems are research tools and thereby in a high state of flux. Secondarily, most of the parameters required for calculation are not available in quantified form.

The continuation of a search for means of calculation is nevertheless advocated, and the following revisions to existing reliability thinking and practice are recommended:

1. A new measure of merit for reliability must be provided.
2. The classical statistical probability concept must be replaced because of its "small sample" insensitivity.
3. In view of reliability being defined as a probability of success, the term, "success", will have to become analog rather than binary in concept.
4. An accommodation for flexibility in the concept of "mission" must be possible for innovationary systems.
5. Reliability must abandon its preoccupation with <u>equipment</u> and reorient itself to the <u>human</u> problem. (Author)

REVIEW: This is a thoughtfully prepared and well written discussion on the subject indicated in the PURPOSE. The author does not claim to have a simple panacea for the ills in current reliability technology, but his paper is well worth the time and attention of those concerned with the analysis of the reliability of space systems. It will promote broader thinking on the subject. Seventeen references from diversified sources are cited in support of the points made. There is evidence in the literature that some attention is being paid to the points enumerated above, perhaps to number 3 in particular. See, for example, the papers covered by Abstracts and Reviews Serial Numbers 71, 448, 450, 491, 706, 875, 893, 895, 896, and 899. ##

Serial Number 1042
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An approach to preconditioning of electronic component parts

AUTHOR: V. R. Monshaw, Radio Corporation of America, Astro-Electronics Division, Princeton, New Jersey

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 551-555

PURPOSE: To describe the results of a voltage-temperature conditioning applied to solid tantalum capacitors.

ABSTRACT: The high-temperature dc leakage current, after a 500-hour burn-in or conditioning, was found to be a rather good indicator of the ability of individual capacitors to survive for either 2,000 or 5,000 more hours of life. A high order of observed probability of correct prediction was achieved. The result is a conditioning and classification which shows high promise for effective screening of solid tantalum capacitors. A beneficial side effect was also noted relative to the stabilization of the electrical parameters. Many of the shortcomings of this early program are discussed, and plans for a continuing experiment indicated. (Author in part)

REVIEW: This experiment appears to have been well planned, well executed and carefully analyzed. The search for easily measured indicators of reliability is most worthwhile and should continue to be vigorously pursued. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: KWIC Index to Reliability and Quality Control Literature

AUTHOR: Jesse H. Motes, International Business Machines Corporation, Space Guidance Center, Owego, New York

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 556-581

PURPOSE: To describe the application of a computer-automated indexing program for the retrieval of technical information in the reliability and quality control fields.

ABSTRACT: An electronic computer has been used to index 800 selected titles in reliability and quality control literature using the Keyword in Context (KWIC) Index. In this method a computer selects key words from the title and lists them in an index format. The published index consists of three parts, viz. Keyword Index, Bibliographic Index, and Author Index. Words which describe the particular interest of the reader are located in the alphabetical key word listing; then a glance to the left and right reveals the specific relationship of the word to the title. If the reader has an interest in a specific report, he may obtain complete bibliographic information on it by matching the letter and number code (appearing opposite the key word entry) with the identical code appearing in the alphabetical listing in the Bibliographic Index. The names of all authors and the letter and number codes of their works are listed in the Author Index. Access to the Bibliographic Index may also be made through the Author Index.

The article includes the three indexes, together with brief descriptions of them.

REVIEW: The indexes described in this paper will be of assistance in the difficult task of retrieving information in the reliability and quality control fields. In order to remain currently useful, such indexes will, of course, require updating at regular intervals. The author, in a private communication, has pointed out that the Reliability Engineering organization at the IBM Owego, New York facility does update this index. The latest addition covers 1500 titles and may be obtained under the IBM report number 63-354-5, dated August 1963.

One of the difficulties inherent in using key words from the title of a paper as a means of indexing is that very often the title does not adequately describe the content of the paper. A commendable feature of the KWIC Index lies in the fact that it is proposed to overcome this difficulty through the editorial insertion into the title of key words as required to adequately represent the content of the paper. In order to do this effectively, the editor will have to be fully aware of what each paper contains. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Predicting reliability and maintainability of complex systems by non-parametric methods

AUTHOR: E. L. Welker, ARINC Research Corporation, Washington, D. C.

SOURCE: Proceedings Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963, pp. 582-593

PURPOSE: To discuss a method for making reliability predictions directly from data, without first fitting some functional form to them.

ABSTRACT: Conventional methods of reliability prediction involve assumptions about the form of an underlying distribution of some random variable related to reliability. The parameters which characterize such distributions are estimated from test data through some form of curve-fitting or data-smoothing procedure. This paper discusses a method of making reliability predictions directly from observed data expressed in the form of a cumulative function or density function showing time-to-failure, time-to-repair, or numbers of failures or repairs in a fixed time.

Convolutions are used with unsmoothed raw data in discrete form to predict system patterns for reliability, maintenance times, etc. Development of the theory makes use of probability generating functions, which are used to derive a system function. A continuous function is fitted to the results obtained. Thus only one curve fitting process is used, and that at the system level. The method is described in terms suitable for computer programming, and is illustrated by examples.

REVIEW: The idea of using raw data to obtain smooth reliability functions for systems, as opposed to the fitting of functions to the separate component reliabilities, does lead to less rounding error and smoothing error, as the author has claimed. The proposed method uses all of the data all of the time. This implies that the true distribution is assumed to be exactly that of the sample data, which in turn implies that it is characterized by as many parameters as there are observations in the data. Thus it is questionable that the method should properly be called "non-parametric". This is a question of nomenclature, however, and implies no reflection on the validity of the approach. It should be pointed out that when the evidence for the use of a particular functional form (such as the exponential) is strong and well established, the conventional approach is quite appropriate. In cases where doubt exists, a comparison of the conventional approach with the one proposed in this paper might be well worth the effort. ##

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Serial Number 1045 -1
Codes 817;831;833;
872;882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability techniques applied to electronic systems

AUTHORS: (compiled by the staff of the Reliability Department (with the assistance of the Human Factors Department), The Martin Company, Baltimore 3, Maryland; presented by Paul H. Zorger and S. J. Hornyak)

SOURCE: Martin Electronic Systems & Products Division, ER 12759, 76 pp., presented to Air Force Institute of Technology, Air University, Graduate Class in Reliability, 13-14 September, 1962

PURPOSE: To discuss the application of reliability techniques to the design and development of large complex electronic systems.

ABSTRACT: System reliability is considered in three parts: mission reliability, operational reliability, and product reliability. Mission reliability is treated briefly, and the paper centers on operational reliability and product reliability.

Operational reliability is further divided into two types: maintained and non-maintained. The operational reliability of single parallel redundancy is analyzed using probability equations derived from a state space diagram or a "truth table". Using assumptions regarding the repair rates, failure rates, and initial conditions, equations are obtained for the reliabilities, the limiting and time-dependent availability, and the mean time between system failures.

Computer methods of pre-determining the inherent reliability of a given design include (1) worst-case analysis, (2) the discrete method wherein all possible combinations of two parameters are varied to locate interdependent system failures, (3) the Monte Carlo method which randomly samples parameter frequency distributions to simulate large-scale circuit operation, and (4) the moment method which makes use of statistical data on parameter distributions to determine the mean and variance of all functional outputs and provides equations relating these quantities to individual parameter variations. Each of these methods may have advantages, depending on the parameter data available, the design specifications, and the complexity of the proposed system.

A "push-to-light circuit" is analyzed in detail using the methods (1) and (2) described above. The computer techniques are carefully explained and an analysis of the output data is given.

Generic failure rates are discussed for a number of components and subsystems. Data on modifiers induced by environmental effects are given. A typical example shows the derating factor for film resistors plotted as a function of ambient temperature and operating

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

power levels. A detailed discussion of the methods available to include generic failure rate data and related derating factors in computer analysis is presented. Basically, the method of analysis presented is a modified worst-case design and optimization technique which provides profiles indicating where trade-offs of derating factors, environmental effects, and drift may be optimized.

It is desirable to obtain the maximum reliability at minimum cost. The total cost of a system may be divided into two parts, the operational cost and the developmental cost. Each of these may be further partitioned into a fixed and a reliability-dependent cost. Minimization of the total cost with respect to the reliability may be effected and yields an optimum reliability for cost given by:

$$R = (M_0^K C_F t) / (M^{K+1} C_{R_0} K)$$

where:

M_0 = standard equipment MTTF,

C_{R_0} = reliability cost of standard equipment,

M = equipment or system MTTF required for optimum reliability,

t = operating time, and

C_F, K = empirically determined constants.

The remainder of the paper deals with the effect of sophisticated but minimal design changes, maintenance technician training for troubleshooting, and availability. The obvious conclusion that better training of technicians results in greater availability is demonstrated graphically.

REVIEW: This is a good basic paper. Many valuable design considerations are smoothly and accurately presented. This will be valuable reference material for anyone concerned with electronic system design. ##

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Serial Number 1046
Codes 800;801

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: What then is dependability?

AUTHOR: Ya. Sorin, Chairman of the Committee on Dependability in the All-Union Council of Scientific Associations

SOURCE: Pravda, January 11, 1962, p. 2 (ASTIA Document No. 288715)

PURPOSE: To outline the nature of the industrial products dependability problem, and to offer a criterion for dependability.

ABSTRACT: Dependability of commercial items is often discussed, but no clear standard of dependability exists. An increase in the dependability of commercial items is equivalent to an increase in national production, both in terms of monetary considerations and total industrial output. Therefore, a means of evaluating dependability must be ascertained and one possibility is to use the mean time between failures (MTBF) for a given device as a measure of its dependability. This must be measured statistically with representative groups of the devices.

Also, the Soviet academies should devote increased effort to research in the area of reliability theory, so as to provide a rigorous basis for dependability estimates.

REVIEW: This is a common-sense view of dependability and its virtues. The paper offers no mathematical approaches to determining the dependability of a given device; rather, it simply reflects one man's concern with the need for dependability standards. The level and tone of the paper would seem to indicate that there has been little progress in the application of reliability theory to industrial production within the Soviet Union. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Opportunistic replacement of a single part in the presence of several monitored parts

AUTHORS: Roy Radner and Dale W. Jorgenson, The Rand Corporation, Santa Monica, California

SOURCE: RAND Corporation Memorandum RM-3057-PR, 29 pp., November, 1962, prepared for United States Air Force Project RAND Contract No. AF 49 (638)-700 (ASTIA Document No. 289507)

PURPOSE: To give a rigorous theoretical justification for the opportunistic replacement of a single non-monitored part in the presence of several monitored parts.

ABSTRACT: This paper presents a rigorous mathematical proof of the optimality of an opportunistic maintenance policy in which the maintenance action to be taken on a given part at a given time depends upon the state of the rest of the system. In particular, if all the parts of the system but one are monitored, and if the non-monitored part cannot be inspected except when it is replaced, then the best time of replacement of the non-monitored part will in general depend upon the times at which the various monitored parts fail. If the monitored parts have exponential distributions of time-to-failure, then the best replacement policy for the non-monitored part has the following form. Let the non-monitored part be labeled 0, and let there be M monitored parts; then there are M + 1 numbers, $n_1, \ldots, n_m$, N, with $0 \leq n_i \leq N$, such that: (a) if part i fails at a time when the age of part 0 is between 0 and n_i, then replace part i alone, (b) if part i fails at a time when the age of part 0 is between n_i and N, then replace parts 0 and i together, and (c) if part 0 reaches age N at a time when all the monitored parts are good, then replace part 0 alone.

This result is proved for the following criteria for judging replacement policies: (1) expected time in which the system is in a good state, (2) expected value of good time minus costs, and (3) the ratio of expected good time to expected cost. In these criteria good time and costs can be measured in terms of either long run averages or sums of discounted values. Computation of the parameters n_i and N is also discussed. (Authors in part)

REVIEW: This paper is a significant contribution to maintenance theory. The development is clearly and logically presented, and the results are of general interest to anyone concerned with maintenance logistics. See also Abstract and Review Serial Number 402 for an earlier paper on this subject by the same authors. ##

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Serial Number 1048
Codes 824;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of noncatastrophic failures in digital guidance systems

AUTHOR: A. Holick, Guidance and Control Division, Hughes Aircraft Company, Culver City, California

SOURCE: IEEE Transactions on Electronic Computers, vol. EC-12, pp. 365-371, August, 1963 (also ASTIA Document No. 292676)

PURPOSE: To evaluate the effect of noncatastrophic failure on guidance systems.

ABSTRACT: A method is presented for weighting noncatastrophic failures in digital guidance systems in accordance with their effect on system accuracy. The method is applicable to all types of noncatastrophic malfunctions; however, this discussion is limited to one particular class, i.e, transient malfunctions. The velocity and thrust termination errors of an inertially guided single stage rocket are derived for several statistical models of transient failures, assuming Poisson arrival and random duration of the failures.

The accuracy degradation caused by transient failures in the information path of a digital guidance computer during boost appears to be considerable and not negligible compared with instrument anomalies.

REVIEW: This is a rigorous, tightly written presentation. The models and techniques used are clearly defined, thereby enhancing the results. As the author states, the object of the paper is to develop a criterion for design comparison, and numerical results are not pursued. The paper achieves this objective well. ##

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Codes 546;551;822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Theoretical explanation of observed decreasing failure rate

AUTHOR: Frank Proschan, Boeing Scientific Research Laboratories, Seattle, Washington

SOURCE: Technometrics, vol. 5, pp. 375-383, August, 1963, also Mathematical Note No. 281, 11 pp., Mathematics Research Laboratory, Boeing Scientific Research Laboratories, November, 1962 (ASTIA Document No. 293692)

PURPOSE: To give a theoretical explanation of decreasing failure rates.

ABSTRACT: Pooled data on the times of successive failures of the air conditioning system of a fleet of jet airplanes seemed to indicate that the life distribution had a decreasing failure rate. More refined analysis showed that the failure distribution for each airplane separately was exponential, but with a different failure rate. Using the theorem that a mixture of distributions each having a non-increasing failure rate (e.g., a mixture of exponential distributions) itself has a non-increasing failure rate, the apparent decreasing failure rate of the pooled air-conditioning life distribution was satisfactorily explained. The present study has implications in other areas where an observed decreasing failure rate may well be the result of mixing exponential distributions having different parameters. (Author)

REVIEW: This paper is a clear and concise explanation of observed data with adequate mathematical rigor to support the conclusions. Seven relevant references are cited. The paper points up the fact that interpretations of data should be made carefully and thoroughly and that some hypotheses may seem to hold but are, in fact, incorrect. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mathematical circuit analysis and design

AUTHORS: Albert Brown and Philip J. Mullock, UNIVAC, Division of Sperry Rand Corporation, Post Office Box 500, Blue Bell, Pennsylvania

SOURCE: AFCRL-62-317, 69 pp., March, 1962, Final Report under Contract No. AF19(604)-5189, prepared for Electronics Research Directorate, Air Force Cambridge Research Laboratories, Office of Aerospace Research, United States Air Force, Bedford, Massachusetts by UNIVAC, Division of Sperry Rand Corporation, Post Office Box 500, Blue Bell, Pennsylvania (NASA accession number N62-17257)

PURPOSE: To describe some methods of analytical and statistical computer-oriented circuit design.

ABSTRACT: A Monte Carlo program prepared in the AT3 language for the Univac I and Univac II computers is described. The program can simultaneously compute five different functional outputs, giving the first four moments of all five outputs, which then may be used to calculate Pearson-type distributions. Provision is made for four types of parameter distributions: (1) rectangular, (2) normal, (3) truncated normal, and (4) trapezoidal. Multiple reference to a single parameter distribution is possible and 200 different parameter distributions may be used.

Several methods are presented for increasing the accuracy of the basic program for special situations. The most significant of these are as follows. (1) Truncation of the parameter distribution to produce more points in the tail of the output distributions and thus yield a better estimate of the probability of system failure. (2) Direct integration of one or more of the variables where possible, combined with Monte Carlo techniques for the rest. (3) Approximation of the circuit functions by regression surfaces. This may not improve the accuracy, but for very complex circuits an increase in the ease and speed of the analysis is obtained.

A worst-case analysis of one-and-two-level logic circuits combined with the computer technique described above is presented.

Direct coupled transistor logic microminiaturized circuits are analyzed using both worst-case and statistical methods. A clear discussion of the computer techniques is developed. The samples used in the statistical analysis are not large, but emphasis is placed on the critical points of the circuit, (i.e. where the fan-out is five instead of the normal three).

The latter portion of the report deals with an analytical treatment of a ferromagnetic parametric oscillator. The approach is based on gross magnetic properties of the core and hysteresis

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A N D   T E C H N I C A L   R E V I E W S

effects are neglected. The flux changes in the core are shown to be described by a generalized form of the Mathieu equation. This equation is solved by use of phase plane techniques and approximations for the harmonics are obtained.

In addition, the asymptotic flux equation is solved for magnitude of the harmonics and their phase angles.

REVIEW: This is a thorough report and has much that should be of value to electronics design engineers. The Monte Carlo techniques in Part I will be of special interest to reliability control engineers.

The analysis of the ferromagnetic oscillator is interesting, but as the authors point out, rather approximate. Inclusion of hysteresis effects in this analysis would be desirable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The science of reliability

AUTHOR: Academician A. Berg (USSR)

SOURCE: JPRS:4845, 7 August 1961, 12 pp., U. S. Joint Publications Research Service, 1636 Connecticut Avenue, N. W., Washington 25, D. C. (distributed by Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 61-31-580, price $0.50)

PURPOSE: To show that unreliability is a national (Russian) problem and to propose general ways to alleviate it.

ABSTRACT: With the increasing use of complex machines and equipment, reliability is an important quality. Examples of causes of unreliability are given for steam plants, electrical distribution systems, metals production plants, chemical industry, farm machinery, electrical contractors, machinery, and instrumentation. While the problem is being attacked in a few places, there is no general awareness of the seriousness of the situation and what to do about it.

(The author then describes the more or less standard procedures which industry should apply to improve reliability.)

REVIEW: This translation makes very interesting reading. It is consoling to find that other people have the same problems as we do and that, in this case, their technology appears to be behind ours. In the discussion of the country's troubles, it is easy to see ours mirrored. The solutions to the problem through education, design reviews, testing to failure, etc. which the author mentions are not applied here to the degree that they should be. ##

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Serial Number 1052
Code 822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The region of applicability of the exponential law in the determination of reliability

AUTHOR: L. Leontyev (USSR)

SOURCE: JPRS:13107, 16 March, 1962, 6 pp., U. S. Joint Publications Research Service, 1636 Connecticut Avenue, N. W., Washington 25, D. C. (distributed by Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) (NASA accession number N62-11922)

PURPOSE: To analyze the failure rate curve over the life of equipment.

ABSTRACT: Ordinarily, the negative exponential distribution of times to failure is assumed to hold. This is true for "burned-in" equipment up to the onset of "wearout". An equation is presented which combines the Normal and the exponential functions. The equation is then analyzed to find the region in which it can be approximated by the exponential.

REVIEW: The text is marked "Duplicated from best copy available" and the reproduction is so poor that it is very difficult to read. There appears to be little of real value in the paper. The theory is rather simple and empirical. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Synthesis of reliable systems from unreliable elements

AUTHOR: L. Leontyev (USSR)

SOURCE: JPRS:13813, 16 May, 1962, 8 pp., U. S. Joint Publications Research Service, 1636 Connecticut Avenue, N. W., Washington 25, D. C. (distributed by Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) (NASA accession number N62-17786)

PURPOSE: To show the reliability formulas for parallel, series and series-parallel elements.

ABSTRACT: Failures by opening or shorting are considered and the appropriate failure probability formulas are derived for series, parallel, and series-parallel redundancy. In some cases putting items in series or in parallel can reduce reliability depending on the relative failure probabilities of open and short. The formula for series-parallel takes into account only the case of paralleled elements in series, and not series elements in parallel.

REVIEW: These results appear in many places in the American literature. There is no need to refer to this translation for them. ##

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Serial Number 1054
Codes 824;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Standard reliability coefficient of electronic products

AUTHOR: P. M. Rabinovich

SOURCE: Standartizatsiya, Nr. 2, 1960, pp. 11-13, Translation prepared by Translation Services Branch, Foreign Technology Division, Wright-Patterson Air Force Base, Ohio, FTD-TT-61-139/1+2 (ASTIA Document No. 269157)

PURPOSE: To show how to estimate tolerance intervals from test sample data.

ABSTRACT: (It is rather difficult to interpret the article since it is an unedited rough draft translation.) The article apparently deals with estimating the standard deviation of a Normal population from the range and then estimating the fraction of that population which would be rejected by a limit test.

REVIEW: As mentioned above, the article is difficult to read. It deals with quality rather than reliability. The author appears to make the mistake of calculating tolerance intervals directly from the Normal tables even though the mean and variance have been estimated from a small sample. Except as an example of Russian work, this article is of little use to anyone. ##

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Serial Number 1055
Codes 824;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some problems on the operational reliability of communications systems

AUTHOR: Geza Sarkozy

SOURCE: Magyar Hiradastechnika, No. 1, 1961, pp. 30-35, Translation prepared by Translation Services Branch, Foreign Technology Division, Wright-Patterson Air Force Base, Ohio, FTD-TT-62-363/1+2 (ASTIA Document No. 286121)

PURPOSE: To show how reliability is calculated from failure data on parts.

ABSTRACT: The article first discusses the importance of operational reliability, and then deals with the factors influencing the lifespan and breakdown factor of component parts and with the numerical value of these factors in various electronic components. With these facts the expected operational reliability of complex systems can be computed by approximation using the methods of statistical mathematics. The article then describes some examples of circuits that can be used to increase the operational reliability of complex systems.

In modern communications engineering installations, especially in complex systems of many component parts, operational reliability is gaining an increasingly important role. Based on theories and test data--if the P factors of component parts are known--the probability of malfunctions to be expected during a fairly long test period can be determined approximately by means of preliminary calculations, i.e., based on this, the expected time of operational reliability for the entire system can be determined. To increase this operational reliability it becomes necessary to install manual or automatic reserve installations, whose cost increases the initial cost of the entire installation; however, it also increases greatly the operational reliability by reducing the number and duration of probable malfunctions. (Author)

REVIEW: The "P" factor referred to is the failure rate. The calculations used are quite simple and the results are standard. Parallel redundancy with switching is also illustrated. The Poisson distribution is used to calculate the probability of 0, 1, 2, ... failures in any time period.

The results are all well known and well presented in papers in the English language. ##

Serial Number 1056 -1
Codes 781;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design requirements for spaceborne digital systems

AUTHOR: Joseph F. Shea, Office of Manned Space Flight, National Aeronautics and Space Administration, Washington, D. C.

SOURCE: Computer Design, vol. 2, July-August, 1963, pp. 38-40, 42, 43

PURPOSE: To examine the functional and environmental requirements for on-board space computers.

ABSTRACT: The performance of increasingly complex missions requires major advancement in capabilities for almost all sub-systems which are used as building blocks for space payloads. For computer systems, the major desirable improvements include (1) digital design (logic, circuitry, and packaging), (2) mathematical techniques, (3) programming flexibility, and (4) reliability. (While the author discusses all four topics, only the reliability section is abstracted here.)

A ten-day lunar mission would require a computer with an MTTF of over 24,000 hours which is about ten times the best that can be done today. The development of subtle redundancy will be necessary, as opposed to brute force techniques like majority voting. In a manned system, maintenance can be performed if the computer design can provide means for isolating and indicating faults. The physical design of the system is very important since the space and launch environments are not very gentle. Also not to be forgotten are the more mundane environments during shipping, storage, and handling.

Flight acceptance tests can reveal manufacturing weaknesses; design deficiencies presumably already have been detected and corrected during design approval tests.

The ground test program must develop confidence in the reliability level the computer is expected to achieve during the mission. Space missions are of such duration, and the amount of hardware available for testing is so small, that a real measure of statistical confidence in the performance of the equipment cannot be obtained. The statistical confidence must be replaced with "engineering confidence" that the design will work for the requisite period of time.

The key to developing engineering confidence is the rigorous identification of the cause for all failures encountered during all phases of developmental testing, particularly during the design approval testing and the flight acceptance testing. The acceptance of any failure during development and preflight tests as a random occurrence should not be tolerated. Experience has

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

shown that such failures invariably have an assignable cause which, if not corrected, will lead to similar malfunctions during the actual missions. (Author in part)

REVIEW: This is a very good summary article on the problem of spaceborne digital systems. Even though it is not detailed, it covers the salient points very well. The last two paragraphs of the abstract (verbatim from the author) apply to any high-reliability project, and cannot be overemphasized. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the reliability of multichannel systems with continuous service

AUTHOR: L. N. Mikhailov (Leningrad)

SOURCE: Automation and Remote Control (A translation of Avtomatika i Telemekhanika, a publication of the Academy of Sciences of the USSR), vol. 23, pp. 1430-1436, July, 1963 (Russian original dated November, 1962) (Instrument Society of America, 530 William Penn Place, Pittsburgh 19, Pennsylvania)

PURPOSE: To compare the long-term reliability of one-, two-, and three-channel repairable systems.

ABSTRACT: The model used here consists of parallel, identical channels. Each channel is characterized by a given mean time-to-failure and a given mean time-to-repair, assuming an exponential distribution. The time-independent probability of finding the system operational is given for one-, two-, and three-channel systems. These probabilites are compared for a range of values of mean time-to-repair. Reliability is seen to increase with redundancy.

A three-channel system in which at least two channels must be operative is less reliable than the simple two-channel case, for a given mean time-to-repair. The use of majority logic to detect the faulty channel of a three-channel system, and replacement rather than repair of the faulty element is investigated. This procedure reduces the mean time-to-repair for the three-channel system below that obtainable for the two-channel case, and hence provides the best reliability.

REVIEW: The paper is concerned with long-term "down-time" expectations rather than time between failures. The treatment is not new, but a clear comparison of the various cases is given and the purpose of the paper is fulfilled. The analysis assumes an infinite supply of spare parts for the case of replacement in the three-channel system. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Getting both reliability and economy in power-transistor circuits

AUTHOR: Ralph Greenburg, Motorola, Inc., Phoenix, Arizona

SOURCE: Electronics, vol. 36, May 24, 1963, pp. 54-57

PURPOSE: To discuss the use of germanium power transistors at high temperatures.

ABSTRACT: Germanium power-transistor failure is usually due to application of over-voltage or to thermal runaway. Up to 110°C, thermal runaway may be avoided by proper selection of circuit parameters and heat sinks. An inequality defining stable operation is given, and the necessity of a compromise between stability and efficiency or cost is indicated.

Improper circuit design often results in transistor overheating, due to unforeseen applied voltages or misinterpreted transistor specifications. Safe operating conditions can be defined, but knowledge of maximum voltage, current, and power ratings are not sufficient for this purpose. Likewise, published transistor specifications are often insufficient for the design of pulse circuits which are both reliable and efficient. More complete transistor specifications would help to alleviate these problems.

REVIEW: This paper is a good outline of some of the problems peculiar to power transistor circuits, and helps to explain transistor failures. The author properly recognizes the need for more complete manufacturer's specifications. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Studies in reliability, I. The algebra of four-state safety devices

AUTHOR: A. D. Wiggins, Applied Mathematics Operation, Hanford Laboratories, Hanford Atomic Products Operation, Richland, Washington

SOURCE: AEC Research and Development Report HW-74100, 46 pp., August, 1962, Hanford Laboratories, Hanford Atomic Products Operation, Richland, Washington, Work performed under Contract No. AT(45-1)-1350 between the Atomic Energy Commission and General Electric Company (Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C., price $1.25) (presented at the 1963 Electro-Nuclear Conference, Richland, Washington, April 29-May 1, 1963, paper no. CPA 63-5143)

PURPOSE: To describe an algebra employed in determining reliability of devices having four states including failure modes.

ABSTRACT: The devices under consideration have two proper operating states and two failure modes, corresponding to the four states of a device which may or may not operate, with or without an activating input. Protective relaying of a nuclear reactor is used in the examples.

A reliability algebra, which is seen to be a natural extension of Boolean algebra, is constructed which gives formal recognition to the two types of errors. Using this algebra, it is possible to enumerate, in a systematic way, all safety system events which give rise to errors, as well as all safety system events which give rise to the two reliable states which remain. In reactor terminology, these states are "catastrophic failure", "spurious scram", "operating continuity", and "genuine scram" respectively.

Probabilities associated with these four states are derived by considering a simple random walk in the plane. The derived expressions for state transition probabilities are seen to be a generalization of the exponential failure law for two states. The theory is illustrated by means of formal calculations carried out in some detail for a pair of devices operating together in a specified configuration. (Author in part)

REVIEW: The treatment in the paper is thorough. Development of the "reliability algebra" includes all necessary proofs, and applications to relay circuits are well illustrated. The reliability function derivation is suitable for the example given, but may prove overly restricted for other applications. The mechanics involved in applying this method appear rather tedious, but may be amenable to simplification or computer solution. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy in unipolar transistor circuits

AUTHORS: J. T. Wallmark and A. G. Revesz, Radio Corporation of America, RCA Laboratories, Princeton, New Jersey

SOURCE: AFCRL974, 18 pp., November 1, 1961, Scientific Report No. 2, Investigations of Fundamental Limitations Determining the Ultimate Size of Microstructures, Contract No. AF19(604)-8040, Air Force Research Division, Air Research and Development Command, Radio Corporation of America, RCA Laboratories, Princeton, New Jersey (ASTIA Document No. 272297)

PURPOSE: To evaluate the reliability of systems employing unipolar transistors in redundant configurations.

ABSTRACT: The method of redundancy using series-parallel four-groups described by Moore and Shannon, has been applied to unipolar transistor circuits. The method has been extended to redundancy on the input side and in the wiring. The gain in reliability, which may be used either in the fabrication of the circuits or in the use of the circuits, is approximately $0.9N^{1/2}$, where N is the number of components in the non-redundant circuit. Thus, a circuit containing 40,000 redundant components may either have up to 235 faulty components in fabrication or a median time to failure increased 85 times or a combination intermediate between these two extremes. By dividing the circuits into 10 parts, each containing 4,000 components, and by pre-testing the parts and rejecting the non-operative ones, the total number of faulty components initially in the circuit could be increased to 745, but the median time to failure would be reduced although still larger than for a circuit without redundancy. (Authors)

REVIEW: This is a brief and quite standard analysis of reliability improvement as a result of applying redundancy. Protection from input short circuits is obtained using a series resistance in the transistor gate. The use of median, rather than mean, time to failure is perhaps insufficiently explained in the paper. Also, the reader should beware of the assumption that failures occur independently regardless of failure mode. All in all, the paper is readable and conveys its intended meaning. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable computation with unreliable circuitry

AUTHOR: L. A. M. Verbeek, Research Laboratory for Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts

SOURCE: 10 pp., Proceedings of the Bionics Symposium, Dayton, Ohio, 1960 (ASTIA Document No. 288410)

PURPOSE: To provide an introduction to redundant neuron networks.

ABSTRACT: The properties of formal neurons are discussed. Neurons are capable of performing logical computations and of being interconnected to form complex logical networks. Four types of neuron error may occur: synaptic, or input error; axonal, or output error; error due to signal level fluctuation; and error due to threshold fluctuation. The probability of neuron error is given as a function of the number of input lines to the neuron and of the standard deviation of the threshold fluctuation. Reliability of neuron networks can be increased by the use of simple redundancy and majority decision elements, although the reliability of the majority element places an upper limit on the system reliability. All-to-all interconnections among the neurons eliminate this dependence on the majority element.

REVIEW: The author's discussion is insufficient to establish the validity of the numerical results. In particular, the expressions for composite error probability are questionable, as is the assumption that equiprobable input states result in the highest error probability due to threshold fluctuation. The paper may prove useful as a discussion of concepts rather than for detailed analysis or numerical results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving system reliability by using redundancy at the semiconductor network level

AUTHORS: Philip R. Thomas, Texas Instruments Limited, Bedford (England) and Joe Watson, Texas Instruments Incorporated, Dallas, Texas

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 11-18, January-March, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

PURPOSE: To determine the probability of mission success for a sequence generator using several redundancy configurations.

ABSTRACT: A system of ten seven-bit registers is required for a five-year space mission, including launch and re-entry. The system elements are register stages and units consisting of one or more logic gates, with equal failure rates. Redundancy is achieved by duplication and two-out-of-three majority voting of the system elements.

Four cases of redundancy in the register are analyzed and compared, as are three redundant feedback loops. It is shown that majority voting at the bit level using a single majority element results in a less reliable system than the non-redundant version. The best case is obtained by using multiple voting and separate connections between the stages. This results in a probability of successful mission of 0.562 as compared to 0.119 in the non-redundant case, and uses 900 elements as compared to 90 (assuming an element mean lifetime of 10^7 hours). Similar results are obtained and tabulated for other element mean lifetimes. With increasing element reliability, the mission success probabilities for the three redundant cases become more nearly equal, permitting the use of the configuration requiring the fewest elements.

REVIEW: This paper is a straightforward comparison of several specific redundancy configurations applied to a given problem. The problem which is treated is realistic, as are the numerical results. The paper should prove worthwhile to the reader desiring a good example of the capabilities and limitations of redundant systems. ##

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Serial Number 1063
Codes 831;832;851;
875

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability aspects of an experimental data processing system

AUTHORS: P. Cox and V. J. McMullan, Automatic Telephone and Electric Company Limited, Strowger Works, Liverpool (England)

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 27-64, January-March, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

This paper is essentially the same as the one covered by Abstract and Review Serial Number 578, although certain minor additions have been made at various points throughout the text. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fail-safe transistor logic

AUTHOR: D. H. Taylor, Mullard Equipment, Ltd., Manor Royal, Crawley, Sussex (England)

SOURCE: British Communications & Electronics, vol. 9, pp. 836-840, November, 1962

PURPOSE: To describe fail-safe circuits based on transistors which were devised in relation to nuclear reactor working.

ABSTRACT: A "fail-safe" circuit is one which will assume a safe state either because of a dangerous input condition or by reason of its own internal failure. The article describes a small safety system used with nuclear reactors, which was successfully tested for reliability. Fail-safe requirements are discussed briefly, the discussion being restricted to those cases where the safe condition is constant.

The basic element of the circuits which are described and illustrated is a grounded-emitter transistor, coupled by means of a transformer placed in the collector circuit. A grounded, non-magnetic screen placed between the transformer windings prevents short circuits. The combination of several elements into practical circuits, and their application, is described.

Another section of the article deals with reliability, which is achieved by redundancy. Alarms warn of failure and call for appropriate maintenance action. Majority logic is proposed to be of the serial type -- a "distributor" interrogating input gates in turn, with fail-safe features.

REVIEW: This very short article is primarily a description of work done, with diagrams and short descriptions. A brief discussion of safety and reliability is included. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable, trainable networks for computing and control

AUTHORS: Bernard Widrow and James B. Angell, Electrical Engineering Department, Stanford University, Stanford, California

SOURCE: 34 pp., presented at the IAS Man-Machine Competition Meeting, Seattle, Washington, August 10-11, 1962, IAS Paper No. 62-184 (Institute of the Aerospace Sciences, 2 E. 64th Street, New York 21, New York) (NASA accession number N62-17009)

PURPOSE: To discuss proposed techniques for enhancing circuit reliability using electronic networks and systems, and to give special attention to trainable linear elements called "Adalines".

ABSTRACT: The development of microsystem electronics has encouraged and given impetus to the search for reliable systems. This is due, on the one hand, to the reduction in size, weight, and cost of redundant components, and on the other, to increased difficulty in replacing parts.

Redundant systems might be classified as "active" or "passive", depending on whether reserve parts are switched in, or assume their replacement function automatically, respectively [1]. The following reliability improvement schemes are listed: (1) error detecting codes, (2) comparison of parallel or sequentially duplicated outputs, (3) standby duplicate equipment, (4) error correcting codes, (5) redundant switching networks, (6) majority vote among an odd number of parallel outputs, and (7) adaptive majority vote among parallel outputs.

Error detecting codes use bits added to each word, such that errors cause unacceptable patterns to occur. The parity check is the most widely used of these codes. Error correcting codes use additional bits, in such a way that either by trial and error or by decoding it is possible to tell if a word is correct, and if not, which bit is in error [2]. A table is given which shows the number of additional bits needed to correct words of given lengths (up to 57 bit words).

Redundant switching networks [3] are arrays of switching elements, so connected that some element failures will not result in circuit failure. The connections are optimized using statistical methods. The need for redundancy can be reduced while maintaining reliability by the use of adaptive vote-taking systems. Von Neumann's majority logic [4] is modified by a system which weights more heavily the votes of subsystems which are seen to be more reliable. Using a drawing, the author proposes an adaptive vote-taker. A. type of multiplexing is also shown. Pierce's analysis of relia-

bility of adaptive vote-taking systems [5] is discussed.

A logic system, called "Adaline", using self-repair, and being trainable, either by the designer, or spontaneously by its environment, is the subject of the rest of the paper. The Adaline neuron [6] has been developed for pattern recognition systems and as a basic element for adaptive logic circuits. This is a threshold logic circuit having input lines, an output line, and an input line to be used for training. The inputs are weighted, and the weights (gains) are set during the training procedure. The authors note, but do not discuss in any detail, the unrealizability of certain truth functions.

The application of the Adaline to adaptive pattern classification is described, including manual training of the neuron, and a typical example is shown. The memory capacity of an Adaline is indicated by its ability to absorb an average number of random patterns equal to twice the number of weights. Adalines can be connected in parallel, with their output delivered from a majority gate. A "job assigner", utilizing confidence level information, is used during training. (The authors call a structure of multiple Adalines a "Madaline".) The results of generalization experiments with respect to noise and rotation are described, and mention is made of other generalizations on translation, size, etc. The use of the Adaline as an adaptive vote taker is discussed.

The Adaline can be used for sophisticated pattern-recognition control systems; the "juggling" of an unstable pendulum on a cart is given as an example. A man successfully does this, and the Adaline, using inputs from sensors on the pendulum and cart, is able, after training, to take over the function. A proposed system will use a photocell matrix as the sensor. Next, the construction of practical adaptive networks is described. They use either trainable magnetic core elements, which are described, or memistors [7], electrochemical memory devices, which are also described briefly. The authors have constructed a Madaline using memistors, and discuss its successful reliable operation. (Operation was reliable despite machine errors and imperfections.) This device has also been put under control of an IBM 1620 computer, and larger, similar installations are planned. The paper closes with comments on the development of an "adaptive computer", which would be a third class of computer beyond the present analog and digital.

REFERENCES: [1] J. J. Suran, "Use of Passive Redundancy in Electronic Systems", IRE Transactions on Military Electronics, Vol. MIL-5, pp. 202-208, July, 1961

[2] M. Phister, Jr., "Logical Design of Digital Computers", John Wiley and Sons, New York, Chapter 10, 1958

[3] C. E. Shannon and E. F. Moore, "Reliable Circuits Using Less Reliable Relays", J. Franklin Inst., pp. 191-208, 281-297, September and October, 1956

[4] J. von Neumann, "Probabilistic Logics and the Synthesis of Reliable Organisms from Unreliable Components", Automata Studies, Princeton University Press, Princeton, N. J., 1956

[5] W. H. Pierce, "Improving Reliability of Digital Systems by Redundancy and Adaption", Technical Report No. 1552-3, Stanford Electronics Laboratories, Stanford, California, July 17, 1961

[6] B. Widrow and M. E. Hoff, "Adaptive Switching Circuits", 1960 IRE WESCON Convention Record, pt. IV, pp. 96-104, August 23, 1960

[7] B. Widrow, "An Adaptive 'Adaline' Neuron Using Chemical 'Memistors'," Technical Report No. 1553-2, Stanford Electronics Laboratories, Stanford, California, October 17, 1960

REVIEW: This paper is a combination of two factors, namely, a summary of the work to date on reliable trainable networks by persons other than the authors, and a review of work done and in progress by the authors and their associates. The summary is quite well done, and the authors' description of their own work is sufficiently explanatory.

As an overall discussion of the then-present status of research in adaptive computers, this is an admirable paper; for more explicit presentations of the specific devices and systems, the reader will want to go to the references. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Theory of adjustable switching networks, I
A. Threshold logic
B. Reliability of switching networks

AUTHORS: (A.) Robert O. Winder,
(B.) S. Amarel, J. A. Brzozowski, and S. Y. Levy,
RCA Laboratories, Princeton, New Jersey

SOURCE: AFCRL-62-318, 145 pp. (A.), 109 pp. (B.), April 30, 1962, Special Scientific Report No. 1 under Contract No. AF19(604)-8423, prepared for Electronics Research Directorate, Air Force Cambridge Research Laboratories, Office of Aerospace Research, United States Air Force, Bedford, Massachusetts by RCA Laboratories, Princeton, New Jersey (ASTIA Document No. 282248)

PURPOSE: (A.) To present the facts referring to and the properties of threshold gates, and a collection of methods and algorithms for solving problems in the field.
(B.) To consider a technique for improving reliability of switching networks, at the logical component level, which will be relatively independent of the reliability of the output device.

ABSTRACT: (A.) This paper, after an introduction giving definitions, simple properties, and some general discussion, divides into two sections: Properties and procedures. The first of these sections includes discussion of a doubly infinite chain of properties of threshold functions, the second limit of which characterizes such functions. The first two properties, which are the most useful as "necessary conditions", are given special attention; they yield interpretations in algebraic expressions for the function and provide a natural ordering of the function's arguments. Relations between the families of properties are given, and their independence is shown. Some other conjectured characterizations of threshold functions are shown to be invalid. The number of threshold functions, as a function of n, is given a relatively good upper bound. The procedures include a practicable method of enumerating symmetry classes of threshold functions, and several synthesis procedures. (Author in part)

(B.) This part of the report includes the following sections: a short introduction, a paper on theoretical considerations of reliability properties of recursive triangular switching networks, another considering those networks built of rectifier gates, and a short "preliminary excursion" into recursive triangles and threshold gates, the latter being in the form of an appendix to the third section.

Reliability is considered at the level of component switching functions, and is thoroughly treated with much basic mathematical

theory. In this work an n-input gate is called an order 0 recursive triangle. Higher order triangles are formed by using the outputs of n lower level triangles feeding an (n+1) st. More specific electronic realization is covered in the third section, with particular attention to reliability in the recursive triangular network. The appendix to the third section comments that threshold gates would appear (economically at least) to be a better choice for triangular recursion than rectifier gates. The effect of probable noise on threshold type recursive triangles is discussed, and the conclusion is drawn that, in the case of more general threshold elements, triangular recursion will probably not prove effective. Future work is suggested.

REVIEW: Part A of this report would, in another format, be called a textbook, and it is a very good one. Insofar as the reliability context is concerned, it serves only to provide background material for the discussion in Part B.

Part B, dealing with reliability, is a thorough mathematical treatment of the reliability of triangular recursive networks formed of threshold logic elements. The authors have handled their subject very well, and, as they comment, there is a great deal more to be done. ##

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Codes 711;833;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in semiconductor devices

AUTHOR: J. E. Thomas, Jr., Sylvania Electric Products, Post Office Box 282, Weston, Massachusetts

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 7-25

PURPOSE: To review the state of the art of semiconductor device manufacture and to recommend fields for research in manufacturing methods.

ABSTRACT: Presumably the greatest single need the Air Force has in the electronics field is for improvement in system reliability. Insofar as improvement in semiconductor devices themselves can contribute to improvement of the system reliability, device reliability is assumed to be the problem of greatest importance. Although to this day there is no known mechanism of degradation or failure which is inherent in the electronic processes in semiconductors, a semiconductor device can change characteristics with time and fail completely from any of several causes; random errors of manufacture are one of the major causes of failure of devices in service. From the systems point of view, some degree of unreliability in the device and interconnections may be acceptable, in that it has recently been shown that any desired degree of system reliability can be achieved by using a modest degree of circuit redundancy. After reliability and cost, the size and weight of electronic systems together represent the next most urgent problem. It is believed that extension and improvement of present-day techniques are all that is needed to achieve any reasonable degree of miniaturization in the case of transistors, resistors, capacitors, and conductors; there seems to be very little hope for any drastic size reductions for antennas, microwave power sources, microwave power plumbing, tape and drum recorders, power supplies of all sorts, mechanical automatic control equipment, and the equipment to remove heat from electronic assemblies. Although conductors can be miniaturized, one of our manufacturing methods problems then becomes the matter of forming and joining metals and insulators so that the relatively tremendous volume now devoted in electronic circuitry to protection, interconnection, and cooling can be effectively reduced.

In the case of non-semiconductors, the primary field for research in manufacturing methods is in materials technology, the important items being: to understand and control the properties of metals, ceramics, glasses, and polymers; to improve the methods of joining

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materials, and to find methods for shaping refractory metals and insulators to the tolerance and surface finish needed by the semiconductor industry. Research in manufacturing methods for semiconductors is required in the areas of bulk properties, surface properties, material shaping, material recovery, and epitaxial growth. Research is also required in the area of methods of utilizing semiconductors in conjunction with other materials.

REVIEW: The statement "... if a fraction of the effort now devoted to exotic electronics were to be expended in improving the reliability of circuit wiring, it should be possible to make the reliability of electrical connections essentially perfect" is rather controversial. It was not so many years ago that semiconductor devices came in the category of exotic devices. It is also quite likely that the solution to the admittedly difficult problem of component interconnection will stem from research in exotic electronics; for example, the work carried out by K. R. Shoulder's group at Stanford indicates one possible approach to the solution of this particular problem.

Despite the above remarks this is an interesting and informative paper with some bearing on reliability; it also tends to strengthen the belief that the future of electronics lies in a better fundamental understanding of materials. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in non-microwave electron tubes

AUTHOR: E. D. McArthur, Research Laboratories, General Electric Company, Post Office Box 1088, Schenectady, New York

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 26-35

PURPOSE: To assess the requirements for the development of manufacturing methods for non-microwave electron tubes to be used in aerospace systems in the period 1965-1980.

ABSTRACT: The major difficulties to be faced in the design of practical electron tubes for use in the aerospace environment are: (a) the need for a much higher rate of data processing, (b) the need to perform all the necessary functions in a different and vastly more destructive environment, and (c) the need for much higher reliability and longer life than is acceptable for strictly ground-based equipment. After these technical conditions have been met, there remains the problem of producing the required devices reliably within a practical economic framework of facilities and manpower. A prerequisite to the design of electron tubes that will operate satisfactorily in the adverse environment of space is a knowledge of the destructive effects of high temperatures, radiation, shock, and low pressures upon modern electronic tubes. Present programs to determine the temporary and permanent effects on the life and performance of modern electronic tube designs are not adequate and should be expanded.

The realm of materials will continue to be of great importance for the continued development of electronic tubes; items of major interest are metals and alloys, and ceramics and insulators. In the former group the less well known metals, refractory metals, and certain light elements such as titanium and beryllium are especially interesting. The extent and accuracy of our basic knowledge of ceramics and insulators is even less than that of metals and warrants much more attention.

In the area of tube fabrication it is recommended that basic studies be made of the joining of like or dissimilar materials. For example the development and evaluation of electron-beam welding should proceed with high priority. New methods of tailoring metals to suit the aerospace environment should be sought out and pursued actively. In the field of special-purpose tubes, the need and opportunity for materials research and special developments is

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greater than in any other.

REVIEW: The major point of interest to be gleaned from this paper is that the author is obviously convinced that electronic tubes will continue to be used in aerospace systems during the entire time period in question (1965-1980). The paper should be read in conjunction with the Long-Range Supporting Research Program prepared by the Advisory Group on Electron Tubes for the Office of the Director of Defense Research and Engineering, which gives a five-year forecast in the same field. ##

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833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in microwave tubes

AUTHOR: W. J. Dodds, Met Com, 76 Lafayette Street, Salem, Massachusetts

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 36-49

PURPOSE: To discuss the type of materials research needed for the further development of microwave tubes.

ABSTRACT: The major direction in which present materials technology limits the development of microwave tube structures is in the requirement for increasingly higher power densities. This may result from extremely high powers at frequencies below 10 KMc, or from only moderate absolute power levels at frequencies up to 200 KMc or higher. Since reliability, longevity, and minimum weight have already been emphasized as necessary for all aerospace systems components, materials aspects of these features in microwave tubes will be treated.

A second application factor encountering limitations in materials is the possible growth of requirements for qualitatively different performance. New materials characteristics in bulk are needed for new means of generation or amplification of microwave energy by interaction with electron, ion, or atom beams. The true potential of such means for microwave tubes as aerospace components is unknown, but could be large, and supporting work in materials is justified. These two factors are discussed with particular reference to the following types of materials: ceramics and insulators, pyrolytic substances, semiconductors, gases for R. F. conduction, special dielectric materials utilizing the Cerenkov effect, garnet crystal structures, spinel crystal structures, ferrites, and ferroelectrics.

REVIEW: For reliability engineers who are interested in the progress and problems in the development of solid state devices, this is an interesting and informative review paper. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in resistors

AUTHOR: Jesse Marsten, International Resistance Company, 401 North Broad Street, Philadelphia 8, Pennsylvania

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 50-55

PURPOSE: To assess the requirements for the development of manufacturing methods for resistors for use in aerospace electronics systems in the 1965-1980 time period.

ABSTRACT: An assessment of the primary requirements for the development of resistor manufacturing methods is made for the 1965-1980 time period. This assessment is based on the specifications outlined in the report of the Communications and Guidance Subgroup plus the following assumptions: (1) the discrete resistor will continue to be used although probably in declining proportions, (2) micro-module and microcircuit assemblies will increase in use, and (3) molecular circuitry may begin to be used in the middle and latter part of this period.

At present the vacuum evaporated metal film resistors come nearest to meeting the stipulated requirements but their development is restricted because of a lack of knowledge of how their electrical properties are affected by their physical and chemical properties. Inherent difficulties with the thin film resistor result from the small size which hinders the initial deposition of the film to the correct value and the subsequent tolerancing to the precise value. These difficulties might be reduced by the use of continuous step-by-step processing in vacuum. Future areas of promise include precision resistors of inorganic compositions, increased power dissipation through the use of new types of substrate material, and some progress with the problem of interconnection.

REVIEW: This is a down-to-earth review of the state of the art of resistance development projected into the time period 1965-1980. One criticism is that the tin oxide resistor is dismissed too lightly in view of its inherent advantages. The fact that it does not at this time meet the requirements with respect to the temperature coefficient of resistivity does not mean that it will not do so at a later date after further development. Reliability is not mentioned at any length but all of the factors discussed have some bearing upon this important subject. The author's plea for more basic research in the conduction phenomena of thin films is very well taken. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in capacitors

AUTHOR: Preston Robinson, Sprague Electric Company, North Adams, Massachusetts

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 56-61

PURPOSE: To assess the requirements for the development of manufacturing methods for capacitors for use in aerospace electronics systems in the 1965-1980 time period.

ABSTRACT: Working on the assumption that the circuits to be employed during the time period in question will be similar to those at present in use, it is logical to expect that the active elements will consist largely of transistors working at low voltages in low impedance circuits; consequently there will be a strong emphasis on thin-film capacitors. Thin films as presently produced are likely to have pinholes and the thin-film capacitors which have been successful to date have incorporated means of overcoming the effects of pinholes. Methods used have included the introduction of liquid and solid electrolytes, resistive materials, and semiconductive materials. The resulting capacitors are not all suited to outer-space requirements and a further program would have to be undertaken to determine those which are, and also to explore additional means of overcoming the effects of pinholes.

The manufacturing methods expected to be used, in addition to those in common use today, include vacuum evaporation, both with and without electric fields and beams, and sputtering. (Author in part)

REVIEW: This paper reviews the expected development of capacitor technology for the foreseeable future, but does not attempt any "blue-sky" predictions, and keeps very much to methods that are now under development. Since the issue of the document of which this report forms a part (February, 1962) there has been a definite move by one very large manufacturer to mechanize the film deposition operation. Both resistors and capacitors of good quality and stability have been made from tantalum films produced by sputtering in an open-ended vacuum system. (This is a continuous system in which the substrates enter one end of the line at atmospheric pressure and emerge at the other end complete with the requisite sputtered films.) This mechanization will be expected to lead

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

to better and more uniform films, and eventually might be expected to do much to eliminate the pinhole problem noted here. As a side remark, the comment might be made that the mechanized system will probably be capable of producing cleaner and more uniform films than is now possible in the laboratory.

The author, in commenting on the above review, has said in part: "I should like here to insert some ... strong statements about the importance of pinholes in thin films, not only as it applies to capacitors but also wherever insulating films are used, for example, in silicon epitaxial transistors, microcircuits, cryogenic devices and the like. When you get into an environment of reduced pressure, the pinhole problem is even worse. For example, thick films which would normally stand, say, 400 volts, will pass large currents in the region of 2-3 volts under reduced pressure, and this because the pinholes, or pores as they are called in thicker films, rely for their dielectric strength on removable adsorbed layers of oxygen or nitrogen." He has also expressed doubt that mechanization will provide an early solution to the pinhole problem, and has stated further that "any terrestrial program which fails to deal physically with the problems of pinholes in thin films is economically unsound; any space program which fails to deal physically with the pinhole problem is unreliable." ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in single crystals

AUTHOR: Roger Merrill, Engineering Physics Department, Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 62-70

PURPOSE: To assess the requirements for the development of special materials with emphasis on single crystals for use in aerospace electronic devices in the 1965-1980 time period.

ABSTRACT: The most apparent approach to the problem in hand is to predict the devices that will be used in future aerospace weapons, and then to develop manufacturing techniques to produce them. However, the electronic devices that will be used toward the end of the time period under consideration are largely a matter of conjecture. As a result, any attempt to define research programs designed to develop manufacturing methods for devices that are now unknown is out of the question. This in turn means that manufacturing methods research should be directed towards gaining a better basic understanding of the manufacturing problems common to a general class of products rather than towards finding empirical solutions for specific end products. Without attempting to predict the specific electronic devices that will be used in the 1965-1980 time period, the following can be stated with a reasonable degree of certainty concerning the manufacture of these devices:

(1) Although new classes of materials will be developed, most of the presently known materials or classes of materials will continue to be used.

(2) Devices and systems will continue to become more complex and will be required to face more extreme environments for greatly increased lengths of time; thus ultrareliability will be a must.

(3) Problems general to all types of devices, such as junctions, seals, connections, etc., will continue to be problems.

(4) Reduced size and weight will be desirable. (Reduced size may be essential for ultrahigh-speed switching circuits.)

(5) Reduced cost is always desirable and may be a necessity.

(6) A much better basic understanding of the effects of stresses imposed during manufacture and application is required.

The paper continues with a discussion of the detailed problem of manufacturing methods for single crystals of controlled purity. This subject is treated with reference to crucible materials, purification techniques, growing techniques, and single crystal thin films.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This paper is well worth reading because of the author's statement of philosophy on the correct approach to the development of manufacturing techniques for aerospace devices. He has little to say about reliability per se, but as the entire question of reliable solid state components is shown to be based ultimately upon the ability to produce super-pure well-ordered materials, the whole paper assumes an importance to the reliability engineer which is not indicated by the title. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in magnetic materials

AUTHOR: P. S. Darnell, Bell Telephone Laboratories, Inc., Whippany, New Jersey

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 71-83

PURPOSE: To consider what may be required of manufacturing techniques, processes, and methods associated with the production of improved magnetic materials needed to support aerospace requirements for the 1965-1980 time period.

ABSTRACT: Magnetic metals and alloys involving metallurgical methods and processes for their fabrication will continue to be used during most, if not all, of the 1965-1980 period. Perhaps their use will decline as magnetic ceramics are developed. The application of magnetic ceramics will continue to expand. Because of the multiplicity of approaches to memory and logic devices, the future role of magnetic films is less certain. However, the future prospect for integrated circuits based upon thin film technology is very promising and whatever is done in this field is in general applicable to thin magnetic films also.

Research and development is required to obtain desired magnetic material properties that are at present beyond the state of the art. Present manufacturing methods require critical examination in order to insure the production of the maximum quantity of optimum quality materials. As many of these manufacturing methods are of long standing, and are not likely to be suddenly superseded, it is believed that a vigorous quantitative analysis should be made with the objective of (1) refining and upgrading current methods and (2) delineating areas where present procedures are no longer adequate. (Author in part)

REVIEW: The author has based his review upon an aerospace electronics systems forecast for 1965-1980 which was prepared by the Communications and Guidance Subgroup of the MAB Aircraft and Astronautics Application Panel (Report MAB-139-M(AA3)). In order to follow the review a copy of this report is required. Although the author is very well known in the reliability field, this paper has no direct bearing on the subject. It is essentially a cautious appraisal of present-day magnetic materials and the techniques for making and handling them. There is little attempt to predict future developments in these materials and processes. ##

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Serial Number 1074
Codes 711;720;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in microelectronics and electronic photography (This abstract and review covers only the portion of the paper dealing with microelectronics.)

AUTHOR: Harry Kihn, Radio Corporation of America, Post Office Box 800, Location S-308, Princeton, New Jersey

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962, (NASA accession number N62-11407), pp. 84-100

PURPOSE: To predict the probable trends in manufacturing methods in microelectronics during the period 1965-1980.

ABSTRACT: The field of electronics is experiencing a revolution in the design and packaging of circuits and subsystems, with the ultimate goal of their optimization in the categories of reliability, performance, initial and maintenance costs, power density limitations, and size and weight. The spectrum of miniaturization dealt with in this paper lies between 10^5 parts/cu. ft. and 10^8 parts/cu. ft. Since the majority of electronic tasks for both military and commercial electronic systems involve the processing of information rather than power, it is possible to reduce the physical size of circuits to a minimum, limited only by such factors as the following: (1) the operating power level of the active devices in the circuit, (2) the state of technology of materials, (3) the state of the technology of fabrication and assembly of components and functional devices, (4) the efficiency of conductive, convective, radiative, and possibly thermoelectric "hot spot" cooling means incorporated in the microelectronic subsystem, and (5) the sophistication of circuit and system concepts required to insure maximum reliability. Each one of these separate factors is discussed in detail with reference to current practice and the probable future trends.

REVIEW: In order to obtain the maximum benefit from this paper, several readings are required--this does not constitute a criticism but rather an acknowledgement of the detailed content. The author has done an excellent job of reviewing a very large and rapidly developing field of electronics. He points out the possible trends of development in the future without indulging in any "blue sky" wishful thinking. His paper contains many useful pointers for the research engineer who is wondering where to go next in the continual search for better active devices. There is no detailed discussion of reliability, but the paper should be required reading for the reliability engineer who has any interest in electronics. ##

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Serial Number 1075
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An assessment of manufacturing methods development requirements in masers and lasers

AUTHOR: J. F. Blackburn, Aerospace Corporation, 2400 El Segundo Boulevard, El Segundo, California

SOURCE: Report of the Ad Hoc Panel on the Manufacture of Advanced Electronic Components, Materials Advisory Board of the Division of Engineering and Industrial Research, National Academy of Sciences, National Research Council, Washington 25, D. C., February 23, 1962 (NASA accession number N62-11407), pp. 124-129

PURPOSE: To make some statements based on general principles which apply to any field of research and development, with particular reference to masers and lasers.

ABSTRACT: Masers and lasers are too new to permit a logical extension of the present state of the art to the future; consequently the statements in the paper are based on general principles applicable to research and development. Of a potentially very large class of devices termed atomic resonant circuit elements, the microwave maser and optical laser have so far been built. The laser seems to have much greater possibilities than the maser principally because it opens up the whole optical spectrum, from microwaves to the far ultraviolet, to exploitation by electrical means. The problem which we face is not that of stimulating this exploitation, but of accelerating the creation of basic knowledge to exploit. It seems probable that the most important areas to explore are included in the following: (1) the fundamental mechanisms important for atomic resonant circuit element action, (2) the ways in which the material can be coupled to the external circuit, (3) the intelligent specification of the properties needed for a given application, (4) the "tailoring" of a material for a given application, (5) the supplying of the necessary input energy to the medium, and (6) the making of atomic resonant circuit elements non-linear so that efficient modulators and detectors can be produced throughout the spectrum. It is noted that the atomic resonant circuit element presents a unique opportunity for an experiment in coordinated research and development. One method in which such an experiment could be carried out is discussed at length. (Author in part)

REVIEW: This paper contains less information that could be of use to the reliability engineer or designer than do most of the other papers in the document in which it appears (see Abstracts and Reviews Serial Numbers 1067 through 1074). This is undoubtedly due to the newness of the technology of masers and lasers. The chief message of the paper is a plea for more funds for research in this field. ##

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Serial Number 1076
Codes 773;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Circuits for testing reliability of relays

AUTHOR: Carl W. Loeseke, General Electric Company, General Purpose Control Department, Bloomington, Illinois

SOURCE: 10 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 14)

PURPOSE: To point out the assets and limitations of two circuits that are widely used for testing machine tool relays, to submit a circuit that will overcome most of the limitations, and to make a plea for a standard test procedure.

ABSTRACT: Some simple methods are described for the evaluation of the reliability of AC machine tool types of relays; these circuits can also be used to evaluate other types of relays. The test circuits are designed to check for the following malfunctions:

(1) Failure of a contact to conduct, called a contact fidelity failure or miss.

(2) Failure of the relay to drop out to the de-energized position.

(3) Magnet requiring several closures before sealing.

(4) Contact opening due to magnet vibration (noise).

(5) Breakages or wear that affect relay operation.

REVIEW: The paper describes some circuits which the author has found to be useful for the evaluation of relay reliability. Nothing new or recondite is described. There is a lack of clarity on certain points. For example, early in the paper the author states that "... we not only want to find and identify each failure but require that the failure can be correctly assigned to the proper relay." The reader can easily infer that the circuits described accomplish this, whereas in fact such is not meant to be implied.

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Serial Number 1077
Codes 222;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Acceptance testing for reliability analysis

AUTHOR: John L. Farbo, Allied Control Company, Inc.

SOURCE: 6 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 15)

PURPOSE: To discuss acceptance tests as applied to relays.

ABSTRACT: The purpose of this discussion is to take a realistic look at the acceptance tests currently in existence and proposed for use. Acceptance tests are only capable of determining the reliability of the relay with respect to the test procedures, and are not capable of determining the reliability of the relay in the end use operational environment unless the acceptance tests exactly simulate the end use operational environment. Therefore, it must be proved that a positive correlation exists between the acceptance test procedures and the operational environmental stresses before the failure rate derived from the acceptance tests has any meaning.

Acceptance tests subject the relays to several of the environmental stresses which the relays could be expected to encounter with a resultant wealth of data from measurements of the relay parameters. This data, if put into a usable format, can enable the engineer to make decisions about rejected lots by limiting the areas of uncertainties. (Author)

REVIEW: This is a fairly elementary discussion of the principles of acceptance testing as applied to relays. The statement that "the cost of an acceptance test program is not measurable" is rather confusing. An attempt is made to justify it by arguing that the costs of time, material, and labor expended on a rejected lot are not measurable because there are no relays available for the final assembly manufacturer to use. Perhaps the use of the word "measurable" was unfortunate, and what is really meant is that the cost of a rejected lot cannot be charged directly to the final assembly manufacturer. ##

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Serial Number 1078
Codes 815;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relay reliability stemming from specifications and applications

AUTHOR: E. U. Thomas, Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York

SOURCE: 14 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 16)

PURPOSE: To emphasize the fact that for optimum reliability a relay must be used for the purpose for which it was designed.

ABSTRACT: In order to obtain the optimum reliability a relay should be used for the purpose for which it was designed. Whatever the reason for a failure, whether it be lack of reliability or misapplication, every relay failure is detrimental to all concerned. The National Association of Relay Manufacturers should do its utmost to reduce the number of misapplications and clarify the understanding of relay specifications. Advertising should be factual and specific rather than imply that relays meet or exceed certain specifications. Some specific cases of relay misapplication are discussed. A list is given of military and manufacturer specifications for relays. There are other miscellaneous tables, addresses of various societies from which relay literature may be obtained, and a list of twelve references.

REVIEW: This is a rather disjointed paper, but the tables, addresses, and lists of specifications may prove to be useful as reference items.
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Serial Number 1079
Codes 815;824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relayability applied to reliability

AUTHOR: John S. Jordan, Struthers-Dunn, Inc., Pitman, New Jersey

SOURCE: 8 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 17)

PURPOSE: To explain the methods of determining the reliability of relays.

ABSTRACT: The intent of this paper is to set forth some of the ground rules for determining the reliability of relays and what can be done to improve reliability through realistic specification and application review, prior to proceeding with the construction of a Hi Rel part. Much has been said in the past about being realistic about the requirements of an application when specifying a relay, and needless to say, most of you are familiar with the "trade-off parameter" approach to improving a relay's capabilities in certain areas of stress. The contents of this paper will then, deal with those areas where higher reliability can be demonstrated for a relay without any change in the basic design of the relay. (Author)

REVIEW: This is a paper on the application of elementary reliability theory to relays. As such it will be of most interest to those who are new to the field. ##

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Serial Number 1080
Codes 815;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Increased relay reliability through proper application

AUTHORS: Charles B. Rau and Ben Winters, Leach Corporation, Leach Relay Division, 5915 Avalon Boulevard, Los Angeles 3, California

SOURCE: 20 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 18)

PURPOSE: To recommend an approach for the drafting of specification requirements and the proper selection of relays by the design engineer, components engineer, specification engineer, reliability engineer, and the buyer.

ABSTRACT: Five case histories are discussed for relays in which misapplications have caused poor reliability. These include the following:

(1) The failure of a coil of a relay used in airborne auxiliary equipment through operation at 120^{o}C when the specified maximum operating temperature was only 70^{o}C. Further trouble was caused by the existence of a higher vibration level than the original specification had indicated and by the aircraft power supply dropping to 9 VDC instead of the specified minimum of 18 VDC.

(2) The failure of a relay through the contacts remaining in a closed position after the removal of the relay power. This particular case resulted in a crashed aircraft. The trouble was due to a field repair station omitting to replace a return spring insulator cap upon reassembly.

(3) The failure of six-pole, double-throw, relays rated for 5 ampere resistive loads at 28 VDC or 115 VAC 400 CPS <u>single phase</u> through use on a three phase circuit for which they were not suited.

(4) A relay designed and qualified for use in a missile destruct circuit worked satisfactorily until moved to a new location in which the vibration level was much higher than specified. The trouble was cleared by relocation in a plane with a lower vibration level.

Various hints and requirements are given to enable the user to determine the correct kind of relay to use for his specific task. There are sections on contact calculations and on relay definitions. Ten important points are listed, the observance of which should result in increased relay reliability.

REVIEW: This should prove to be a very useful paper to those who are concerned with the specification/selection of relays. The case histories are eloquent reminders that most failures are due to human error. ##

Serial Number 1081
Codes 771;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Bureau of Ships program to determine the characteristic life profiles of electromagnetic and thermal time delay relays

AUTHORS: Joseph Brooks, Department of the Navy, Bureau of Ships, Washington, D. C. and Daniel N. Schochet, Associated Testing Laboratories, Inc., 200 Route 46, Wayne, New Jersey

SOURCE: 22 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 19)

PURPOSE: To describe a program for evaluating the reliability of hermetically sealed relays manufactured in accordance with Military Specifications MIL-R-5757 and MIL-STD-242D.

ABSTRACT: This paper describes an experiment designed to yield the inherent life characteristic profiles or failure rates of electromechanical and thermal time delay relays at the 90% confidence level. The relays utilized in the experiment have been selected from Types RY4NA3B3L01 and RY4LC3B3L01 of Specification MIL-R-5757 and the types described on Pages 1407.3, 1407.4, 1407.6, and 1407.10 of Specification MIL-STD-242D. These life profiles are considered as inherent measurable characteristics of the individual electronic parts and are, hence, to be included in the military specifications. The inclusion of this data in the parts specifications permits the equipment design and analysis engineers to treat the life of an electronic part as an operational parameter.

The program includes the following phases: (1) establishment of the basic experiment, (2) procurement of the parts to be tested, (3) performance of the tests and acquisition of data, and (4) analysis of the data. At the time of preparation of the paper, phase (1) had been completed and phases (2) and (3) had been initiated. The basic considerations in the design of the test experiment are discussed under the headings: (1) complete relay failure, (2) severe degradation of performance, and (3) secondary degradation of performance. Various failure modes and mechanisms are described under each heading. The test plan and test procedures are described. The reasons for the choice of the Weibull distribution as an underlying model for the data analysis phase of the program are discussed. Illustrative figures, charts and tables are presented. Relevant military specifications for relays are given in an appendix. (Authors in part)

REVIEW: This is a well written discussion which should be of interest and use to those concerned with the planning of test programs for relays. It would seem likely that the authors could supply some worthwhile case studies when the program is completed. ##

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Serial Number 1082
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On stockpile electrical reliability of sealed switching devices for nuclear weapons

AUTHOR: Paul Mahler, Picatinny Arsenal, Dover, New Jersey

SOURCE: 8 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 20)

PURPOSE: To discuss the reliability of items for special weapons during their shelf life or during that of the weapons of which they form a part.

ABSTRACT: The following criterion is proposed for determining the electrical reliability of missile parts: "If, at any time before launching, missile failure is thought to be possible, for any reason whatsoever, then, from that moment until something is done to restore confidence in the missile's reliability, it would have to be considered unreliable."

Four actual cases are described as evidence to demonstrate that a need for such a criterion exists. Other criteria are proposed for electrical reliability, insulation resistance, insulation breakdown, contamination of circuits, and for stockpile electrical reliability. Guide lines are given for the identification of a contaminant in a sealed enclosure. Some rules are suggested for the manufacture of uncontaminated switching devices.

REVIEW: The proposed criterion for determining the electrical reliability of missile parts is very nice from a philosophical point of view, but is hard to apply. This may be illustrated by arguing that any single component is less than perfect; hence a system must also be less than perfect (despite the possible use of redundant circuits); therefore the application of the criterion to a system tells us that it would have to be considered unreliable. By a simple extension of this argument all present-day missiles must be considered to be unreliable. This is, of course, quite true, but some are more reliable than others--the criterion, as stated, takes into account only the black and white and leaves out the large area of grey between perfect and completely unreliable.

This criticism may be unfair since the general tone of the paper is that of an after-dinner speech rather than a technical paper. Judging it on this basis, it is interesting and the cases given to support the need for such a criterion reveal some of the difficulties facing the relay manufacturer in his quest for reliable relays at rock bottom prices. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effects of combined operating environments on reliable relay life

AUTHORS: A. P. Boylan and W. J. Fontana, U. S. Army Electronics Research & Development Laboratory, Ft. Monmouth, New Jersey, and W. H. Lesser, Specialty Control Department, General Electric Company, Waynesboro, Virginia

SOURCE: 24 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 21)

PURPOSE: To describe a comprehensive analytical experiment for the purpose of determining the functional relationship between relay life and selected critical operating environments.

ABSTRACT: The lack of life test data at a variety of load conditions constitutes a big gap in relay application engineering today. In order to partially fill this gap, the U. S. Army Electronics Research and Development Laboratory has undertaken a program to establish the functional relationship between relay life and combined operating environments. This paper is concerned with an evaluation of the "unimite" relay performed by the Specialty Control Department of the General Electric Company. The evaluation included the fabrication and testing of discrete lots of relays to provide statistically valid data on the performance capability of the design, and the design and conduct of a comprehensive analytical experiment for the determination of the functional relationship between relay life and selected critical operating environments. The basic test plan is a five-factor, two-level, one-half replicated fractional factorial experiment. This is supplemented by the centroid (nominal severity level) point and ten prong points (maximum/minimum severity levels), resulting in a total of 27 test runs and the over-all test plan is called a central composite experiment. Steps in the data analysis are outlined. Illustrative tables and charts are included.

Results of this test program successfully showed the effects of combined operating environments on relay life. In general, an increase in contact current, contact voltage, or ambient temperature will reduce expected life but an increase in coil voltage and rate of contact operation will increase expected life. Some reversals, however, were found in certain environmental combinations. (Authors in part)

REVIEW: This is a detailed presentation which should be useful to those who are concerned with the design of experiments for the purpose of evaluating relay life in terms of operating environments. The model used and other relevant statistical considerations are clearly described. ##

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Serial Number 1084
Codes 773;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Practical contributions in testing relays

AUTHOR: Francis J. Soychak, IBM General Products Division, Burlington, Vermont

SOURCE: 12 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963, (Paper Number 22)

PURPOSE: To outline some of the National Association of Relay Manufacturers' Testing Criteria and to point out some of the design problems encountered in building test equipment following these criteria.

ABSTRACT: The ground rules for testing and evaluating relays have always been an area of discussion between manufacturer and user. The National Association of Relay Manufacturers' Reliability Guidelines for Relays and Recommended Specification for High Reliability Relays are a positive step toward obtaining the common language required by manufacturers, test equipment designers, salesmen, and users. This paper is concerned with the unforeseen parameters in relay test equipment which can drastically affect the results of relay testing. Some areas which should be considered during test equipment design are discussed.

The justification of the test criteria is discussed under the headings: miss duration, sensing period, and voltage detection level. Test equipment design is considered under the headings: logic design, counter considerations, amplifier design, coil suppression, load supply and contact load, pulse generation drifts, line noise, and duty cycle considerations.

REVIEW: This is a brief paper which in effect tends to supplement/interpret the NARM documents to which it refers. Its chief message appears to be "... when testing relays, one must be constantly on the alert for extraneous factors which can creep into the testing program and drastically affect the results." ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluation of relay life

AUTHOR: C. B. Brown, Bell Telephone Laboratories, Incorporated, Columbus, Ohio

SOURCE: 13 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 24)

PURPOSE: To present a method of assessing the life of a relay in terms of its expected rate of readjustment, with specific reference to the general purpose telephone relay.

ABSTRACT: In the life testing of relays, the usual practice is to select representative samples and take variables data on the following characteristics: operate current, release current, operate time, release time, armature travel, back tension, and contact gauging. For some types of relays, some other characteristics are measured. The periodic measurements of the characteristics provide measures of their degradation, and the relative rates of degradation provide information as to the characteristic which will cause ultimate failure of the relay. With card release construction, the characteristic that is usually of most interest is the contact gauging, which is the measure of the point in the travel of the armature at which the contacts either open or close. Zero contact gauging exists when make contacts do not close or break contacts do not open by the time the armature strikes the core.

An example is given in which the break contact gauging of the relay was the controlling factor. From the data obtained in the periodic measurements, one can compute and plot the mean, maximum, and minimum contact gauging initially and at each measurement interval. However, it is more pertinent to consider the changes that are observed in individual relays during the test. Therefore, at each measurement interval the change in break contact gauging for each relay was computed and then the mean and standard deviation for the change in gauging were calculated. In the past the practice has been to consider that the relays have reached end of life when the mean plus three standard deviations is equal to the minimum allowable gauging for the relays under test. This practice fails to allow for the facts that most general purpose telephone relays can be readjusted, and that very few relays are initially adjusted to the minimum gauging condition. The practice is therefore unduly conservative and misleading.

To overcome this difficulty, it is proposed that life estimates be presented in terms of a curve which shows the relationship between

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

the number of operations and the probability of need for readjustment. Such a curve can be derived by combining the statistical distribution of initial adjustments as manufactured with the estimated statistical distribution of change of adjustment with number of operations. The mean and standard deviation of initial gauging are obtained on the assumption of a consistent manufacturing process. When a sample of relays is tested, the change in gauging is measured for all relays on test. This change in gauging on a particular relay is considered to be independent of initial gauging on that relay, and of the changes on other relays of the sample at the point of life at which the observation is made. The mean and standard deviation of the change in gauging are estimated from the observed data. The mean and standard deviation of the distribution of gauging are obtained by combining respectively those of the initial gauging and of the change in gauging. This distribution is assumed to be normal (Gaussian). It is also assumed that the relays require readjustment when the gauging reaches zero. The percentage of relays requiring readjustment is obtained from a table of normal deviates. An illustrative example is presented.

REVIEW: The method proposed in this paper would appear to be preferable to the former method. No justifications are presented for the assumptions which are made, and this tends to weaken the presentation. However, the author has indicated in a private communication that while the justifications were omitted from the paper because of limitations on time and space, the validity of the assumptions is supported by a large volume of laboratory data which has been collected in the course of relay life tests.

In effect, initial gauging and change in gauging are assumed to be independent normal (Gaussian) variables. Since the standard deviation of the change in gauging is estimated from a sample, the quantity which the author presents as a normal deviate is in fact a Student's t statistic. When sufficiently large samples are involved, this error will not cause serious trouble, but when the sample size is small, an appreciable error in the estimated percentage of relays requiring readjustment could result. Since the author did not give the sample size for his example, it is not possible to evaluate the effect of the error in that particular case. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The design engineer's most reliable piece of hardware--the general purpose relay - Phase II

AUTHORS: C. W. Derrickson and C. P. Wegenka, North American Aviation, Inc., Columbus, Ohio

SOURCE: 13 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 31)

PURPOSE: To show the reliability achieved to date for relays used on A-5A aircraft.

ABSTRACT: Among engineers there is an attitude that relays are inherently unreliable. Due to this bad reputation of relays, there has been considerable effort in the aircraft industry to develop static switching devices to replace relays whenever possible, as well as to design circuits with as few relays as possible. This paper is intended to show that relay reliability on the A-5A is better than that previously experienced on other aircraft, and to indicate what can be expected if adequate quality control is exercised and if the relays are properly applied. It consists of the presentation and analysis of failure data on most relays purchased by North American Aviation and installed on A-5A aircraft.

The procedures are briefly described and summaries of failure data are given in tables. The conclusions drawn include the following.

(1) Static switching is not as reliable as electromagnetic switching for general purpose use where the duty cycle does not exceed ten actuations per hour and coil voltage is applied most of the time. For intermittent operational requirements and/or high duty cycle rates, there is insufficient data from which conclusions may be drawn.

(2) DC relays are much more reliable than AC relays, regardless of the manufacturer.

(3) No statement as to the predominant type of failure can be made for any specific relay or for relays in general.

REVIEW: This paper will be of interest and use to engineers concerned with the selection of relays or other switching devices for aircraft use. The data presented should be of assistance in connection with decisions on the acceptability of various relays from the standpoint of reliability. ##

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Codes 773;774

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Instrumentation for mass relay life testing

AUTHORS: J. K. Scott and C. V. Leach, Westinghouse Defense Center, Electronics Division, Baltimore, Maryland

SOURCE: 20 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 42)

PURPOSE: To describe the instrumentation used in testing large numbers of relays.

ABSTRACT: This paper describes the instrumentation used in a large-scale program to secure a complete history on certain hermetically sealed telephone-type relays with contact ratings specified at 26.5 VDC, 120 VDC, and 115 VAC (with a maximum of 10 amperes). Life testing is conducted for 100,000 operations and successful units are continued on test until every pole has failed. Approximately 1,000 relays are involved in the program. The test specification is based on MIL-R-5757D and MIL-STD-202; none of the requirements are beyond the state of the art.

The most difficult problems encountered in setting up the test program were instrumentation and life testing. Other problems included continuity monitoring and operate and release time monitoring. The use of water-cooled loads was decided upon; the load tank and load banks are described. The means set up for the monitoring of contacts, for continuity monitoring, and for operate and release time monitoring are discussed. Problems encountered with water loads and corrosion and electrolysis are indicated. Although the test program has not yet been completed, it is felt that much knowledge has already been gained from it.

REVIEW: This is a worthwhile paper for those concerned with the design, construction, and use of instrumentation for the testing of large numbers of relays. Since the test program is not yet complete, no data or results are given. These, when they become available, will also be of interest. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relay degradation--a new reliability tool

AUTHORS: Bernard R. Schwartz and Arthur Siegel, Electromechanical Devices, Radio Corporation of America, Camden, New Jersey

SOURCE: 10 pp., presented at the Eleventh National Conference on Electromagnetic Relays, National Association of Relay Manufacturers and School of Electrical Engineering, College of Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1963 (Paper Number 45)

PURPOSE: To describe a new method of screening relays in order to remove those which do not exhibit a normal life expectancy.

ABSTRACT: Prior to May 1960, engineers who dealt with reliability had no standard direction. They used a basic knowledge of statistics, but depended upon their company's normal approach to quality control in order to test for the required attributes. It was at this point that the "Parts Specification Management for Reliability", better known as the "Darnell Report", was issued. The Darnell Report indicated awareness of relays in that it used 10,000 operations as the base instead of 1,000 hours. Thus it indicated clearly that relays were to be treated differently, and that time was not the critical factor affecting failures. Unfortunately it did not go far enough in indicating the failure mechanism differences between electronic component parts and electromechanical parts, such as relays.

Upon the initiation of an investigation into the mechanisms of failure of the most widely used relay types, it became evident that the standard military specification test procedures were not adequate for isolating the most critical difficulties. It was found desirable to judge each relay on its own merits and therefore a 100% screening test was deemed mandatory. The most satisfactory new approach to relay evaluation would appear to be to study the degradation of characteristics as a result of various environmental exposures. The first efforts in the utilization of degradation as the basis of predicting future failures were to determine the necessary test procedures. First, gaseous contamination from the coil was stimulated by placing the relay in a chamber whose ambient was that of the maximum temperature rating of the relay. The coil was then energized with maximum rated voltage or current. The relay was then cycled for 3,000 operations, to highlight deterioration of electrical characteristics. The next area of observed difficulties was at minimum rated temperature. Failure modes caused by different contraction rates of adjacent materials could be isolated by the application of minimum rated voltage or current. Cycling at this minimum temperature amplifies difficulties that might exist in the normal

operation of the relay and the method was found to be most revealing. The next exposure chosen was a simple run-in, with contacts monitored for each operation. After the prior high-temperature and low-temperature exposures, this test was found to be more sensitive to failure mechanisms than if it were done without this prior conditioning.

At the start of the test program, various parameters are measured; after each exposure these measurements are repeated and the changes noted. Relays having parameter changes greater than that allowable are rejected. The outcome of this investigation is the specification given as Appendix I in the paper. This specification covers the procedure for screening relays to remove those units which will not exhibit normal life expectancy. It is applicable to miniaturized, hermetically-sealed, electromagnetic relays with contact ratings up to and including 2 amperes at 28 VDC, resistive load. (Authors in part)

REVIEW: This is a very interesting and instructive paper and should be required reading for all reliability engineers who are concerned with relays. The evaluation of relays by the study of the degradation of characteristics in different environments is a very sound technique, which has already been applied, with success, to other components. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Productivity rating and reliability index

AUTHOR: J. A. Baker, General Electric Company, Schenectady, New York

SOURCE: ISA Journal, vol. 10, September, 1963, pp. 60-64

PURPOSE: To present a planned approach to instrument maintenance.

ABSTRACT: In order to spend time and money optimally on the maintenance of instruments useful in manufacturing processes and elsewhere, there must be a system for allotting this time and money. It should be based on how unreliable the instrument is, and how critical it is to the process. The greater either of these is, the more the attention that should be given to the instrument. A numerical reliability index is derived for each instrument (regardless of its application) by means of a rating chart. The headings are: age, environment, duty, visual inspection and electrical tests. These areas should all be evaluated by competent instrument-maintenance people. The criticalness of the instrument is rated by the maximum allowable time out of service. These times might be A: 1 hour, B: 1 day, and C: 2 days. From these ratings a maintenance priority is generated. (An example is given.)

REVIEW: This method of allocation of maintenance is certainly worth considering, especially by those who use only the hit and miss approach. There are probably other equally good methods, and these should not be abandoned without careful consideration. There is not enough information in the article for a novice to intelligently apply the system, but the author restricts its use to experienced personnel anyway. For another paper in this topic area see Abstract and Review Serial Number 1092. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: New tests for steel structures insure fracture-safe designs

AUTHOR: (Editorial Matter)

SOURCE: The Iron Age, vol. 192, August 22, 1963, pp. 63-65 (Reprint No. 427)

PURPOSE: To describe new tests that provide the designer of steel structures with information for eliminating fractures.

ABSTRACT: As the temperature of structural steel is reduced, its normally ductile behavior in the presence of stress raisers changes to brittle behavior. Every year there are many costly failures of this sort. The basic piece of information needed is the nil-ductility transition temperature (NDTT). The test for this has been refined to the point where it is very reproducible. The procedure, devised at the U. S. Naval Research Laboratory, uses a fracture-analysis diagram. Details on the use of the fracture-analysis diagram are found in NRL Report 5920.

REVIEW: This is a very important subject for designers of structures. The problem achieved prominent notoriety by the cracking in two of ships during World War II. This particular article deals only with the test for NDTT, not the design aspects. ##

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Serial Number 1091
Code 814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The cost of quality is highest--when you don't have it

AUTHOR: H. F. Jones

SOURCE: The Iron Age, vol. 192, August 29, 1963, pp. 66-68 (Reprint No. 430)

PURPOSE: To show that high reliability can actually make money for the manufacturer.

ABSTRACT: The automotive industry has increased its warranty to cover a much longer period than before. As experience is gained with the programs, the total cost of the warranty has been decreasing. This is due in large measure to emphasis on quality/reliability from the top down. Chrysler Corporation notes that its employees are proud to be making a car with a 50,000 mile/5 year guarantee.

It is lack of quality that is expensive, because the dissatisfied customer goes elsewhere. The good warranties are also helpful in bringing people into automobile sales rooms.

REVIEW: Good, meaningful warranties (as opposed to misleading advertising claims) are very worthwhile. They require an investment in machinery and design that is expensive to begin with, but can pay off. This article demonstrates that high reliability and long life can be of vital concern to non-defense consumer industries.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Punched cards put maintenance under tight cost controls

AUTHOR: T. M. Rohan

SOURCE: The Iron Age, vol. 192, September 5, 1963, pp. 41-42

PURPOSE: To show how to cut the costs of maintenance.

ABSTRACT: By using punched cards for the input information, a maintenance system can be set up that will improve the reliability of machines and reduce the costs of the maintenance work. Much more information can be handled by a computer than by a manual system. Scheduled maintenance is initiated by issuing a card in advance which serves as a job ticket; there is a space for comments by the serviceman. The ability to easily analyze a great deal of information produces useful results in reducing equipment failures. (Sources of information are given.)

REVIEW: A good maintenance program can save more than it costs. The type of program described here may well fall in this category. Machine weaknesses uncovered by this technique should be reported to the manufacturer so that reliability of future machines can be further increased. For another paper in this topic area see Abstract and Review Serial Number 1089. ##

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Serial Number 1093
Codes 711;775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Metals 'sound off' on fatigue

AUTHOR: W. N. Redstreake, Automation Editor

SOURCE: The Iron Age, vol. 192, September 19, 1963, pp. 97-99 (Reprint Number 438)

PURPOSE: To describe some of the acoustic emissions of metals in fatigue.

ABSTRACT: The crystalline structure of metals emits high frequency "sound" when it is stressed in fatigue. The testing machines must be very quiet and well shielded from external noise. Machines have a cycle rate of less than 1 cycle/hour--a distinct disadvantage. The ultrasonic emissions come from the surface and are believed to be related to the slip phenomenon that occurs in fatigue.

REVIEW: This paper reviews for the layman some of the basic work being done in this field. While there is no material of direct use to designers, this is an important subject in design and an awareness of it is worthwhile. ##

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Serial Number 1094
Code 711

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Peening adds life to gears

AUTHOR: (Editorial Matter)

SOURCE: The Iron Age, vol. 192, September 26, 1963, pp. 142-143

PURPOSE: To describe the process at Ford Sterling Parts Plant for shot peening rear axle gears.

ABSTRACT: The shot peening process increases the life of gears by a factor of three on an accelerated test. It is done after the phosphate coating operation, and some of this coating is driven into the metal. The shot peening is done as the final mechanical operation on the gears before assembly. (The article describes the machines and the handling of materials for them.)

REVIEW: This is an example in which shot peening improves the wear life of parts. Such is not always the case. Before shot peening is used in an effort to increase the wear or fatigue life of a part, a careful study of the residual and operating stresses should be made. ##

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Serial Number 1095
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure mechanism in thin films may work as transducer

AUTHOR: Robert Cushman (Summary of a paper given by J. J. Wortman and R. M. Burger, Research Triangle Institute, Durham, North Carolina at the Symposium on the Physics of Failure in Electronics, IIT Research Institute, Chicago, Illinois, September, 1963)

SOURCE: Electronic Design, vol. 11, October 25, 1963, pp. 14, 15, 21

PURPOSE: To show how a thin film "capacitor" can behave.

ABSTRACT: A metal-dielectric-metal thin-film structure can show unusual properties. It can act as a fuel cell using oxygen from the air and consuming one electrode (aluminum). This could be both a source of failure in parts not intended for fuel cell use and a possible application of the device. The dielectric is a 150A.-thick aluminum oxide layer grown on an aluminum electrode. The top electrode is thin evaporated gold. The possible ramifications of this effect are discussed.

REVIEW: This is an interesting possible failure mechanism. Further effort should be devoted to finding out how much of a threat it really is. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Systems engineering--a major new technology

AUTHOR: Donald S. Feigenbaum, International Systems Company

SOURCE: Industrial Quality Contol, vol. 20, September, 1963, pp. 9-13 (presented at the 17th Annual ASQC Convention, Sherman House, Chicago, Illinois, May 20-21-22, 1963)

This paper is the same as the one covered by Abstract and Review Serial Number 1008. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Vendor rating for missile reliability

AUTHORS: Harold L. Gilmore and Laurent Paquin, Avco Corporation, Wilmington, Massachusetts

SOURCE: Industrial Quality Control, vol. 20, September, 1963, pp. 13-16 (presented to the Mid-Hudson Section, ASQC, Poughkeepsie, New York, September 11, 1962)

PURPOSE: To present the Avco vendor rating system and an evaluation of it; to indicate the need for such a system, and its value to management.

ABSTRACT: The research and development division of the Avco Corporation is primarily known for its success in the development of the re-entry vehicle utilized in the Titan and Minuteman programs. This work has involved the development of a structural housing as well as sophisticated electromechanical components utilized in the arming and fuzing systems. Due to the high reliability requirements in this business, it became essential to have effective vendor control. Some of the major factors involved in the decision to establish a vendor rating system are: (1) most of the materials and parts are purchased from outside vendors, (2) the equipment specifications call for a high degree of reliability, and (3) most of the components are extremely expensive and non-standard items.

The vendor quality rating system is based on the percentage of discrepant items supplied by vendors. It provides a rating figure indicating the level of quality that a particular vendor may be expected to produce on a specific part, as well as a rating figure which indicates his overall quality. The essentials of the operation of the system are given in the paper. Typical report forms and quality trend charts are illustrated. An evaluation of the system indicates that it is accomplishing its purpose. (Authors in part)

REVIEW: This is a clear and concise description of a vendor rating program which is performing well for one company. Clearly such a program can make a significant contribution to system reliability. The ideas presented are worth the attention and consideration of those concerned with the procurement of components for which high reliability is mandatory. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Cost aspects of reliability

AUTHOR: Hauw T. Go, Transitron Electronic Corporation

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, August, 1963, pp. 6-7

PURPOSE: To show the functional relationship between component testing cost and reliability level in order to convey an understanding of the cost aspect of reliability.

ABSTRACT: Reliability is usually specified in terms of the failure rate and the confidence level associated with it, the test condition, and the definition of failure. Reliability verification is accomplished by production testing, and the total testing cost can be considered to be the sum of the costs of the tests. A functional relationship is given to show that testing cost can be minimized, except where one test influences another, by arranging the test sequence in order of decreasing cost-to-yield ratio.

Power pre-aging or burn-in is used as an example to show the relationship between reliability and cost per unit.

REVIEW: The author clearly illustrates that demonstrated high reliability and high cost per unit are rather directly related. It should be emphasized that the costs with which he is concerned are those related to the proving of the reliability level (stated to be directly proportional to the needed sample size). A proper perspective in these matters will be an asset to the buyer of components.

In the summarized expression for Test Cost there is a minor error. The product within the sum should be taken over the range from 1 to i-1, and could be expressed in the form $\prod_{j=1}^{i-1} Y_j$. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: What about burn-in?

AUTHOR: Lawrence F. Jones, Westinghouse Semiconductor Division

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, August, 1963, pp. 10-11

PURPOSE: To show how burn-in can be an effective method of improving component reliability when the failure rate decreases with time.

ABSTRACT: Operation of electronic components under simulated application conditions is called burn-in. It is performed in order to detect components which fail early in their expected life. If the failure rate is constant, then the burn-in doesn't accomplish anything; the same percentage of units will fail in each time interval even if burn-in were not used. If the failure rate decreases with time, burn-in weeds out the units that fail during the period of highest failure rate, and the resulting failure rate is lower.

The difficulty in determining the burn-in period to apply to a specific device results from the fact that devices vary in their failure rate pattern. The failure rate pattern for a given device may also change with changes in process or changes in screening tests, and the specific failure rate pattern for a given device is generally not known until a relatively large amount of life test data has been taken.

The Weibull is one statistical distribution which can characterize situations involving a decreasing failure rate. In this distribution the shape parameter (β) indicates the increasing or decreasing nature of the failure rate. If β equals one, the failure rate is constant with time (a case represented by the exponential distribution). If β is less than one the failure rate decreases with time, and if β is greater than one the failure rate increases with time. The smaller the value of β, the faster the failure rate decreases.

The faster the failure rate decreases, the more useful burn-in is in reducing component failure. Tables of failures for burn-in time are given for β=0.5, a typical distribution for semiconductor products, and β=0.1, an extreme example. Burn-in specifications are discussed briefly with the recommendation that the manufacturer perform the tests. (Author in part)

REVIEW: The article is clearly written with good illustrations which aid in understanding the nature and usefulness of burn-in. ##

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Codes 771;844;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Using accelerated testing to evaluate semiconductors

AUTHOR: Bernard Reich, U. S. Army Electronics Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, August, 1963, pp. 12-13

PURPOSE: To show the value of accelerated testing as a reliability tool, and to indicate what one should look for in interpreting test data.

ABSTRACT: Improvements in the reliability of semiconductors make it exceedingly difficult to determine life characteristics of these devices without large numbers of test samples or long test times. Therefore severe tests are required to stress the devices so as to produce significant numbers of failures with small sample sizes. The results must then be interpreted to predict the device behavior under normal conditions.

As an example of accelerated testing, the application of temperature and power stresses is presented and various methods are discussed. The typical results of accelerated life tests are analyzed where power-and temperature-based tests give discrepant predictions.

Some accelerated life tests are ineffective. An example is discussed in which the stress level in a silicon planar device is a step function with respect to time. Prior to the application of these tests and in analyzing the observed data some knowledge of the device design and construction must be available. (Author in part)

REVIEW: This article will give the purchaser or administrator an idea of what accelerated life testing involves. It must be kept clearly in mind that a major problem in the interpretation of the results of accelerated testing is that of drawing valid inferences concerning behavior under normal use conditions from data obtained under accelerated-stress conditions.

The absence of captions on the figures in the paper is a source of minor inconvenience to the reader. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Let's cut the doubletalk concerning reliability

AUTHOR: Everett E. Taylor, Filtors, Inc.

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, September, 1963, p. 2

PURPOSE: To advocate the establishment of a standard confidence level and standard test specifications in reliability engineering.

ABSTRACT: Reliability tests are usually made on a sample of the units in a set, and the confidence level specifies the percentage of the time that we expect the test results to be correct. Manufacturers can obtain artificially high reliability figures by using low confidence levels or by using low stress parameters in testing. The author advocates the use of a standard confidence level and standard test specifications, so that failure rates will mean something.

REVIEW: This is a short, clear, and pointedly-written paper with an important message. Most readers are already aware of the problem, but speaking out like this is necessary if any corrective action is to be stimulated. This is not to say, however, that the solution proposed by the author is necessarily the best one. Clearly a high reliability figure is meaningless if the degree of confidence associated with it is low. On the other hand, the demonstration of high reliability at a high level of confidence will in general be very expensive. It is necessary therefore to consider both sides of the picture, and to arrive at a suitable compromise between degree of confidence and cost. Sometimes one factor will be critical, while in other cases the other must receive prominent consideration. Thus the establishment of a single standard may not be the best answer. Something involving a small number of different standards for different clearly defined cases may be more appropriate. ##

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Serial Number 1102
Code 814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Adapting the materials control concept to the smaller company

AUTHOR: Carl Cooper, Consolidated Avionics Corporation

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, September, 1963, pp. 6-7

PURPOSE: To discuss the organization of product planning around an interdepartmental committee.

ABSTRACT: This paper describes a reorganization of procurement and product planning facilities around a total materials idea, which, together with worst case analysis sets guidelines for value analysis. Responsibility for planning a product's production is given to a committee composed of representatives from production, design engineering, and procurement. When an engineer has designed a product, the design is brought to the committee, and the representative of each department can then present for consideration modifications to improve reliability or reduce product cost. Various aspects of the approach are discussed briefly.

REVIEW: The idea presented is a straightforward method of coordinating design and production. The concept should exist naturally in small companies but a more formal organization may be necessary in large companies.

The author, in a private communication, has indicated that although the concept <u>should</u> exist naturally in small companies, his experience confirms the fact that it does not, and that purchasing personnel normally do not get involved until it is too late for value engineering. ##

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Serial Number 1103
Code 824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The best estimate of reliability in the exponential case

AUTHOR: E. L. Pugh, System Development Corporation, Santa Monica, California

SOURCE: SP-895/000/00, 7 pp., 20 July, 1962, System Development Corporation, Santa Monica, California (ASTIA Document No. 288790)

PURPOSE: To give an unbiased estimate of reliability.

ABSTRACT: Estimates of reliability, R, are invariably too low. This may be caused by using biased estimates. The usual estimator for true mean life, $\hat{\theta} = T/n$, where T is total operating time and n is number of failures, is unbiased but gives biased estimates of R.

The minimum variance unbiased estimate of R is

$$R^* = (1-t_m/T)^{n-1}, \quad T > t_m$$
$$= 0 \qquad\qquad , \quad T \leq t_m,$$

where t_m is mission time. The derivation is outlined in the paper.

REVIEW: This is an interesting piece of mathematics, and may have useful application. Note that for n = 1, $R^* = 1$ or 0, so that the formula is not of much help in that case. Also there is an implicit restriction as to the type of test; the test implied is that of fixed $n \geq 1$ with T the random variable. It would be interesting to evaluate the unbiased estimate of R for fixed T and variable n.

It should be noted that formula (15) for R^* in the paper is not complete. The complete form is given in the above abstract. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Element reliability over a life history

AUTHOR: Howard L. Leve, Structural Mechanics Section, Missile and Space Systems Engineering, Douglas Aircraft Company, Inc., Santa Monica, California

SOURCE: Engineering Paper No. 1475, 5 pp., Missile and Space Systems Division, Douglas Aircraft Company, Inc., Santa Monica, California

PURPOSE: To show a model for which the reliability of an element over its history is the minimum value attained during that history.

ABSTRACT: Consider a bar element with random tensile strength τ and a probability density function $y(\tau)$. Reliability at time t is

$R(t) = \int_{S(t)}^{\infty} y(\tau)d\tau$, where $S(t)$ is the stress. Since this is true

for any t, it is true for the highest value of $S(t) = S_n$. Let

$R_n = \int_{S_n}^{\infty} y d\tau = R_L$, which is the lowest reliability for any time.

If R_{Li} is R_L for the i th stress history and if the probability

of occurrence of the i th history is p_i, then $R = \Sigma\, p_i R_{Li}$, where R is the reliability of the bar element with respect to a tensile mode of failure. The role of this result is shown in [1].

REFERENCE: [1] Leve, H. L. "Reliability Goals--The Effect of Dependency," Douglas Aircraft Company, Inc., Paper Number 1425, July 1962

REVIEW: It is difficult to evaluate the significance of this result in the absence of further information. For those who are not acquainted with mechanical failure, it should be pointed out that this result does not apply in the cases of fatigue or creep-rupture. ##

Serial Number 1105
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimizing reliability

AUTHOR: John C. Kemp, General Electric Company, Light Military Electronics Department, Advanced Electronics Center, Ithaca, New York

SOURCE: 7 pp., presented at the 1962 Western Electronic Show and Convention (WESCON), Los Angeles, California, August, 1962

PURPOSE: To show how to optimize the design of a majority voting unit.

ABSTRACT: The reliability of a digital computer is improved by increasing the reliability of its parts; each part may require a different approach depending upon the part function, its criticalness, and its original form. This paper is restricted to majority redundancy. Optimum reliability configuration is used in the paper to denote that configuration which gives the maximum improvement in reliability relative to a functionally equivalent nonredundant computer for the same mission time, environment, components, and roughly the same logic and circuit design. After a non-redundant computer has been mapped out, it is improved by redundancy where needed. The factor F, the ratio of the failure probability of the non-redundant part to that of the redundant part, is maximized subject to practical constraints. The six-element voter (three logic circuits feeding a net of three voters, with three outputs and three inputs) is used for the example. Let p be the failure probability of the logic element and q be that for the voting element. If p is held fixed, $q = 0$ for maximum F (F_{max}), but if q is fixed, there is a non-zero optimum value of p for F_{max}. For small p and q, $F_{max} \doteq 1/p$. Curves are shown from which values of p/q, F, and relative mission length (mission time/MTBF of individual voting circuit) can be related.

Some practical results are given. (Author in part)

REVIEW: It is not entirely clear what the author is trying to do in this paper. The variation in F is taken with respect to p for a fixed q. Since it is pointless (if not a violation of the assumptions) to increase p of a particular circuit, the author must mean something else. A reasonable guess might be that he is adjusting the amount of circuitry that goes with one voting element set; thus the p corresponding to a q does vary. The author is not at all explicit on this point. Apparently T/M_q is used to estimate q, although the author does not say so. This requires the "exponential" assumption (which is not made explicitly). The complexity multiplier is given with no explanation of what it means or how it is derived. Possibly the author can furnish the additional information for those who are interested. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Current management reliability objectives

AUTHOR: Lysle A. Wood, Boeing Company, Seattle, Washington

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 1-5 (Keynote address presented at the Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963; abstracted under the title "How to sell reliability" in Evaluation Engineering, vol. 2, March/April, 1963, pp. 22-23)

PURPOSE: To discuss the objectives for reliability at the general management level.

ABSTRACT: The attainment of a successful reliability program in an industrial operation demands leadership and coordination from the top levels of company management. General management is responsible for making decisions in three areas, viz. (1) cost analysis, (2) personnel direction, and (3) operations evaluation. For many products, overall reliability must be considered in terms of overall cost effectiveness. Cost analysis may be used to balance the cost of increased reliability against the cost of field support and/or the total cost of completing a given mission. Personnel direction affects reliability in three ways: through employee training, through employee motivation, and through operating policies. Management must provide all personnel with sound training and strong motivation to do reliable work, and these efforts must be supplemented by well planned and clearly defined operational policies and other directive type documents. Reliability improvements achieved by the above considerations will be transitory unless a sound operations evaluation program is implemented. The results of these evaluations will constitute a feedback that will provide information on the success of current reliability procedures and yield insights that may be used to improve these techniques.

An example of the above considerations may be found in the Boeing Company's work on the Minuteman Missile Program. In this case, a comparison of support costs versus improved reliability costs showed that large sums of money could be saved by increasing the reliability of the various components and subsystems of the Minuteman booster. Reliability improvements in a single high-population transistor have effected savings of approximately $2,000,00 per wing. The Boeing Company has appointed a Division Reliability Director and has established a Coordination Committee to determine which employee activities affect product reliability and to establish policies regulating and shaping these activities. The establishment and updating of these policies is aided by a strong operations evaluation program. The development of this

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

reliability program has necessitated expenditures of approximately half a million dollars per year by the Boeing Company.

The payoff from reliability research work lies in its successful application to project work. To insure this application, reliability program plans are submitted to the customer. These plans are divided into two sections. The "narrative" section summarizes the reliability resources available and their proposed application to the particular project. The "task plan" section is a detailed chronological breakdown of the project steps with accomplishment criteria clearly defined and scheduled. At present, it appears that the policies described above are adequate and that the traditional management practices of the aerospace industries are adaptable to reliability achievement.

REVIEW: This is a well considered statement of a means of developing reliability resources and applying them to customer needs. This paper will be of use to all management personnel concerned with reliability improvement. The author, in a private communication, has indicated that information on the degree to which the principles expressed in this paper have been implemented in practice is contained in the Reliability Program Plan for the Saturn Booster. The Boeing Document number is D5-11013. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability management -- a challenge

AUTHOR: W. Austin Davis, USAF Ballistic Systems Division, Norton AFB, California

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 6-9 (Address presented at the Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963)

PURPOSE: To discuss the importance of sound reliability management.

ABSTRACT: The development of reliability as a specialized field of endeavor has been spurred by the great dependence of our defense system upon electronic equipments. The technical developments in reliability programs began in 1952 but management aspects of reliability are younger still, where intensive effort began only in 1958. To aid in the establishment of sound reliability management, a Congressional committee made intensive investigations into the status of the nation's ballistic missile program and its reliability. An Ad Hoc Committee for Guided Missile Reliability was established by the Office of the Assistant Secretary of Defense for Research and Engineering. This group, combined with an additional study group investigating the ideas involved in the management of parts reliability specifications, established, in 1960, the acceptable criteria for organized contractor reliability programs.

The development of the U. S. ballistic missile defense capability in only eight years is a major achievement in research and industry-military cooperation. This program has provided a backlog of knowledge in both technical reliability and reliability management. The task facing management today is to achieve the most effective collation of this knowledge and experience and bring it to bear on current problems. Three general criteria for judging the effectiveness of reliability programs are:

(1) Be sure that essential reliability tasks and standards are integrated into all essential program elements, such as parts selection, budgeting, and the writing of specifications.

(2) Examine analytically and in detail all reliability operations, making certain that each operation is clearly defined and achieves the desired results.

(3) To avoid cumulative reliability problems, keep a close check on the "experience retention level" in company operation and maintain the operations evaluation feedback that is necessary to keep this factor at the highest possible level.

REVIEW: This is a general discussion of the nature of the reliability management problem, with brief historical asides and some now-standard criteria for evaluating reliability management practices.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Space -- a sound investment

AUTHOR: W. R. Kirchner, Liquid Rocket Plant, Aerojet-General Corporation, Sacramento, California

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 10-14 (Address presented at the Ninth National Symposium on Reliability and Quality Control, San Francisco, California, January, 1963)

PURPOSE: To indicate that the exploration of space represents a worthwhile investment of the taxpayer's money.

ABSTRACT: The cost of space exploration is now (1963) budgeted at 4.2 billion dollars annually and will probably reach 13.6 billion by the end of this decade. The customary justification given for this expenditure is based on the prestige and leadership demands of the cold war and the requirements for national defense. A more important contribution of the program is, and will continue to be, the increased pace of technological development that results from attempts to solve the highly complex problems associated with the conquest of space. The space program has already produced great advances in scientific and medical technology with the impact being most obvious in the case of the communications satellites. The possibility of increased ease of communication between the world's nations may lead to great breakdowns of the cultural barriers dividing the major civilizations. Medical science now seriously considers the possibility of modifying the physical nature of man to better suit him to the new space environment. The accelerated development in all areas of science and medicine will inevitably produce results beneficial to our entire society.

History shows that, previously, great technological advances have been brought about by a major war. This is now an obvious impossibility, for war would involve the annihilation of millions of people and the destruction of most of our civilization. Contrasted with this price, 13 billion dollars seems small indeed.

REVIEW: The point of this paper is well taken. It is the nature of man to attempt to do those things that are conceptually possible; the results of his efforts are generally of great value to society. The chief message for reliability personnel seems to center about the critical role which they play in the success of astronomically expensive and hazardous space missions. However, the paper is somewhat disorganized in its presentation, and its continuity could have been improved. ##

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Serial Number 1109
Codes 424;543;824;
831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A method for the statistical evaluation of small subsystem performance

AUTHORS: F. R. Decker and A. J. Welling, Minneapolis-Honeywell Regulator Company, Electronic Data Processing Division, Newton Highlands, Massachusetts

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 15-21 (presented at the Radio Fall Meeting of the E.I.A. Engineering Department, Toronto, Canada, November 12, 1962)

This paper is essentially the same as the one covered by Abstract and Review Serial Number 820. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Significance of large life testing programs

AUTHOR: R. A. O'Brien, Corning Electronics Divison, Corning Glass Works, Corning, New York

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 22-25

PURPOSE: To point out that one-time large-scale life tests have a continuing value.

ABSTRACT: In 1960, about 25,000 CYFR capacitors were put on life test and one year later another 25,000 were put on test. The 1000-hour results are presented in graphical form and an equation for adjusting the failure rate for dc voltage, temperature, and time is given. The most important factors which will maintain the significance of these tests in years to come are:

A. Process control and stability. This must include protection against any changes other than those thoroughly engineered and evaluated.

B. Maintenance of materials control at all times.

C. A continuing program of correlative acceptance life testing as a part of the procurement document. (Author in part)

REVIEW: The author makes good points with regard to proper quality control being the key to continued validity of extensive life tests. The question of revision of life data is not explicitly mentioned. The graphs for the 1000-hour tests for each of the two years are different (an improvement is shown); there is no indication of how this is taken into account. The acceleration formula is based on failure rates at 60% confidence (presumably for each set of conditions). Different values of the empirical parameters would probably be obtained if a criterion other than 60% confidence were used. If the life curves are valid, one would expect more than 60% confidence in the results. ##

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Serial Number 1111
Codes 813;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Benefits of the Titan II parts improvement program

AUTHOR: Donald G. Cummings, AC Spark Plug Division, General Motors Corporation, Milwaukee, Wisconsin

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 26-29 (presented to the Chicago Chapter of the PGRQC)

PURPOSE: To discuss the Titan II parts improvement program.

ABSTRACT: While the Minuteman parts improvement program has had wide publicity, that for the Titan II has not. The inertial guidance system had to have parts with 1/50 the failure rate used on the Thor. An analysis of the best available components, of better application, etc. showed that the manufacturer would have to improve his product substantially. The parts where an improvement would have the biggest impact (i.e., yielding the largest reduction in probability of failure for the smallest cost) were selected and the manufacturers were contacted. In this case they were asked to determine the proof required that the lower failure rate had been achieved. The manufacturers also accepted about 1/2 of the added cost. The program which was finally selected achieved 95% of the potential improvement at 60% of the cost of the possible program. The parts being improved are trim pots, crystal can relays, transistors, slip rings, torquemotors, blowers, wire-wound resistors, and motor tachometers. Improvements by a factor of 2 to 40 in failure rate have been obtained. This program is leading to new procurement documents, new methods of supplier selection, and new industry standards. Hopefully future parts will have better off-the-shelf reliability. This program has supplemented, not duplicated, the Minuteman one.

REVIEW: Any effective parts upgrading program is to be commended; the approach here--aimed at getting the most reliability improvement for the money--is certainly a good one. This is an interesting summary of AC Spark Plug's experience. (It may be noted that there is no such thing as _the_ Minuteman improvement program or _the_ Titan II program. For example, the one described here pertains explicitly to the Titan II inertial guidance system only.) ##

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Serial Number 1112
Codes 431;432;838;
882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Time to failure and availability of paralleled systems with repair

AUTHOR: D. P. Gaver, Jr., Department of Mathematics, Westinghouse Research Laboratories, Pittsburgh, Pennsylvania

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 30-38

PURPOSE: To discuss the time to failure and availability of redundant systems in which repair is permitted.

ABSTRACT: This paper discusses reliability properties of some simple paralleled or redundant systems, where repair is possible in case of failure. We are assuming here that a "failure" may always be instantly identified, and the appropriate steps taken. In certain problems such an assumption is not warranted. The "systems" discussed are composed of two identical "subsystems," e.g., computers, or radars, and the system is considered to be in a state of failure when, and only when, both subsystems are simultaneously in such a state. Such system design strategies have been proposed for various applications, but have received little analysis.

Two measures of reliability are discussed: (1) the time to system failure, measured from an instant at which both subsystems are operative, and (2) the long-run availability of the system, where the latter means the average fraction of the time during which the system is able to perform its function. Analysis is based on the assumption of "random" (Poisson-like) failure for the subsystems, and independent but otherwise arbitrarily distributed repair times. It is of some interest that several of the important operational measures deduced depend in detail upon the form of the distribution of repair times, as it is summarized in its Laplace transform, and not simply upon certain simple averages or moments of repair time. (Author)

REVIEW: This is a mathematical paper, and makes a contribution to the theory of systems employing redundancy. Its orientation relative to other work in the field is indicated; some 12 relevant references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the meaning of quantified maintainability

AUTHOR: Nicholas Maroulis, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: IEEE Transactions on Reliability, vol. R-12, June, 1963, pp. 39-48

This paper is essentially the same as the one covered by Abstract and Review Serial Number 130. ##

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Serial Number 1114
Codes 802;843

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: New reliability slide rule

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, March/April, 1963, p. 15

PURPOSE: To describe a slide rule for making calculations associated with the exponential distribution.

ABSTRACT: The four-inch circular rule has two faces for calculating various reliability parameters. Side A calculates:

1. Mean time to failure.
2. Reliability.
3. Hours of operation.

Side B calculates:

1. Mean time between failure lower bound (or the upper bound of failure rate) for selected confidence levels.
2. Total hours of test for various confidence levels.

Scales are provided for various discrete confidence levels from 50 to 99 percent. The slide rule also allows for computation involving failures from 0 to 100 for each of the confidence levels.

A handbook supplied with the slide rule discusses derivations and provides several examples.

REVIEW: In a private communication from the Aero Geo Astro Corporation, the suppliers of this slide rule, the following additional information is furnished. Side A has the relationship $R = \exp(-t/m)$ and side B the relationship $\text{Conf} = 1 - \sum_{c=o}^{r} (\mu^c e^{-\mu})/c!$, where t = time, m = MTBF, μ = expected number of failures, and r = observed number of failures. Side B is used to calculate the MTBF lower bound for selected confidence level given total hours of operation and r, and to calculate total hours of test for various confidence levels given lower bound for MTBF and r.

This rule may well be of help to those who must make the indicated calculations. In making estimates of a parameter where the observed random variable has only discrete values, such as r for fixed total hours of operation, it should be noted particularly that the confidence calculated from the equation is only a lower bound on the true confidence. While the rule can be used to make calculations other than those listed, care should be used to be sure that they are done properly--it is easy to do them incorrectly, and hence to draw wrong conclusions. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On reliability inference

AUTHOR: Edward L. Pugh, System Development Corporation, Santa Monica, California

SOURCE: SP-935/000/01, 15 pp., 5 November, 1962, System Development Corporation, Santa Monica, California (ASTIA Document No. 290092)

PURPOSE: To discuss reliability inferences of a more direct type than those based on an acceptance-rejection procedure: a best point estimate of reliability and a confidence relation.

ABSTRACT: Much of reliability inference has been based on the exponential distribution. This paper is concerned with a best point estimate of the reliability and a confidence relation, which are derived under (a) no assumption concerning the distribution of time to failure and (b) the assumption of an underlying Weibull distribution. In the results for (a) it is noted that the best estimate and the confidence statements seem overly conservative. This is because the magnitudes of the failure times are not taken into account in the inferences. To utilize this information, it is necessary to make some assumption regarding the distribution of time to failure. In (b) a Weibull distribution is assumed and an order statistic confidence relation is obtained. For the same example as in (a), it is found that the confidence value is much higher when the relation obtained in (b) is used. A sufficient confidence relation is then derived, and is found to be more sensitive to the particular form of the Weibull distribution (value of the shape parameter) than is the order statistic confidence relation. The relative merits of the two confidence relations are discussed. A best unbiased estimate of reliability is obtained and compared with other available estimates.

REVIEW: This is a mathematical paper which will be of more interest to the theorist than to the reliability engineer. It follows and in part extends the work of the earlier paper by the same author covered by Abstract and Review Serial Number 1103. ##

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Serial Number 1116
Codes 844;873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Microwave tube repair

AUTHOR: Joseph F. Hull, Electron Tube Division, Litton Industries, San Carlos, California

SOURCE: Microwaves, vol. 2, October, 1963, pp. 22-26, 59

PURPOSE: To discuss the benefits of microwave tube repair, including how to design tubes to prevent certain failures.

ABSTRACT: Greater emphasis on repairability, warranted life and similar practices that increase economic efficiency all lead to what will be the ultimate in microwave tube marketing: the sale of operating hours of tube life or kilowatt hours of microwave energy. The economic factors in a tube repair program are the initial cost of the tube, volume of production, costs of repair, and life of the repaired tube. To be worthwhile, tube repair must reduce the cost per hour of tube life. Advantages of tube repair include conservation of material and human resources, and improved tube design resulting from better feedback of failure information to the manufacturer.

Any tube type being considered for repair must include sufficient safety margins with respect to destructive limits so that the deterioration of any of the main components of the tube during life is insignificant. Any components that suffer unavoidable deterioration must be easily replaceable. During the repair program, a general pattern of component failure rate emerges.

In a tube that is well designed for repair, the main body must not contain any components that have a significant deterioration rate. Whenever a failure occurs in the main body of the tube, it is usually necessary to discard it and salvage the other components for the repair of other tubes. However, it is sometimes possible to design the entire tube body in sections so that any portion can be replaced in case of failure.

Failures involving tubes can be generally classified into two classes: equipment failures that result in tube failures and tube-based failures. Common equipment failures are (1) loss of cooling, (2) faulty electrical contact fingers at the r.f. output or d.c. input, and (3) accidental breakage due to handling. Typical failures within the tube are (1) arcing, (2) loss of vacuum, (3) loss of thermionic emission, (4) window failures, and (5) excessive wear of moving parts. Each of these problems is discussed, including design methods for its elimination. (Author in part)

REVIEW: This article is a good study of tube failure and repair which will be useful to persons using tubes or considering their repair. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of a single-degree-of-freedom mechanical system

AUTHOR: W. H. Bleuel, Jr., Endevco Corporation

SOURCE: IEEE Transactions on Aerospace, vol. AS-1, August, 1963 (Support Conference Proceedings), pp. 575-579 (presented at the International Conference on Aerospace Support, Washington, D. C., August, 1963)

PURPOSE: To present a method of approximating the inherent reliability of a system with a single degree of freedom.

ABSTRACT: A technique is developed to evaluate the reliability of a transducer which is a system with a single degree of freedom. The transfer function of the design is analyzed, a failure mode analysis is applied, and the relative frequency of occurrence of the modes is established from data and engineering judgment. The effect of the various failure modes on the transfer function is then approximated. The reliability can then be determined using a statistical technique.

In order to account for both mechanical and electrical failure modes, a model is developed which includes a failure mode of either type. The overall reliability is assumed to be the product of the electrical reliability and the mechanical reliability. An assumption in this model is that the electrical and mechanical failures are independent events. Also, the conditional failure rates are assumed to be constant during the useful part of the component's life.

The technique is restricted in accuracy to the accuracy of the transfer function approximation and the mechanical failure mode probabilities. (Author in part)

REVIEW: As stated in the conclusions, it is shown that the mechanical reliability can be estimated by evaluating the effect of mechanical failure modes on the transfer function of the product. However, it is assumed from the beginning that the overall reliability is the product of independent mechanical and electrical reliabilities, and nowhere in the paper is this assumption validated as is implied.

A more consistent use of analytical details would be appropriate. In the section "Mechanical Reliability" everything could be omitted except the first sentence and the last paragraph. The transfer function for the system is presented in analytical form and then graphed. Getting down to business, failure is defined in terms of the deviation from the graphed response. From there all analytical developments are assumed. ##

Serial Number 1118
Codes 782;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of modular assemblies

AUTHORS: R. E. Warr, J. Bozovich, and T. Andrews, General Electric Company, Ithaca, New York

SOURCE: WADD Technical Report 60-515, 39 pp., July, 1961, Directorate of Operational Support Engineering, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, Contract No. AF33(616)-6726, Project No. 4156, Task No. 40007 (ASTIA Document No. 267146)

PURPOSE: To report on an investigation of the reliability of modular assemblies by comparison with a group of similar parts (resistors, capacitors, etc.) assembled in a conventional manner.

ABSTRACT: The modular type assembly chosen for this investigation was the Tinkertoy stacked ceramic-wafer module originally conceived by the National Bureau of Standards and subsequently applied in military and commercial applications. A statistical comparison of the electronic reliability of a military equipment (AN/SSQ-23 sonobuoy) partially utilizing Tinkertoy type modules and an identical equipment utilizing conventional assembly methods has been performed. Modular and conventional parts have equivalent reliability, but there is conflicting evidence on which type of assembly has the best reliability under shock and vibration tests. The following theoretical considerations favor modular construction: (1) minimum amount of human labor involved in the construction, (2) uniformity of the design, (3) excellent compatibility of components, (4) complete encapsulation possible, (5) structural rigidity, and (6) excellent heat sink base. Possible negative factors that might lead to problems include (1) high heat dissipation per unit volume, and (2) increased number of connections.

For the sonobuoy discussed it is found that modular construction results in slightly increased cost and reliability. It is also concluded that conventional assembly methods presently have a cost advantage over modular assemblies. At high production levels this advantage disappears because the module construction method involves a minimum amount of human labor. As more manufacturing experience is gained, the advantage should be increasingly in favor of modular construction. (Authors in part)

REVIEW: This article is a reasonable attempt to compare modular construction with conventional construction. The conclusions reached are those which would be expected by reasoning based only upon the theoretical considerations. The statistical arguments contribute little because there is a lack of data, but the first author, in a private communication, has indicated that the general conclusions of the report are being supported through currently published micromodule and microelectronic life test data. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor switches: the best design for the worst case

AUTHORS: William Roehr and Dean Bailey, Motorola Semiconductor Products, Inc., Phoenix, Arizona

SOURCE: Electronic Design, vol. 11, August 16, 1963, pp. 52-59

PURPOSE: To demonstrate, with a worst-case design of a resistor-capacitor-transistor logic inverter circuit, the utility of new sets of characteristic curves that can be used with common design equations.

ABSTRACT: The characteristic curves used in the design are (1) collector-emitter saturation voltage as a function of base drive current and collector current, (2) base leakage current as a function of reverse bias voltage, (3) area of permissible load loci for latch-free operation, (4) total control charge as a function of base current, (5) temperature coefficients as functions of collector current, (6) current gain as a function of collector current and temperature which is necessary to compute the collector-emitter saturation voltage, and (7) the base-emitter voltage as a function of collector current. The worst-case conditions are (1) in the ON state, the transistor must be supplied with a sufficient base current to keep the transistor in saturation and thus maintain the specified output voltage, (2) in the OFF state, the transistor must be supplied a reverse bias voltage to maintain the transistor in cut-off, and (3) the maximum required load current must be available. A systematic design procedure is given, showing how each component is determined, basing the design upon a Motorola type 2N964A germanium mesa transistor and a type 1N3605 diode. (Authors in part)

REVIEW: This article is an excellent presentation of the design of a transistor circuit for worst-case conditions when adequate transistor characteristics are available. The curves given are limit curves which are not normally readily available from manufacturers. The effects of temperature variations are included in the design. Several minor mistakes were found in the paper. In Figure 1 the resistor from the transistor base to $+V_{BB}$ should be labeled R_B, and V_C should be V_{CC}. In Figure 2 the diode voltage is V_D and not V_{D_1}. The answer to the equation at the top of page 56 should be 0.2V, not 2V.

When using worst-case design, it must be remembered that the most reliable component does not always produce the most reliable system. In particular, the requirements on the rest of a system resulting from the worst-case design of a component may reduce the overall reliability of the system because more parts may be needed. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Sterilization -- an example of reliability improvement through monitoring

AUTHOR: William F. Jemison, Sandia Corporation, Albuquerque, New Mexico

SOURCE: 18 pp., presented at the AIEE Summer General Meeting, Denver, Colorado, June 17-22, 1962, AIEE Conference Paper No. CP62-1187 (SCDC 2602)

PURPOSE: To present a not-so-well known method of reliability improvement, known as "sterilization," which consists of sensing an unwanted or dangerous situation in a circuit and rendering the circuit impotent.

ABSTRACT: Monitoring may be subdivided into the four elements: (1) sensing, (2) discriminating, (3) decision, and (4) action. Most systems will accomplish (1) automatically; however, elements (2), (3), and (4) may be achieved either manually or automatically. If all steps are treated automatically, then the action taken will be the result of predetermined "programming" of the particular monitoring system involved. Sterilization is a type of fully automatic monitoring wherein an unwanted or potentially dangerous condition in the system is sensed and rendered impotent in a predetermined manner.

Three modes of operation may be associated with a given system or subsystem, viz. (1) early closing or short circuit, (2) satisfactory operation, and (3) late closings, delayed or zero output, and open circuiting. The probabilities of occurrence of these modes are denoted by π, P, and Q respectively. Frequently, reliability specifications on a given subsystem or component may be impossible or impractical to achieve unless some type of redundancy is used. In cases where both failure modes (1) and (3) are significant, series or parallel redundancy will decrease the probability of occurrence of one of these modes at the expense of increasing that of the other. Series-parallel and parallel-series grids will achieve reductions in the probabilities of both modes; however, the added expense, size and complexity of the resulting system is often undesirable. It is possible to achieve significant reliability gains by using dual channels (parallel redundancy) in combination with sterilization (a monitor in series with each active element).

The subscripts t, s, and m respectively are used to denote an active element in a system, an unmonitored system made up of one or more active elements, and a monitoring element in a monitored system. The following results are found to hold.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Dual-channel unmonitored system

$$\pi_s = 2\pi_t - \pi_t^2 \quad (1)$$

$$P_s = P_t^2 + 2P_tQ_t \quad (2)$$

$$Q_s = Q_t^2 \quad (3)$$

Clearly, this scheme reduces the probability of late or insufficient operation and approximately doubles the probability of early operation or short circuit.

Dual-channel system with monitor

$$P_{sm} = P_t^2(P_m + Q_m)^2 + 2P_t(P_m + Q_m)[\pi_m + P_m(\pi_t + Q_t) + Q_tQ_m]$$

$$= 1 - (\pi_{sm} + Q_{sm}) \quad (4)$$

$$\pi_{sm} = 2\pi_tQ_m - (\pi_tQ_m)^2 \doteq 2\pi_tQ_m \quad (5)$$

$$Q_{sm} = [\pi_m + P_m(\pi_t + Q_t) + Q_tQ_m]^2 \quad (6)$$

To illustrate the effectiveness of the sterilization technique, consider the following probability definitions and results.

Active Component	Monitor	Unmonitored System	Monitored System
$Q_t = 0.0084$	$Q_m = 0.0385$	$P_s = 0.9741$	$P_{sm} = 0.99806$
$\pi_t = 0.0130$	$\pi_m = 0.01$	$\pi_s = 0.0254$	$\pi_{sm} = 0.001$
$P_t = 0.9786$	$P_m = 0.9515$	$Q_s = 0.0001$	$Q_{sm} = 0.00094$

The introduction of the monitors into the dual-channel system produces a significant increase in the probability of successful operation of the system and reduces both the probability of early operation and the probability of late operation as compared to the single-channel unmonitored system, (π_t, Q_t). Q_{sm} is greater than Q_s but still significantly below the unmonitored single-channel value Q_t.

Graphical analysis of equation (4) for the above example shows that P_{sm} is most strongly influenced by Q_m. If $Q_m = 0$, then π_m

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can be as large as 0.13 and P_{sm} will still be greater than P_s.

The following general conclusions may be drawn.

(1) In a single-channel system, sterilization can be effective in controlling dangerous or highly undesirable outputs at the expense of no output at all.

(2) In a dual-channel system, sterilization can be effective in controlling dangerous or highly undesirable outputs and also yield a considerable bonus in increased reliability.

(3) A sterilized dual-channel system will usually not be as reliable as a series-parallel net but can be almost as reliable and can considerably reduce the weight of and space required for hardware.

(4) A sterilizing monitor does not have to be extremely reliable to be effective. (Author in part)

REVIEW: This paper contains a great deal of information concerning the application of redundancy techniques to reliability problems. The above abstract presents the central thesis of the paper and ignores the development of the more conventional redundancy techniques. Several examples are given in addition to the one presented in the abstract and a rather complete list of references is also presented. The techniques discussed should be very valuable in design problems where reliability, weight, and space are important. ##

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Serial Number 1121
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and redundancy considerations in selecting spacecraft batteries

AUTHORS: Joseph M. Sherfey and Klaus Johannsen, Goddard Space Flight Center, Greenbelt, Maryland

SOURCE: NASA Technical Note D-1452, 6 pp., October, 1962

PURPOSE: To give a mathematical approach to the problem of choosing a spacecraft storage battery configuration with maximum reliability.

ABSTRACT: One of the problems in designing a spacecraft power supply is the selection of a suitable configuration for the cells which form the electrical storage battery. The usual practice is to connect in series the number of cells necessary to obtain the desired voltage; two or more of the "strings" thus formed are then connected in parallel to form the battery. In some instances the number of parallel strings is dictated by system constraints or some extraneous consideration. In other cases, however, the designer is free to choose the number of strings, provided that he makes a suitable choice of cell capacity. This paper gives a mathematical approach to the problem of making an optimum choice of the number of strings, based on the following assumptions:

1. The probability (P) that a given string will survive at least to a given time (t) is independent of the size of the cells it contains, i.e, there is no inherent quality difference between large and small cells;
2. The several strings are independent in the sense that failure of one or more does not influence the expected lifetime of those remaining;
3. The total number of strings (n) includes a number (k) of redundant strings, and no more than k strings can fail without leading to immediate failure of the system.

The probability of system success is expressed as a sum of terms of a binomial distribution, and is plotted and tabulated as a function of P for various values of n and k. It is pointed out that a spacecraft battery may be designed either with the objective of a maximum probability of functioning for a given fixed time, or with that of a maximum expected lifetime. Whichever criterion is used, the tabulated data enable an optimum choice to be made among various cell configurations. (Authors in part)

REVIEW: This note is clearly and concisely written; it accomplishes its purpose. The utility of the method to designers will, as the authors have indicated, depend on the availability of adequate test results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A reliability model and analysis for Project Mercury -- 3-orbit manned and unmanned mission

AUTHORS: William Wolman and Fred Okano, National Aeronautics and Space Administration, Office of Manned Space Flight

SOURCE: NASA Technical Note D-1558, 24 pp., December, 1962

PURPOSE: To give the development of a mathematical model, data requirements, and other assumptions used in the reliability evaluation of the Project Mercury 3-orbit mission.

ABSTRACT: This paper describes a reliability study of the Project Mercury 3-orbit mission carried out by the National Aeronautics and Space Administration. The purpose of the study was to obtain overall estimates of reliability for the Mercury capsule and booster system for both the unmanned and manned missions, the inputs being test data on parts, components, and subsystems. It was also desired to highlight the areas of unreliability that exist in the system. The approach is general, and can be modified for application to other space systems.

The assumptions on which the study was based are stated in detail. The probability models used are described. The sources and types of data on which reliability estimates were based are indicated. A general probabilistic model described in an earlier paper (see Abstract and Review Serial Number 900) is extended to include the abort situations, and is related to the Mercury study. The method used in evaluating astronaut performance is described.

REVIEW: This is a good description of the steps taken to use available data to estimate the reliability of an actual system. As indicated in the ABSTRACT, the theoretical framework for the method was described earlier. The foreword which precedes the paper is a frank discussion of the limitations of the approach. An awareness of these shortcomings is important, but it must also be realized that there exists at present no better means of obtaining a quantitative estimate of the reliability of a complex system than the use of the concepts on which this analysis is based. ##

Serial Number 1123
Codes 824;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimating the reliability of automation systems from the results of tests of an incomplete apparatus structure

AUTHOR: S. M. Kuznetsov (Moscow)

SOURCE: Avtomatika i Telemekhanika, Vol. XXII, No. 8, pp. 1108-1116, Translation prepared by Translation Services Branch, Foreign Technology Division, Wright-Patterson Air Force Base, Ohio, FTD-TT-61-199, 21 Nov., 1961 (ASTIA Document No. 267715)

PURPOSE: To present a method of estimating the reliability of a system from the results of tests made on part of the system.

ABSTRACT: The estimation of the reliability of automation systems involves the testing of a large amount of apparatus. The volume of testing which can be done is limited by the capacity and availability of testing equipment. Systems consisting of a large number of complex and cumbersome units must be tested separately, and some of the units are often not tested at all. Under these conditions there is a need for a method of estimating the reliability of a system from the results of tests made on an incomplete apparatus structure.

Modern automation systems include a large number of monotypic elements, nodes, and moduli operating under approximately identical and close-to-optimum conditions. An expression for the probability of system failure is written, on the assumptions that the system consists of k different groups of monotypic elements operating independently and that the failure of any element causes system failure. An approximation for the estimation error is given. It is shown how the system reliability can be estimated by combining statistical and indirect analytical methods of estimating errors, when the system consists of groups of monotypic elements contained in tested and untested devices. The dependence of the error in the estimate on the structure of the system and the ratio of the volumes of the groups of elements contained in the tested and untested devices is established.

REVIEW: In this paper standard statistical techniques and simple assumptions are applied to an interesting problem in system reliability analysis. Unfortunately the readability of the paper is seriously marred by poor reproduction of most of the displayed equations.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: a major challenge to the buyer

AUTHOR: Wynn A. Gunderson, The Boeing Company, Aero-Space Division, Seattle, Washington

SOURCE: 8 pp., presented at Section Meeting, Phoenix Chapter, American Society for Quality Control, Phoenix, Arizona, April 13, 1963

PURPOSE: To describe reliability management in the Boeing Aero-Space Division, its relationship to materiel organization, and some of the challenges which it presents to the buyer.

ABSTRACT: An important facet of any program for achieving product reliability, and one to which insufficient attention has been paid, is the control of the activities of the buyer. This paper is concerned with the implementing of an effective reliability program within a procurement organization. The "Reliability Resources Development Plan" of the Boeing Aero-Space Division is described. A model task list for a purchasing organization is given, as follows:

1. Prepare organization procedures to comply with corporate reliability policy.
2. Establish and maintain an experience retention system.
3. Identify and list in an index discernible failure modes.
4. Revise and update supervisory position descriptions oriented to reliability.
5. Write suppliers reliability guide.
6. Develop an approved suppliers list.
7. Establish index for suppliers resources evaluation checklist.
8. Develop a reliability training and motivation lecture plan.
9. Establish and operate an operations evaluation and analysis system.
10. Issue status report on purchasing reliability tasks.

The accomplishment of tasks 2 and 3 in the above list are described. The steps taken to extend the reliability program to subcontractors' facilities are indicated. A Suppliers Reliability Guide issued by Boeing is described. Reference is made to a Parts and Material Accountability and Control system, a case study method of accumulating failure experiences, and the recruitment of competent personnel.

REVIEW: A statement made early in the paper to the effect that "little has been said about...reliability management" is easily challenged. However, the particular phase of management which is considered in the paper has received less attention than some others. The role of procurement in reliability is undoubtedly important, and this paper does a good job of calling attention to it. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The decision theory approach to complex experimentation

AUTHOR: M. O. Locks, Mathematics and Statistics Group, Rocketdyne, A Division of North American Aviation, Inc., Canoga Park, California

SOURCE: 7 pp., presented at the National Meetings of the Institute of Mathematical Statistics, Minneapolis, Minnesota, September, 1962

PURPOSE: To describe a model for estimating reliability from development tests which are performed on a system which is continuously being modified for reliability growth.

ABSTRACT: Consider a complex physical system which is being developed for some specialized purpose, required to be delivered with given reliability. The expense of and time required for evaluating the system prohibit sufficient repeated testing under nominal conditions for an objective reliability verification. Instead, development tests are ordinarily performed in blocks in which each test point is different, the effects of several variables are considered, and most of the environments are severe and introduce stresses beyond those encountered under normal operating conditions. A failure under this type of overstress is not always an indication of unreliability under nominal conditions. Nevertheless the data generated by the development test series are, apart from prior information, the only available knowledge about the reliability of the system.

This paper is a progress report on work performed to date in constructing a decision theoretic model for the analysis of the results of engineering experiments and sequential decision making related to the modification of complex equipment during development. Acceptance testing for fixed configurations, and the testing and redesigning of variable configurations are treated. A framework is provided for using the results of tests performed under a variety of environments for estimating reliability. (Author)

REVIEW: This is a brief mathematical paper. As the author has indicated, it is in the nature of an interim report, and further work on the approach remains to be done. ##

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Serial Number 1126
Codes 770;783;812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An evaluation of environmental testing

AUTHOR: John D. Losse, AC Spark Plug Division, General Motors, Department 40-30, Milwaukee 1, Wisconsin

SOURCE: Electronic Industries, vol. 22, July, 1963, pp. 70-72, 76

PURPOSE: To discuss the need for trained personnel, improved accuracy, and maintained standards as shown by the contemporary environmental testing programs.

ABSTRACT: The Environmental Test Industry's survival and expansion depends on continued demonstration to prove its worth to management in product development. To do so, it must meet these three objectives:

(1) To orient, train, and employ skilled engineers in this specialized field.

(2) To improve the overall accuracy of its recommendations.

(3) To establish and maintain standards current with today's technology. (Author)

REVIEW: A set of three objectives parallel to those given in this paper could be listed for almost any engineering field. The call for an environmental engineering degree is answered by the trend toward a general engineering degree rather than many specializations. The desire for standards is natural but in many fields standardization is made difficult by lack of basic understanding and diversity of applications. No comments have been made concerning the correlation of the simulated environment with the field environment, the accuracy of measurement in each, nor about the continuous review and updating of the standards as more field information is obtained. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Random-motion testing of electronic components

AUTHORS: Roland J. Ostrander and Richard H. Tuft, Mechanical & Environmental Equipment Eng., Quality Control & Test Section, Re-Entry Systems Department, Missile & Space Div., General Electric Co., Philadelphia, Pennsylvania

SOURCE: Electronic Industries, vol. 22, July, 1963, pp. 82-86

PURPOSE: To review methods of vibration testing and to show the usefulness of random-motion testing.

ABSTRACT: The object of vibration testing is to subject apparatus to a test environment that is as close as possible to the actual mechanical operating environment. In the past, random motion was not specified because it could not be effectively simulated. Plain sinusoidal vibration was the standard requirement. Now, random-motion generators have been developed and are used in testing. Random motion is usually obtained from a random-noise generator. Random noise by definition is an acoustical or electrical quantity whose instantaneous amplitudes occur as a function of time according to the normal (Gaussian) distribution or probability curve.

Filters are used to compensate for resonances within the vibration system. Some testing machines automatically adjust these filters for each test.

REVIEW: The article is a readable and informative review of random-motion vibration testing for someone who has had no experience in such testing. ##

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Serial Number 1128
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Diode resistance to nuclear radiation

AUTHORS: Alvin B. Kaufman and Richard C. Eckerman, Litton Systems, Inc., Guidance & Control Systems Division, 5500 Canoga Avenue, Woodland Hills, California

SOURCE: Electronic Industries, vol. 22, August, 1963, pp. 134-136, 138

PURPOSE: To discuss the effects of irradiating semiconductor diodes while they are energized.

ABSTRACT: Fifteen Pacific Semiconductors microdiode type PD-105 were irradiated in a nuclear reactor. Five of the diodes had constant forward current applied and five had continuous reverse voltage applied. The remaining five diodes were not energized until the integrated exposure had reached approximately 10^{15} nv_et and subsequently only long enough at any time to measure their characteristics. In the reactor used, this exposure is closely equal to the thermal flux (nv_ot) but the reporting in either figure is for a measurement of exposure, not as a damage criterion.

Test results show that the energization of silicon diodes, while subject to a nuclear exposure, increases, to a marked degree, degradation of performance when compared with on- and off-operated diodes. (Authors in part)

REVIEW: This is a good presentation of a simple, thorough experiment. It would have been useful to discuss the physical basis for the effects of irradiation. (Note: the unit nvt means neutrons/ cm^2.) ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improvements increase ceramic capacitor reliability

AUTHOR: Larry Nordquist, CDE Division, Federal Pacific Elec. Co., 50 Paris Street, Newark 1, New Jersey

SOURCE: Electronic Industries, vol. 22, September, 1963, pp. 76-80

PURPOSE: To discuss the improvements in ceramic capacitor reliability obtained by fluorination of the dielectric material and advanced encapsulation techniques.

ABSTRACT: The construction and classification of ceramic capacitors is reviewed. Ceramic capacitors are classed as general purpose, temperature-compensating, or precision. Common failure modes which come from manufacture are dielectric degradation, poor encapsulation, and material deficiencies. Control of these failures requires a combination of sound design practice and proper selection of compositions and materials.

A new fluorinated ceramic capacitor is capable of operating at 200°C. for 2000 hours. The form factor is a CK63 disc capacitor having a capacitance of 10,000 pf. Improvements are noted with fluoride additions to the dielectric barium titanate.

The fluoride materials react with both the crystalline structure and matrixes of the barium titanate complexes, altering their chemical composition. This additive acts in a manner similar to the trivalent and pentavalent additions, except that the single valence fluoride ion (F-) replaces oxygen in the crystal complex and reduces anion vacancy to a point where ion and proton migration is greatly restricted. As a result, the dielectric has a high resistance to electrochemical reduction and degradation.

Results are presented on a life test evaluation of a thousand capacitors having a fluorinated dielectric, silver leads, and glass encapsulation. Test conditions were maintained at 200°C and 500 v. to accelerate failure mechanisms. Failure rate calculations based on test conditions resulted in failure rates of 0.229%/K hrs. at 90% confidence level and 0.1189%/K hrs. at 60% confidence level. When considering this capacitor for operation at normal conditions of 250 v. and 85°C by using standard voltage and temperature accelerating factors, failure rates of 3.12%/10^9 hrs. at a 90% confidence level and 1.61%/10^9 hrs. at a 60% confidence level are established. (Author in part)

REVIEW: The paper is a well-written report on a well-engineered chemical development for ceramic capacitor manufacture. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Building reliability into space instruments

AUTHOR: Stuart C. Baker, Marshall Laboratories, Subsidiary of Marshall Industries, 3530 Torrance Boulevard, Torrance, California

SOURCE: Electronic Industries, vol. 22, October, 1963, pp. 98-101, 107

PURPOSE: To survey the approach a manufacturer should use to improve the reliability of instruments.

ABSTRACT: Reliability is often defined by the space scientist not just in terms of total instrument failure, but more significantly in terms of the stability of measurement accuracy over the mission duration. Five important avenues toward reliability are considered to be (1) proper electrical design, (2) proper mechanical design, (3) component evaluation, (4) workmanship to high standards, and (5) quality control.

Proper electrical circuit design includes a thorough analysis using the block diagram, intelligent choices of components, component derating, use of redundant components in special cases, and using a "worst-case" design. The extent to which worst-case design may be used to dictate increased stability is limited by items such as budget, schedule, weight, and power. A proper mechanical design means that the instrument meets the structural and thermal specifications, assembly can be done by experienced personnel, and the final instrument can be opened, after assembly, for change or rework without impairing reliability. The purpose of component evaluation is to identify and reject those components which could fail. Methods which have been successfully used to upgrade component reliability include (1) operational run-in at elevated temperatures under high power, (2) thermal cycling, (3) thermal shock, (4) mechanical shock and vibration, (5) mechanical shock at low and high temperatures, and (6) X-ray examination. Workmanship practices are established in an engineering group through the processes of hard experience and common sense. Lectures, training programs, blown-up diagrams, and qualified supervision are factors and devices which have been found successful in promoting excellence of workmanship. Quality control is exercised through the processes of vendor surveys, receiving inspection of incoming parts or components, component evaluation, certification of weld schedules, and in-process inspection of the completed flight unit. (Author in part)

REVIEW: Although the exact choice of the five "avenues" to reliability can be questioned, the paper clearly demonstrates that the reliability of manufactured equipment can be enhanced by a detailed study of the apparatus and its fabrication methods. ##

Serial Number 1131
Codes 833;838;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component reliability--a survey

AUTHOR: G. W. A. Dummer, Royal Radar Establishment, Malvern, Worcestershire (England)

SOURCE: British Communications & Electronics, vol. 10, pp. 434-437, June, 1963

PURPOSE: To present some recently compiled facts on the reliability of certain electronic circuit components.

ABSTRACT: Failure rate per thousand hours is the basis used for comparing reliability; the limitations of this basis are illustrated. Factual data for the reliability analysis is based upon operation of components in (1) submerged telephone cable amplifiers, (2) electronic telephone exchange equipment, (3) computers at room temperature, (4) civil airlines, (5) laboratory equipments, and (6) commercial radio and television equipments operated at room temperatures. Data and discussion are presented on the reliability of fixed resistors, variable resistors, fixed capacitors, connectors, cables and wires, relays, switches, and transformers and inductors.

Redundancy can play a valuable part in reliability improvement providing that careful consideration is given to the form in which redundancy is applied whether it be group redundancy, parallel redundancy, or standby redundancy. In parallel group redundancy the probability of failure can be reduced to as little as the product of the failures of the parallel units.

Techniques for reliability improvement are now generally known--stricter control of incoming raw materials, quality control during manufacture, cleaner working facilities, more thorough inspection, test techniques for weeding out 'rogues' and, of course, large scale testing. Gains in equipment reliability when using conventional good-quality components can be obtained by controlling temperature and humidity variations, and the influence of good equipment design together with component de-rating should not be overlooked. The evidence so far obtained points to an order of improved reliability over conventional components by the use of microcircuit techniques, and possibly two or more orders by the use of solid circuit techniques. (Author in part)

REVIEW: The article is a well-written and easily understood presentation of the reliabilities of some electronic components. The use of physical reasoning in comparing reliabilities of components is very good, and it should be understood that such reasoning must accompany all statistical comparisons. ##

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Serial Number 1132
Codes 831;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An integrated marine radar system

AUTHORS: A. Harrison and D. Chamberlain, Kelvin Hughes Division of S. Smith & Sons (England) Ltd., Dagenham, Essex

SOURCE: The Radio and Electronic Engineer (The Journal of the British Institution of Radio Engineers), vol. 26, pp. 157-172, August, 1963 (presented at a meeting of the Radar and Navigational Aids Group in London on 9th May 1962)

PURPOSE: To examine the duplication equipment in marine radar systems from a reliability point of view.

ABSTRACT: An introduction to statistical fault analysis is given. The binomial expansion and Poisson distribution are discussed. The probability of successful operation of a series of individual units is given as the product of the probabilities of successful operation for each unit, whereas the probability of failure of a set of parallel units equals the product of the probabilities of failure for each unit.

Failures are classed as either minor or major. Minor failures are corrected on board ship; major failures require depot services. It is assumed that three hours are required for the repair of a minor failure and three hundred hours may elapse before depot services are available to correct a major fault. Assuming these time intervals, then simultaneous failures must be considered.

It is shown that it is more reliable to provide switching facilities for parallel operation of the transmitter and display units, which are least reliable, than to have two independent systems. Detail is given on the switching arrangement used and the assembly of the system.

REVIEW: The conclusion that, for the system considered in this paper, greater reliability is achieved by using fewer units and switching facilities than by duplicating the entire system is undoubtedly of considerable practical importance. It suggests that it might be worthwhile to look at other systems for which pertinent data are available from the same point of view.

The amount of expository material in this paper makes for rather tedious reading, and some of it might well have been abbreviated for publication in an engineering journal. However, the author in a private communication has indicated that much of this material was added at the request of the referee before publication, who possibly reasoned that what is a well-trodden path to the statistician is often unknown territory to the systems engineer. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability program

AUTHOR: J. E. Culbertson, Environmental and Reliability Test Laboratories, Western Electric Company, Winston-Salem, North Carolina

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 1-9

This paper gives a very brief introduction to the philosophy of management for reliability and discusses the EIA Reliability Program Guide for the Management of Firms Contracting for Electronic Products with the Armed Services. The Program Guide was covered by Abstract and Review Serial Number 580. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy and reliability

AUTHOR: W. E. Hansalik, Autonetics, a Division of North American Aviation, Inc.

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 10-20

PURPOSE: To evaluate methods of utilizing redundancy to improve logic system reliability.

ABSTRACT: An analysis of a logic system utilizing hypothetical "ultra-reliable" switching devices in conjunction with elements of ordinary reliability is presented. These switching devices are assumed to have unlimited life when not in operation. The analysis suggests that if sufficient redundancy is introduced, system mean life becomes dependent primarily on the reliability of these devices. An example indicates a system mean life 30 times that of the nonredundant system.

A comparison is made of mean times to failure (MTTF) for machines employing fixed majority logic (strongly connected), with those employing a form of adaptive majority logic (weakly connected). It is shown that MTTF is bounded for the strongly connected machine, but is a logarithmically increasing function of component duplication for weakly connected machines.

Determination of mean life of fault-masked systems and of Markov processes is discussed. Fault masking appears to improve short term reliability, but not system lifetime. Markov processes are reduced to linear flow graphs for the purpose of determining MTTF when failure modes are present.

REVIEW: The error correcting scheme proposed in the first section of the paper is insufficiently explained, and the analysis is based on a pyramid of assumptions which may be invalid in practice. The concept of a system based on one extremely reliable type of element is valid, but the resulting system appears overly complicated. The rather sketchy treatment in the paper leaves the advantage of the system open to question.

Taken as a whole, the paper is an exercise in determining mean lifetime of various system configurations. The conclusions presented are useful in the theoretical evaluation of the effect of redundancy techniques on system reliability. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Methodology for performance degradation analysis

AUTHORS: Sheldon Weisman and Bernard Tiger, Reliability and Maintainability Techniques, Radio Corporation of America, Camden, New Jersey

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 21-27, 205

PURPOSE: To present a procedure for performing circuit degradation analysis.

ABSTRACT: If the circuit transfer function is known, and if the part-degradation behaviors are known, then the probability of the circuit performance being out of specified limits can be calculated. In general, it is assumed that performance can be approximated by a linear function of the component values over the range in which they are expected to vary. If these variations are independent, small, uncorrelated, and normally distributed with known means and variances, then the performance variations are normally distributed and easily calculated. Several examples are given.

REVIEW: This is a good paper on the subject. By now this technique is reasonably well known, although at the time the paper was written (early 1962) it was much less so. The assumptions under which the derivation is valid are well stressed and should be kept in mind. In passing, it should be remarked that for engineering purposes many distributions can be approximated by the normal (Gaussian) when the 10% tails on either side are excluded. If only the 1% tails are excluded, the situation is greatly restricted. If only the 0.1% tails are excluded, the probabilities are rarely of use except for order of magnitude. Again, the authors are to be commended for placing so much emphasis on the conditions under which the analysis is valid. (The reference alluded to in the text is found on p. 205.) ##

Serial Number 1136
Codes 221;612;824;
837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of sequential sampling to Monte Carlo methods of reliability analysis

AUTHORS: G. H. Beatty and B. C. Spradlin, Battelle Memorial Institute

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 28-35

PURPOSE: To show how sequential sampling can be applied to Monte Carlo methods of network analysis for the purpose of demonstrating adequate reliability.

ABSTRACT: If a mathematical model for circuit performance is known, and the probability of part variation is known, the probability of the circuit performance being within tolerance can be calculated. A Monte Carlo method can be used to select a set of component values at random and then to calculate the performance. Each time the performance is calculated, another piece of information is obtained--the performance will be either good or bad. Thus standard sequential acceptance plans can be used for deciding whether to accept or reject the circuit design.

REVIEW: This is a simple explanation, with a reasonable amount of detail about the method. The procedure is quite satisfactory from a theoretical point of view. In many cases the cost of analysis will be worthwhile. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--a product of AGREE-3 testing

AUTHORS: R. L. Vander Hamm and R. L. Pollock, Collins Radio Company

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 37-40

PURPOSE: To describe an AGREE test program and the consequent improvement in the product.

ABSTRACT: This paper describes an AGREE-3 test program and results which substantiate the effectiveness of this test procedure to improve equipment reliability markedly. The test program was conducted on the AN/ARN-58, a completely transistorized airborne instrument landing system.

A preproduction test conducted on two units for 1800 hours each resulted in a mean-time-between-failures (MTBF) of 281 hours. Following corrective action on deficiencies demonstrated during the preproduction test, a production AGREE-3 test on seven units resulted in an MTBF of 742 hours. Facilities and costs associated with these tests also are discussed.

It is Collins firm opinion that the results of the AGREE-3 tests on the ARN-58, though quite dramatic, are typical of results that can be achieved through a similar program on any equipment, particularly new design. Experience has shown that any newly designed, complex electronic equipment will have part and design deficiencies undetectable except through a formal test program, such as AGREE-3 or extensive field operation. The advantage of determining these deficiencies for correction through preproduction and early production testing as opposed to failure analysis of field failures and corrective action is obvious. Equipment performance and reliability are sharply improved at an early point in equipment life, and over-all costs of maintenance and logistics are reduced drastically. (Authors)

REVIEW: This is a good plug for comprehensive, intelligent reliability testing with feedback during all development and production phases. The AGREE testing should be extended, where applicable, as suggested in this paper. Other papers on AGREE testing have been covered by Abstracts and Reviews Serial Numbers 16, 206, 505, and 1040. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation environments inside space vehicles

AUTHOR: Robert L. Daniels, Aeronutronic Division, Ford Motor Company

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 194-198

PURPOSE: To review the properties of space radiation and vehicle shielding, and to estimate the design importance of radiation fluxes.

ABSTRACT: The wide assortment of proposed radiation belts, space fluxes, and energy spectra which the space electronics engineer will probably encounter during this decade are amenable to a certain amount of systematic analysis. Much information concerning the radiation flux inside a space vehicle can be deduced by dividing the external flux into three energy groups.

Low energy particles (electrons less than 1 Mev, protons less than 15 Mev) comprise the bulk of many proposed distributions. Their detection difficulty leaves their flux to be a matter of speculation and extrapolation. Fortunately, however, their low energy is also insufficient to allow them either to penetrate a vehicle skin of normal thickness or to create significant amounts of secondary radiation. The effects of the Akasofu-Chapman belt of particles with energies less than 300 kev, for instance, may be summarily ignored. Medium energy particles are more easily measured in space. They are also most likely to contribute the largest primary and secondary fluxes inside the vehicle. Only the effects of direct penetration, secondary electron formation, and bremsstrahlung radiation, however, need be considered and methods for their calculation are well established. The largest flux contribution may, therefore, be computed with the greatest certainty. The effects of high energy particles are more difficult to analyze from the standpoints of both interior flux contribution and equipment damage. Their flux, however, is so small that their effects may usually be neglected in comparison with the computational and experimental uncertainties.

Calculating interior flux by adding the individual contributions of various overlapping radiation belts seems a logical method of obtaining a first approximation to the environment of electronic equipment operating in any explored region of space. (Author)

REVIEW: This is a good summary of much of the information a designer needs to know about radiation environments. It is wise to emphasize again that this type of information is subject to change as new evidence is received. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: K factors in quantitative reliability

AUTHOR: R. H. Hollis, Sanders Associates, Incorporated (95 Canal Street, Nashua, New Hampshire)

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 274-278

PURPOSE: To present the concept of using numerical factors representing manufacturers' actual capabilities in determining equipment failure-rate estimates on the basis of component data.

ABSTRACT: These factors of usage-maturity-relationships to "inherent" design--and relationships to specified determination of "inherent" reliability--should be considered as numerical factors in every proposal for reliable hardware. The numerical factors should be considered based on the bidder's past experience under ground rules of similar equipments. These factors should be considered just as much as Dunn & Bradstreet ratings, depressed area needs, and any other quantitative measure put on the bidder.

Parts vendors have to show the reliability of their products by past experience or by new tests. Weapons, weapon systems, designers and manufacturers should demonstrate in a similar quantitative manner their capability of assuring reliable products. The AGREE testing methods when stipulated are satisfactory; however, sometimes they can be too late and too expensive for use. Where AGREE testing is prohibitively expensive and time-consuming, the methods and factors mentioned should be stipulated. (Author)

REVIEW: Some more specific examples would have helped to make the paper more readable. It is somewhat difficult to be sure that you know exactly what the author is trying to say. In the time since this paper was written, the use of factors applied to failure rates to account for environment, etc. has become more common.

The author, in a private communication, has indicated that information which could have been used in compiling more examples was, at the time the paper was written, both classified and proprietary. He has also mentioned that factors of the type discussed in the paper are included in MIL-STD-756. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: To tell the truth: reliability engineering review

AUTHOR: William W. DeVille, Philco Corporation, A Subsidiary of Ford Motor Company, Western Development Laboratories, Palo Alto, California

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 279-285

PURPOSE: To give a brief summary of the philosophy and scheduling of the reliability program at Philco Corporation, Western Development Laboratories (WDL), and to illustrate it with three examples.

ABSTRACT: The WDL Reliability Organization is necessarily quite extensive--consisting of specialists in statistical, circuit, parts applications, thermal, and mechanical reliability engineering analysis--as well as many engineers engaged in the collection and analysis of data.

The WDL Reliability Assurance Department employs one group of engineering specialists, called the reliability engineering review activity, which spends full time reviewing the reliability programs, organization, and designs of WDL subcontractors.

The design review is an important part of the reliability program. The following three examples are described:

1. UHF satellite command receiver
2. TWT transmitter
3. Data link transmitter. (Author in part)

REVIEW: This is an interesting paper for those concerned with reliability reviews. The calculations on parallel redundancy are perhaps too abbreviated since they appear to be wrong. There seems to be the incorrect implication that a parallel circuit composed of elements with constant conditional failure rate (hazard function) will also have a constant hazard function. For the redundant situation, MTTF is not a good measure of reliability improvement for mission times less than the MTTF of one component. For example, the MTTF (calculated as in the paper) for a circuit consisting of two identical components in parallel is 3/2 that of the single component. Suppose for example that the component has a failure probability of 0.01 during mission time. The circuit consisting of two identical components in parallel has a failure probability of 1/100 that of the single component. Clearly the extent of this improvement is not reflected by the factor of 3/2 in MTTF. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Unit redundancy scheme for higher control system reliability

AUTHOR: A. S. Escobosa, Flight Control Engineering, Computers and Data Systems Division, Autonetics, Anaheim, California

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 286-292

PURPOSE: To present a method of fault masking operational amplifiers in analog systems.

ABSTRACT: Redundancy is achieved in an analog system by connecting three operational amplifiers in a parallel-type configuration to perform a single operation. The addition of a series resistance to isolate the output impedance of the high gain amplifiers permits satisfactory, uninterrupted functioning of the group in spite of failure of one or more of the operational amplifiers. This is a fault-masking or "shared responsibility" configuration which does not require switching mechanisms to remove or replace failed components.

Paralleled inverting amplifiers are analyzed for the case of no failure, for zero gain in one and in two amplifiers, for open input or feedback resistors, and for combinations of these failures. Loss of gain does not appreciably affect the group output, while opening one resistor causes, in the worst case, a 50% error (in the case of low-level inputs). Analysis also shows that the amplifier linear output voltage capability should be twice that required for the group output.

An expression for the reliability of the redundant system is developed, based on failure probabilities of the amplifiers and associated computing impedances. Failure probability of the redundant system is found to be less than that of a single operational amplifier. In the case of high-reliability parts, the failure probability of the redundant system is multiplied by about $6t/M_c$, where t/M_c is the failure probability of the computing components.

REVIEW: The redundancy scheme is valid under the assumptions given in the paper. This approach to the use of parallel-connected units is worthwhile and could be applied to other types of closed loop systems to achieve increased reliability.

The paper stops short of a complete analysis. Not considered in detail are:

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

1. The general case of unspecified input and feedback impedances.
2. Amplifier failure resulting in saturation rather than zero output.
3. Multiple input amplifiers.

Also, the reliability prediction for the redundant unit applies only under the assumed failure modes.

In equation (33) t should be replaced by t^2.

The material is well presented and the principles are easily understood. The method can readily be extended to other specific analog applications. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimation of component and system failure rates from test data

AUTHOR: Robert Mirsky, Aerospace Communications and Controls Division, Defense Electronic Products, Radio Corporation of America

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 293-296

PURPOSE: To show how to estimate MTBF from failure data.

ABSTRACT: Estimating the failure rate of extremely reliable components requires a statistical approach which is far more sensitive to small changes than the usual methods used in reliability analysis. In order to accurately estimate system performance based on test results, special techniques had to be developed for use with high reliability components. (Author)

It is assumed that time-to-failure has an exponential distribution.

REVIEW: The approach here is not that of classical statistics, with which the problem has been treated in detail. For example, the maximum likelihood estimate of the true MTBF, Θ is $\hat{\Theta}=T/r$, if it exists, where T is total satisfactory operating time and r is the number of failures. If the total time T is fixed and r is the test result, then r has the Poisson distribution. If the total number of failures is fixed and the total time T is the test result, then $2T/\Theta = \chi^2_{2r}$ where χ^2_{2r} has the chi-square distribution with 2r degrees of freedom. Confidence limits and the properties of these estimators are adequately presented in the literature.

The statistical foundation for the approach in this paper is inadequately explained. ##

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Serial Number 1143
Codes 770;851;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relationship of field reliability to reliability chamber test results

AUTHOR: R. H. Gauger, Hazeltine Electronics Division

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 297-309

PURPOSE: To report on comparisons between estimates of reliability obtained from the field and those obtained from in-plant tests.

ABSTRACT: Today the majority of contracts for new military electronic equipment contain definitive reliability requirements. In most cases, reliability testing is required, to demonstrate the equipment reliability before the equipment is delivered. The relationship of reliability demonstrated in the plant to that shown under operational field conditions is of particular importance to the customer, in addition to being of interest to the contractor. The system monitored was developed under a tri-service program and involved a total of 13 types of airborne, ground and surface equipments. Typically, each equipment consisted of three to eight "black boxes" or components. The complexity of each component or black box ranged from a typical 30-tube circuit for a receiver-transmitter to over 1,000 transistors for one of the newly designed components. The test environment was specified in the contract and was based on the test levels of AGREE task group 3, levels M, H, and X.

Field usage provided the final measure of the equipment reliability To determine this reliability, a well controlled maintenance and failure reporting system was established. This included indoctrination of all military and civilian personnel in the procedures for maintenance and failure reporting, establishment of Hazeltine personnel at the sites to monitor maintenance and failure reporting, control of all replacement parts, and inauguration of a detailed equipment logging procedure. The data from field and chamber tests were treated somewhat differently because of their nature (explained in the text). A factor K is the ratio of the estimated MTBF's from field data and test chamber data. The values of K ranged from about 1/2 to 2, depending on conditions (detailed results are given in the text). (Author in part)

REVIEW: These are interesting data and the agreement between field and test chamber results is remarkably good. This information is of importance in setting meaningful specifications. ##

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Serial Number 1144
Codes 710;720;770;
782;835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of welded electronic connections

AUTHOR: Mark Hurowitz, Sylvania Electric Products, Inc., Electronic Defense Laboratories

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 310-318

PURPOSE: To present results of tests on unprotected electronic welds.

ABSTRACT: This paper is essentially concerned with the most fundamental of three potential processing areas capable of introducing unreliability in any module: reliability in welded joints utilized for electrical connections between components for space technology and high strength electronic assemblies. Until we know how good such a joint is, how much strength is in its basic assembly, it is impossible to specify fundamental finishing treatments and appreciate potential applications.

The tests described in the paper were designed to answer the following questions: (1) What is the effect of current flow on a joint? Does it induce galvanic action or corrosion in the capillaries left by welding? (2) What is the effect of salt contamination on the material being welded? How clean must the leads be before welding? (3) When different metals are joined, is there any tendency toward corrosion? (4) Are there any adverse effects when operating in a high relative humidity?

The conclusions to be drawn from this series of tests are the following: (1) Salt contamination and/or high humidity have no appreciable effect on the joint strength or resistance of welded joints. However, microphotographs of the high-humidity salted samples have revealed extensive deterioration and corrosion in the base material. Component lead cleaning in solvent prior to use is sufficient, and subsequent handling with reasonable cleanliness will not affect weld life reliability. (2) Properly welded joints are reliable without protection from moisture; they should not suffer appreciable deterioration in the time scale and under the conditions encountered in these tests, provided they have been cleaned. Regarding subsequent finishing operations, these cannot yet be justified on the basis of joint deterioration. They may, however, be required for protection against people, the hardest environment of all to design against. (Author in part)

REVIEW: This is a good article on some of the problems in welding electronic components. Those who are vitally concerned in this area will find the article rather short; the author can probably furnish more information. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Product improvement

AUTHOR: E. W. Kimball, Martin Company

SOURCE: 1962 Conference Proceedings, 6th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1962, pp. 319-326

PURPOSE: To analyze the classes of causes for failure and to show how failures can be tracked down, explained, and corrected.

ABSTRACT: This paper suggests that product improvement can best be achieved by exhaustive analysis of failures which occur during environmental and field testing. The hardware in question has already been subjected to 100% inspection and functional testing at the unit, assembly and system level, so the great majority of workmanship defects have been eliminated. Failures of accepted equipment are the same ones which will cause abort of a tactical mission. The exact cause must be learned and corrective action taken. It must be stressed that comprehensive failure analysis on hardware returned from the field is essential for developing reliable military electronic equipment.

The chart below shows cumulative data from three years' experience on a major weapons system.

	In House	Field
Poor Workmanship	57%	15%
Design	4%	52%
Improper Operation	29%	17%
Handling	6%	9%
Unknown	4%	7%

(Author in part)

REVIEW: This is a basic article on some of the problems of failure and failure analysis. It is useful for drawing attention to those areas in need of it. ##

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Serial Number 1146
Codes 522;524;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Factorial experiments in environmental testing with factors applied sequentially

AUTHORS: R. R. Prairie and W. J. Zimmer, Sandia Corporation

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 9-15 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To discuss the role of factorial experiments in environmental testing in which the factors are applied sequentially.

ABSTRACT: Factorial experiments are used extensively in environmental testing when it is desired to determine the effect of a combination of factors on the response of a component. In such cases it is often impossible to apply the factor levels simultaneously, and they must be applied in sequence. The order of application becomes a matter of importance. In this paper a design and method of analysis for a 2x2 experiment is presented which allows the estimation of order effect as well as the usual main and interaction effects. Only experiments in which the low level of the environment is its absence are considered.

The design uses four units, each tested three times. Two units receive environment A followed by B, while the other two receive environment B followed by A. The first test made is for order effect, since the type of analysis used to estimate and test for environmental effects depends upon the information obtained regarding the order effect. The relative efficiency of the sequential factorial design as compared to the ordinary factorial design is indicated. A numerical example is given to illustrate the statistical analysis.

REVIEW: This paper accomplishes its purpose very well; the underlying assumptions and the details of the analysis are clearly presented. The approach described is of considerable importance in the field of environmental testing, since many situations arise in which it is necessary to apply the environments sequentially. The attention given to the determination of an order effect is in contrast to the approach in the paper covered by Abstract and Review Serial Number 204, which is also concerned with environments applied sequentially. In that paper, the author did not attempt to determine the effect of the particular ordering actually used. ##

Serial Number 1147
Codes 500;771

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical techniques for environmental testing

AUTHOR: Richard M. Jaeger, Philco Western Development Laboratories

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 55-60 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To give an outline of statistical techniques for environmental testing, with emphasis on the concepts underlying the statistical tools available to the environmental engineer.

ABSTRACT: Three basic phases in any effective environmental test are: planning, execution, and evaluation. Subdivisions of these phases are outlined. It is indicated that very often statistical considerations are overlooked at the test planning phase. This paper is a discussion of available statistical tools of which the environmental engineer should be aware. The topics covered include factorial and fractional factorial designs, accelerated life testing, response surfaces, sequential testing, data reduction and presentation, statistical model testing, inferential statistical analysis, and non-parametric tests.

REVIEW: In keeping with his objective of outlining some of the statistical techniques available to the environmental engineer, the author does not go into detail on the topics covered. His basic premise appears to be that the engineer need not have an extensive background in statistics or be able to apply the concepts, but that he should be aware that useful techniques exist. If this is to be the basis of a satisfactory working arrangement, competent statistical personnel must be available, and must communicate effectively with the engineers. ##

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Serial Number 1148
Codes 715;782;831;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Methods of predicting the performance of semiconductor electronic circuits and systems in a nuclear environment

AUHTOR: S. C. Rogers, Sandia Corporation

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 129-138 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To review briefly the effects of radiation on components, to discuss methods of determining the probability of failure as a function of radiation and the minimum radiation level at which a circuit or system may fail, and to indicate how good design practices can minimize the effects of radiation on semiconductor circuits.

ABSTRACT: The performance of electronic circuits and systems in a radiation environment can be determined if the radiation induced component changes are known and if system performance as a function of component changes can be determined. The most economical way of determining alterations of system performance caused by radiation combines analysis with an experimental technique intended for laboratory use. The analytical method requires that the performance of the system be expressed mathematically in terms of component performance. These equations are then solved using component parameters appropriate to discrete radiation levels. This approach also can be used to determine the probability of system failure as a function of radiation exposure. The experimental technique involves measuring system performance after substituting radiation degraded components into it. Although this latter technique only yields the radiation levels for zero and 100% probability of failure, it is a simple and powerful tool. Exposing a system to radiation in order to determine failure levels or failure probabilities is not practical because the large variations normally encountered in semiconductor device parameters may cause failure to occur over a large range of radiation exposure levels. Therefore, a few observations on a specific system are not a reasonable basis for predicting radiation performance of similar systems. (Author)

REVIEW: This is a good presentation of the advantages and limitations of the analytical and experimental methods of predicting the performance of circuits in a nuclear environment. The material is presented in a reasonable amount of detail, and nine pertinent references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Permanent radiation effects in semiconductor devices

AUTHOR: Robert S. Caldwell, The Boeing Company

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 145-151 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To summarize briefly the mechanisms for defect production in semiconductor devices when exposed to nuclear radiation, the resultant changes in the basic semiconductor properties, and the effects of such property changes on the operation of classes of semiconductor devices.

ABSTRACT: Most semiconductor devices have in common one important physical characteristic upon which their successful operation depends. This characteristic is the presence of a nearly perfect atomic lattice structure which does not exist to such a high degree of perfection in any other class of electronic parts or devices. It is for this reason that such devices are the most susceptible to permanent changes when exposed to nuclear radiation since such radiation particles generally produce defects in the lattice through various mechanisms.

Permanent changes result from elastic collisions between incoming particles and lattice nuclei in which sufficient energy is transmitted to the nucleus to move it out of its normal site. The mechanisms by which fast neutrons, heavy charged particles, high-energy electrons, gamma rays, and X rays produce lattice defects are described.

Effects on semiconductor properties include reduction of minority carrier lifetime, changes in conductivity, changes in carrier mobility, effects on the photoconductivity of photoelectric devices, and surface effects. Details are given regarding effects on diodes, photoelectric devices, transistors, field-effect transistors or tetrodes, and silicon controlled rectifiers. (Author in part)

REVIEW: For those who are interested in the mechanisms of the effects of nuclear radiation on semiconductor devices, this should be a useful paper. The material is presented in reasonable detail; illustrative graphs are included, and some 18 pertinent references are cited. ##

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Serial Number 1150
Codes 770;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Integrated Polaris environmental test program

AUTHOR: Tim B. Seman, Lockheed Missiles and Space Company

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 327-332 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To discuss the Polaris vehicle environmental ground test program.

ABSTRACT: The historical background of the development of the Polaris Fleet Ballistic Missile System is outlined. The nature of the environmental tests conducted early in the program is indicated. These consisted mainly of developmental and design confidence type tests. Some reliability testing on sub-components was sub-contracted to commercial laboratories. The schedule would not permit large quantities of specimens to be tested under the controlled conditions required to establish reliability factors. Qualification testing was instituted at the mid-program stage. The organization of an integrated ground test program is described. The objectives of the program include demonstration of ability to meet customer requirements, estimation of reliability, establishment of safety margins, and assessment of ability to meet specialized requirements. The environments taken into account include temperature extremes, vibration, low pressure, and humidity during transportation, and pre-launch pressurization, water immersion, flight altitude, shock, random vibration, acceleration, and high temperature during launch and flight. An example of a test plan is given. Brief reference is made to a Flight Confidence Test Program and to a revision of the Engineering Evaluation Test Program.

REVIEW: This is a concise description of an integrated environmental test program designed to obtain a maximum amount of usable data from a given amount of testing. Important considerations affecting the success of such programs are the availability of an adequate number of test items, and the cooperation and communication between all personnel involved. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability testing

AUTHOR: H. F. Eppenstein, The Boeing Company

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 549-552 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To suggest methods of improving the planning and control of reliability test programs.

ABSTRACT: The basic problem in reliability analysis is that of making accurate predictions. For this purpose testing is necessary, as it is for various other purposes related to the design, development, and fabrication of equipment. Much redundant effort could be eliminated by adequate communications between the groups doing testing. This could be accomplished by setting up a planned integrated test program which would make data available to all groups. A proposed method of doing this is illustrated with a matrix the rows of which correspond to the types of data desired while the columns correspond to the types of tests used in the program. The matrix is an allocation of the expected, necessary data at various hardware levels and test phases. Weighting factors are assigned to each test type on the basis of the environmental, operational, and hardware levels used during the test. These are used to obtain the percentage of desired information actually present in the test programs. Adjustments are then made to the planned data at the various hardware levels and testing phases, by reducing testing if the total is greater than 100 percent, increasing it if under 100 percent.

The ultimate goal is the design of an overall test program which will result in the minimum amount of data that can be economically used for prediction, measurement, and control of a product with a known degree of accuracy. The possible applicability of some results from game theory and decision theory to this problem is indicated. It is recommended that a joint government-industry committee be established to study the problem of efficient data acquisition in order to stop the spiraling costs of testing.

REVIEW: This paper is addressed to an important question: the finding of ways to increase the efficiency of the data-collection process in large programs. No doubt this problem has plagued many people, and it will not be easy to find a solution which is generally acceptable. The idea of setting up a government-industry committee to study it seems to be very worthwhile, and may represent the only real hope of achieving a solution. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation effects on capacitors and dielectric materials

AUTHOR: Donald J. Hamman, Battelle Memorial Institute

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 553-560 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To discuss the effects of nuclear radiation on dielectric materials and capacitors.

ABSTRACT: The effects of nuclear radiation on electrical insulators and insulation materials are both transient and permanent in nature. The effects vary widely, depending upon the composition of the insulator, the type of material (organic or inorganic), the type of radiation, the radiation-exposure rate, the total radiation exposure, and such environmental conditions as temperature and humidity. These factors are not independent of each other, and the effects caused by their interaction can be extremely complex.

The majority of experiments involving organic and inorganic insulating materials were designed to obtain radiation-damage information on structural characteristics, such as tensile strength, changes in crystal structure, capture cross section, extent of gas evolution, etc. These parameters are difficult to interpret in terms of dielectric qualities. However, a few experiments have been designed to study the effects of radiation on certain electronic components, such as ceramic and air-type capacitors and in essence provide some insight as to the effects of radiation on the electrical properties of dielectric materials. The important electrical properties of insulation materials are (1) dissipation factor, (2) loss factor or loss tangent, (3) dielectric strength, (4) volume resistivity, (5) surface resistivity, and (6) dielectric constant. Unfortunately, many of these electrical properties are difficult to measure under the radiation environment, and, hence, complete information is not available.

Several effects may take place when electrical insulation and insulators, of the organic and inorganic types, are exposed to nuclear radiation. These effects are often recognized as: gas evolution from organics, discoloration, changes in conductivity or insulative quality, embrittlement, softening or other changes in mechanical properties, increase in hygroscopicity, and formation of corrosive and toxic gases. Some of these effects may be either transient or permanent. Transient effects on the electrical properties of insulation are not linear with respect to radiation rate and are generally more pronounced than the permanent effects. The rate of recovery may be rapid or slow depending on material

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and environmental conditions after cessation of the radiation exposure. An insulator will often continue to provide insulation to electrical flow in a satisfactory manner, even though the mechanical properties are severely damaged, since its function infrequently involves mechanical strain.

The effects of nuclear radiation on organic insulation, inorganic insulation, and air are discussed. Effects on capacitors are considered for the following dielectric types: glass and vitreous enamel, mica, ceramic, paper, plastic, and electrolytic. (Author in part)

REVIEW: This is a fairly detailed discussion of the effects of nuclear radiation on dielectric materials and capacitors. It represents a collection of information from a wide variety of sources, as indicated by the bibliography of 19 items. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Achieving satellite reliability through environmental tests

AUTHOR: John C. New, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 561-574 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To discuss the role of environmental tests in the achievement of satellite reliability.

ABSTRACT: Following a general introduction in which the reliability problem for space systems is defined, this paper is concerned with the role of the environmental test program in achieving that reliability. Reliability must be designed into the system, and testing serves to evaluate the efficiency of the design. Testing can serve as a design tool, spotting design weaknesses and failure modes. However, the fact that spacecraft are generally unique systems of which only a very small number (two or three) are built means that there are no data based on experience with the system. The philosophy of the environmental test program is based on the concept of developing confidence that the spacecraft will perform successfully. The program consists of a realistic series of environmental exposures which simulate the mission profile and duplicate the space flight conditions as nearly as possible. Some aspects of the application of the test philosophy and details on a typical test program at the Goddard Space Flight Center are given. The importance of the human element in achieving satellite reliability is emphasized.

REVIEW: This paper is a clear exposition of the philosophy and operation of an environmental testing program for one-of-a-kind spacecraft. It is prefaced with introductory material including an elementary discussion of the reliability problem. An appendix contains summarized information on Goddard Space Flight Center Satellites and Space Probe Projects. These features make it a valuable paper for the orientation of the newcomer to the field. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The role of systems' environmental tests in authenticating design criteria

AUTHORS: R. J. Schreiber and E. L. Kritter, Raytheon Company

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 617-620 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To discuss the role of environmental testing of prototype systems in assessing the adequacy of design criteria.

ABSTRACT: Environmental testing of a prototype system must not only evaluate the performance of the system under environmental conditions, but must also assess the adequacy of those environment criteria which are influenced by the system design. External climatic environments based on intended use are usually clearly specified. However, those environments which are induced by operation of the system are dependent on system design. Thus it is system redesign which must alleviate any problems related to the induced environments. Such redesign is guided by environmental test data, which also serve to enhance future efforts in meeting system requirements and effecting cost savings.

The following phases in the evolution of environmental criteria are discussed: preliminary estimates, mock-up evaluation, instrumented flight tests, and environmental test programs. It is indicated that, in addition to design authentication, the test program can provide valuable human factors data and information on margins of safety in system performance.

REVIEW: This is a brief paper which discusses the important role which environmental testing at the system level can play in pointing the way toward appropriate redesign when such is required. It does not go into detail on the implementation of the ideas, nor are any references cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Van Allen radiation and effects on solar cells

AUTHOR: Joseph F. Weller, U. S. Naval Research Laboratory

SOURCE: Proceedings of the Institute of Environmental Sciences 1963 Annual Technical Meeting, Los Angeles, California, April, 1963, pp. 621-624 (Institute of Environmental Sciences, Post Office Box 191, Mt. Prospect, Illinois)

PURPOSE: To describe the radiation environment in space, to outline the basic mechanisms of radiation damage, and to summarize the results of radiation-damage experiments on solar cells.

ABSTRACT: Solar cells are among the more important components of a satellite because they provide the electrical power for the operation of the satellite's electronics. Because of their semiconductor properties, the cells are readily damaged by protons and electrons, and this damage is enhanced since they are surface-mounted and do not have the satellite skin to protect them. In the face of these problems, actual and potential measures to improve the radiation resistance of the solar cell system are described.

The space radiation environment considered includes the two Van Allen belts and a radiation belt created by a high-altitude nuclear explosion. The inner Van Allen belt consists mainly of protons, while the outer one is principally an electron belt. Upon coming into contact with solar cells, charged particles produce atomic displacements which result in changes in the minority carrier lifetime and its diffusion length, i.e., the time between the creation of a carrier and its recombination and the distance it travels during this time. Since solar cells use carrier diffusion across p-n junctions to provide current, limiting the number of carriers crossing the junction by having them recombine will result in a decrease in short-circuit current and power output of the cell. A significant discovery in radiation damage of solar cells has been the fact that n/p silicon cells are more radiation-resistant than p/n silicon cells. Relevant experimental results are summarized. Suggested measures to improve radiation resistance of solar cells include switching from p/n to n/p cells, increasing the purity of materials, and developing heavier atomic materials such as gallium arsenide. (Author in part)

REVIEW: This is a brief description of the effects of space radiation on solar cells, and an indication of steps which can be taken to deal with this problem which has an important bearing on the overall reliability of satellites. For those desiring more details, nine relevant references are cited. Other papers on the reliability of solar cells have been covered by Abstracts and Reviews Serial Numbers 651, 743, 764, and 775. ##

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Serial Number 1156
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effects of radiation on electronic components and materials

AUTHOR: W. E. Harrison, Jr., Air Arm Division, Westinghouse Defense Center, Baltimore, Maryland

SOURCE: Electrical Design News, vol. 8, November, 1963, pp. 54-59

PURPOSE: To summarize the available information concerning the effects of nuclear radiation on components and materials, and to develop a logical structure that would provide a basis for formulation of experimental work to expand knowledge in this field.

ABSTRACT: Order of magnitude estimation of lifetime in a radiation environment now can be made for many materials and components from existing radiation-effects data. Radiation data on the following are summarized in five charts:

(1) Radiation resistance of various types of materials.
(2) Approximate Van Allen belt radiation effects.
(3) Approximate limits of gamma investigations.
(4) Approximate limits of fast neutron investigations.
(5) Approximate limits of thermal neutron investigations.

Overall solar radiation is approximately 1.8 particles per sq cm per sec. These particles are mostly protons and electrons in the 75-mev range and higher.

Detailed data are given on the inner and outer Van Allen radiation belts.

REVIEW: This is a brief but useful summary of radiation environments and their effects on materials and components. It forms a good basis for further study starting with the references given in the paper. ##

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Serial Number 1157
Codes 782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Can RFI control prevent weapons failures?

AUTHOR: Richard J. Sanford, Advanced Engineering Division, U. S. Naval Ordnance Laboratory, White Oak, Maryland

SOURCE: Electronics, vol. 36, November 8, 1963, pp. 43-45

PURPOSE: To demonstrate how the control of radio frequency interference can prevent circuit failure.

ABSTRACT: Effects of electromagnetic radiation on weapons circuits has been considered after it was discovered that the unrestricted use of a number of our operational weapons in the vicinity of operating transmitting antennas impaired both the reliability and the safety of the weapons. Failure can occur in devices such as those the operation of which depends upon electrical heating of resistors which will be sensitive to radio frequency radiation heating.

The radio frequency equivalent circuit is given for a silicon controlled rectifier, and a silicon controlled rectifier filter is presented which protects against 32 volt rms signals between 100Kc and 30Mc.

REVIEW: This paper is a good illustration of the fact that shielding alone is not always sufficient to eliminate noise in a circuit; filters in the signal line may also be necessary. It is obviously important for high reliability that the intended environment (including RF fields) be well known. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Pessimistic circuit design

AUTHOR: N. A. Fruci, Development Laboratory, International Business Machines Corporation

SOURCE: Electro-Technology, vol. 72, October, 1963, pp. 74-78

PURPOSE: To describe the pessimistic method of circuit design.

ABSTRACT: The pessimistic method (a modified version of worst-case design) uses the end-of-life tolerance for the component which has the greatest effect on d.c. performance. All other components and parameters are taken to their initial tolerance using worst-case tolerance direction.

The input circuit to a common-emitter pnp transistor is used to demonstrate pessimistic design. Switching circuits with 10-, 20-, and 30-ma collector currents are designed, the transistor being the pessimistic component.

The switching circuits are analyzed statistically (Monte Carlo method) by assuming the circuit parameters to have either of two distributions: uniform and "fabricated" non-uniform. While the uniform distribution is simple to use, the fabricated non-uniform distribution gives a more realistic evaluation of the pessimistic design method. Curves are shown which give the fraction of the circuits expected to be "safer" than the pessimistic design.

REVIEW: A good analysis of a simple transistor circuit is presented in a well-written paper. For further study the reader will appreciate the bibliography which includes eleven entries. The behavior of the circuits is shown only for those which are "safer" than the bottom 10%. It would have been helpful to push this limit down to at least 1% if not further. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Checkups for combinational gates

AUTHOR: Karl Menger, Jr., Computation Laboratory, Harvard University, Cambridge, Massachusetts

SOURCE: IEEE Transactions on Aerospace, vol. AS-1, August, 1963 (Support Conference Proceedings), pp. 954-960 (presented at the International Conference on Aerospace Support, Washington, D. C., August, 1963)

PURPOSE: To present a shortcut method of checking for catastrophic failure of combinational gates.

ABSTRACT: It is assumed for the purpose of this paper that a given gate will fail only due to permanent shorting or opening of one or more of its inputs. Exhaustive analysis will show whether the gate has indeed failed, but a shortcut is presented so that only a "reasonably small" number of input combinations need be investigated. This results in knowledge of whether or not the gate is functioning properly, but it does not indicate which input or inputs are faulty, nor does it identify malfunctioning components. Hence the procedure is not diagnostic.

The author investigates a three-input majority gate, and shows that for gates with more than three inputs exhaustive analysis is impractical. The shortcut procedure gives a set of distinct input vertices. These are shown by the author's Theorem 1 to be a checkup. It is remarked that multiple failures may need to be considered as well as single failures, and that checkups may be considered as entities independent of the checked function.

Bounds are investigated, it being shown that for all M-place switching functions over all $M \geq 1$, there is no minimum checkup containing more than 2M of the possible 2^M inputs, and the shortcut does not yield a checkup with fewer than M + 1 tests.

It is claimed that this approach gives conservative results for single gates, and that for this purpose any tree system can be considered a single gate.

REVIEW: This is a useful shortcut to the testing of combinational gates, assuming that failures will be of the catastrophic type described by the author. It can be used to form a basis for self-monitoring circuitry, but not for that of the diagnostic and self-repairing type. The shortcut is very powerful, the presentation is quite lucid, and the examples are good. ##

Serial Number 1160
Codes 612;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Computer simulation model of large scale data communications systems

AUTHORS: H. R. Seltzer and E. W. Veitch, Surface Communications Division, Radio Corporation of America, Camden, New Jersey

SOURCE: IEEE Transactions on Aerospace, vol. AS-1, August, 1963 (Support Conference Proceedings), pp. 1446-1458 (presented at the International Conference on Aerospace Support, Washington, D. C., August, 1963)

PURPOSE: To show how systems modelling is done, and to describe how computer simulation is useful as an ancillary technique.

ABSTRACT: Objectives of simulation include determining the capability of the system and its subsystem components to meet its design objectives before testing the actual system, determining the effects of failures, and the capability of self-monitoring circuits to detect them and locate the failed element.

The computer simulation process is defined, the assumptions are listed, and notation is defined. Chief among the assumptions are that line switching is being simulated, the internodal relationships are fixed, and transmission speeds and delays are well delineated. The program is to easily accept changes in logical design, accept varieties of input pulse characteristics, be fast, simulate time delays, accept any arrangement of static and dynamic failures, and detect and locate spike or race condition occurrences.

A matrix is shown to detail the computer simulation process. The structure of the program is described, and the program procedure is also given in detail. An example of a simulation run is depicted, and simulation failure analysis is analyzed and discussed, with figures of merit. Noise effects can also be simulated.

The article concludes by giving various capabilities and advantages of the technique.

REVIEW: Computer simulation is a valuable aid to systems design. The authors have discussed this particular application in considerable detail, and make a good case for the method. The format is largely outlines and lists, which makes it very readable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Network coding for reliability

AUTHOR: John Tooley, Laboratory for Electronics, Inc., Boston, Massachusetts

SOURCE: AIEE Transactions, pt. I (Communications and Electronics), January, 1963, pp. 407-414

PURPOSE: To present a redundancy technique using error-correcting codes and new device design to gain more improvement in reliability for a given redundancy than is achieved by classical techniques.

ABSTRACT: Reliability is extremely important in systems which are inaccessible due to location, component density, etc. Improvement of component reliability does not offer an adequate answer to this increasingly important problem. Some other approaches have the disadvantage of excessively high redundancy ratios (the ratio of the number of devices in the redundant network to the number in the nonredundant network). The problem of how to improve reliability by coding is defined in terms of logical vectors. A binary adder is used to illustrate the notation, and is later made redundant. A model of the logical behavior of noisy devices is constructed using probabilities of occurrence of given outputs. (The author decomposes his model into two sections: a nonprobabilistic computing section, followed by a probabilistic noncomputing section.)

The method of solution is to map the outputs of the computing section onto disjoint "message" subsets at the output of the model, giving all members of the message subset the same meaning. To map with a desired low ambiguity, it is necessary to increase the dimensionality of the outputs. This introduces redundancy. The redundancy ratio is used as the measure. The binary adder is made redundant and analyzed. Noisy networks are cascaded and this method is used to improve their reliability. The paper closes with a discussion of the resulting improvement in reliability. An improvement factor is defined as the ratio of system error probability before and after coding. This factor is plotted against probability for various error-correcting codes, and as a function of fan-in. The gain in reliability improvement is obtained by making a trade-off between the number of redundant devices and the logical complexity per device. The technique appears to hold promise as a realistic means of reducing the redundancy required for a given degree of reliability improvement.

REVIEW: This is an interesting exposition of the coding approach to the improvement of reliability. The author uses a good example, and justifies his use of the technique. Plots of the improvement factor as a function of fan-in are particularly useful. ##

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Serial Number 1162
Codes 813;832;871

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Human factors, reliability and maintainability work together

AUTHOR: Vincent E. Quagliana, Human Factors Analyst, Sylvania Electronic Systems

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, November, 1963, p. 9

PURPOSE: To show the need for reliability groups to work with others in the overall interests of reliability and maintainability.

ABSTRACT: The main goal of the human factors engineer in maintainability and reliability is to reduce unnecessary and undesirable human performances that may affect the equipment performance. The final objective is an optimum relationship of personnel and equipment after consideration of all the recommended human factors, maintainability, and reliability aspects, and the purely hardware or electronic requirements.

An inclusive program is described and the advantages of developing an integrated human factors, maintainability, and reliability program are outlined. (Author)

REVIEW: The author says that humans are not naturally efficient and sometimes err. "Human engineering" is concerned with reducing these undesirable traits. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Pay-off of effective standardization overlooked by industry management

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, November, 1963, pp. 20-21

PURPOSE: To review the paper "The Broad Impact of Standardization" by Andrew Schultz, Jr. and talks by A. T. McPherson, G. R. Tatum, and W. W. Thomas presented at the Standards Engineers Society's Twelfth Annual Meeting.

ABSTRACT: The basic problem is to enjoin designer and manufacturing engineer to achieve a compromise between design performance and manufacturing economy. Three problem areas created by America's practice of voluntary standardization are national coordination, compliance with standards, and inadequate participation in international standards.

Standardization, in the economic sense, is an act which results in reducing diversity. Far too often standardization is after-the-fact activity to remedy diversity which is uneconomical. Standards should be introduced as part of the development and design process so that "the introduction of a standard involves only the incremental effort associated with a deeper design investigation."

In considering total costs and cost savings involved, Thomas drew five conclusions:

1. There is a possibility that standardization might increase total costs rather than reduce them.
2. The possibility of standardization costing more than it saves is diminished where the known or accurately predicted number of multiple uses of the part is increased.
3. The possibility of a loss in connection with additional use is diminished as the unit cost of the item increases.
4. The possibility of a loss is increased if standardization is considered for items evolving from a rapidly changing technology.
5. The possibility of a payoff is increased as the non-recurring costs for the item become a proportionately greater portion of the item's total unit cost. Conversely, as the non-recurring costs of an item become a smaller proportion of the unit cost, the possibility for uneconomic standardization is increased. (Author in part)

REVIEW: Item four in Thomas's conclusions brings out an important idea. In a rapidly changing technology (e.g., satellite design) standardization is difficult. Conversely, in a slowly-evolving technology (e.g., television manufacturing) standardization is easy. Consumer testing is the only sure way of testing product usefulness. Standardization can affect reliability by providing items of known rather than unknown characteristics.

In a private communication, Mr. Thomas (Radio Corporation of America, Defense Electronic Products, Camden 2, New Jersey) has enclosed a copy of his complete paper, entitled "Achieving the results of standardization without formal standards," and has indicated that additional copies are available in limited quantity. The paper is concerned with the optimization of diversity by means other than the formal standardizing process. The principles are equally applicable to military and industrial practices, and the paper should be worthwhile reading for designers and manufacturing engineers.

Dr. McPherson's complete paper, entitled "Standardization from the national viewpoint," is concerned with some of the problems that have arisen from the American practice of freedom of enterprise in standardization. For those who may wish to request copies, the author's address is National Bureau of Standards, Washington, D. C. ##

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Serial Number 1164
Code 810

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Make reliability meaningful

AUTHOR: F. J. Ruther, Reliability Manager, Hq. Air Force Logistics Command

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, November, 1963, p. 21

PURPOSE: To urge reliability specialists to speak in a language that management personnel can understand.

ABSTRACT: The jargon of reliability can be very difficult for management personnel to understand. If the manager does not understand the jargon used to describe the problem, it is completely unfair to fix the blame for inactivity upon the manager. The people that call themselves experts, and take great pleasure in surrounding their dealings with an aura of mystery, must shoulder the blame when the problem they profess to be so great is not actively pursued and solved. The expert, in order to be heard and to be understood, must speak in the language meaningful to the man that makes the decision. (Author in part)

REVIEW: The article is a reminder of that old but often forgotten lesson on the difficulties of communicating technical information to non-technical persons. ##

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Serial Number 1165
Codes 774;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Underwater testing aids solid-state reliability

AUTHOR: (Editorial Matter)

SOURCE: Electronics, vol. 36, October 25, 1963, pp. 93-94

PURPOSE: To describe the use of a water environment for a fast and accurate thermal cycling life test for silicon rectifier diodes.

ABSTRACT: Thermal fatigue is referred to as the deterioration of various parts due to the stresses encountered in the many high-low temperature excursions (thermal cycles) which results in a failure. A fast and accurate thermal cycling life test is needed to test silicon rectifier diodes. Series strings of diodes submerged in a controlled-temperature water bath are raised to maximum rated junction temperature in five seconds by a half-wave rectified line frequency current. A large thermal stress is thus impressed on the diode since the case remains at the water temperature. The current is cut off, the device cools, and then the heating cycle is repeated. Before-and-after end-point tests determine whether or not a rectifier has passed the specified minimum number of thermal cycles.

REVIEW: This is an example of a "burn-in" type of test that is useful in removing potential early failures. Tests of this type can greatly improve reliability. ##

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Serial Number 1166
Code 773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Automatic monitoring of components on life test

AUTHORS: I. F. M. Walker and K. J. D. Willard, British Telecommunications Research Ltd.

SOURCE: Electronic Components (incorporating Radio & Electronic Components), vol. 4, pp. 1007-1011, October, 1963

PURPOSE: To report on an instrument which automatically measures capacitance, series resistance of capacitors, and resistance of resistors at a rate of 2000 components per hour.

ABSTRACT: Increasing emphasis on the reliability of electronic equipment has produced a demand for more information on the behaviour of components over long periods of time and under various operating conditions. The acquisition of such information can be extremely costly and could well price a component out of the market. Some of the cost is in the provision of test samples; for example, to determine a 0.1%/1000h failure rate requires a 10,000h test of 3000 components. However, since only failures need to be determined, measurements need not be made very frequently. On the other hand in many cases the changes with time of the parameters of a component are required. In this case, the more frequent the measurement the more reliable the result since any random excursions outside permissible limits will be detected. In addition, such information can assist in the formulation of laws governing the behaviour of a component under various stress levels; knowledge which can prove valuable in reducing the amount of testing required. Again large samples are needed if statistically reliable results are to be obtained and in this case the cost of measurement may be excessive. The equipment described in this article was developed with a view to reducing this cost.

The instrument can be used to monitor at frequent intervals any quantity which can be measured by a d.c. or a.c. bridge. (Authors in part)

REVIEW: The report is thorough, including all the information and references necessary to study, apply, and improve the instrument. The emphasis is on the machine rather than on the components measured by the machine. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: High-reliability computers using duplex redundancy

AUTHOR: R. W. Lowrie, Minneapolis-Honeywell Regulator Company, St. Petersburg, Florida

SOURCE: Electronic Industries, vol. 22, August, 1963, pp. 116-121, 128

PURPOSE: To describe a scheme for duplex redundancy of logic circuits and to compare it with majority logic.

ABSTRACT: This paper proposes parallel operation of two identical logic circuits or computer sections, with associated circuitry to detect any disagreement between the two. Upon detection of an error, a diagnostic subroutine or external hardware would localize the fault and initiate switching action to disable the faulty section. This method of redundancy is compared with triplicated majority logic, and computational results are presented which indicate that the proposed duplex system requires less hardware than the majority logic version, provides a greater MTBF, and makes possible an external fault indication to assist human repair of the system.

The primary difficulty associated with the duplex redundancy lies in the time and the reliable equipment required for diagnosis. Real-time data may be lost while diagnosis is in progress, and there is the danger of destroying the contents of various registers.

To summarize the comparison of duplex and majority (triplex) logic, it is claimed that the duplex logic results in an MTBF which is 50% greater than that obtained with majority logic, and requires 20% fewer components.

REVIEW: This is a rather abbreviated article and some of the figure numbers are mixed up; both of these factors hinder understanding. The article gives an idea of the results, but the basic logic is not detailed. Another paper [1] (see Abstract and Review Serial Number 1268), part of which is on the same subject, is authored by one of the persons cited in the acknowledgements at the end of the present paper. In [1] the author treats the triplex-redundancy majority-vote computer which is also discussed in the present paper, except that he considers whether an element fails to a "0" or fails to a "1". The analysis of the triplex system is tricky, as shown on the reverse side of this sheet.

REFERENCE: [1] Rhodes, L. J. "Effects of failure modes on redundancy," Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 360-364

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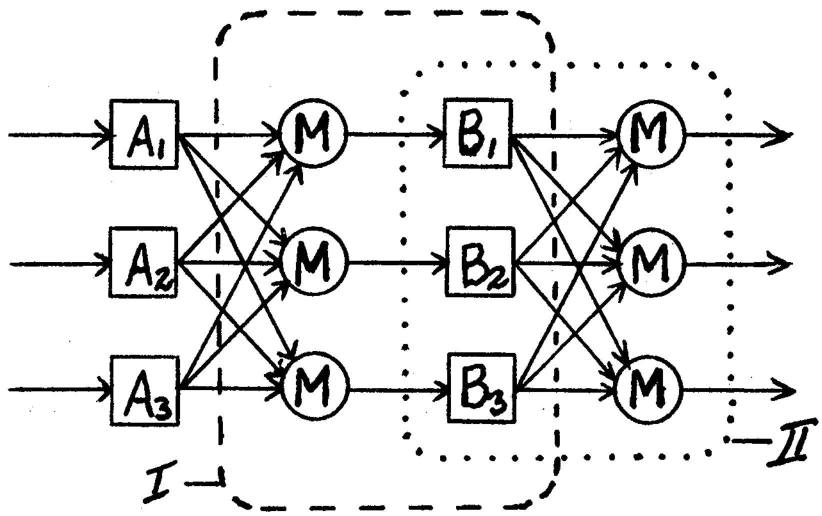
RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS



The above figure corresponds to Figure 3 in the present paper or to Figure 1 in [1]. Section I, shown in the dashed lines, is not equivalent to section II, shown in the dotted lines. In [1], section I is analyzed, taking into account the kind of failure; in the present paper, section II is analyzed without regard to the kind of failure. It can be shown that if the analyses are performed on the same section the result in the present paper is equivalent to that in [1] for the probability of failure to a "1" either zero or unity (i.e., everything always fails to a "1" or else everything always fails to a "0"). It turns out that neither section I nor section II is representative of the complete system, but that the entire group consisting of the A's, the B's, and the M's should be analyzed as a unit. This would not be the case if the inputs to the B's were triplicated; then sections I and II would be equivalent, the analysis in the present paper would be correct, and that in [1] would be incorrect. (The three inputs shown for the A logic units in Figure 3 in the paper tend to be confusing since only one input is shown for the B logic units.)

The equation for the duplex-system reliability is based on the implicit assumption that the failures of a logic section to a "1" or to a "0" are equally likely, and that the failure of an "OR" unit never occurs.

The author may well have a good approach, but the editorial confusion, the lack of clarity regarding circuits and analysis, and the omissions in algebra obscure the results. It should be pointed out that for redundant systems composed of "exponential" elements (as assumed in the present paper) the MTBF does not give a sufficiently good idea of the reliability improvement. The curves showing probability of mission success vs. mission time are much more helpful in this connection. ##

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Serial Number 1168
Codes 833;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The need and means for self-repairing circuits

AUTHOR: James B. Angell, Electrical Engineering Department, Stanford University, Stanford, California

SOURCE: 1963 IEEE International Convention Record, Part 2, New York, New York, pp. 193-199, March, 1963

PURPOSE: To describe the use of redundant, adaptive structures capable of limited self-repair, and to present components suited for such networks.

ABSTRACT: Adaptive structures offer the possibility of self-repair, which is desirable as a means of increasing the lifetime of systems not accessible for human repair. This feature would also increase manufacturing yield of complex microelectronic circuits by permitting satisfactory operation in spite of initial defects. In addition, one may visualize self-organizing systems in which one basic structure can be organized or adapted to perform any of a variety of functions.

Systems reliability may be improved by the use of error correcting codes, redundant networks, majority vote-takers, and adaptive vote-takers. The adaptive vote-taker, as an element for self-repair, accepts redundant binary inputs and generates an output which agrees with the majority of the weighted inputs. Adaptation consists of decreasing the weight or significance of any inputs having a history of error. Thus any logic element which fails has its franchise rapidly revoked by the adaptive majority element, and its brethren carry on, unimpeded by the voice of the "insane" member. Adaptive vote-takers can also be used as logic gates and trained to perform OR, AND, NOR, or NAND functions.

Weighting elements in adaptive circuitry are functionally similar to motor-driven potentiometers or variable transformers. These elements should have drift-free gain which can be adjusted by means of an electrical signal. Other desirable features are continuously variable gain, nondestructive readout or gain sensing, nonvolatile gain settings, and low cost. One such adaptive element is the Memistor, which utilizes the resistance of an electroplated copper film as the gain setting. Several ferromagnetic devices have also been developed which exhibit an electrically variable gain setting.

REVIEW: This paper should be viewed as an introduction to the present status and future hopes of adaptive systems research. As such, it is well done and quite stimulating. No detailed results are presented. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Assessment of achieved reliability through statistical analysis of field failure data

AUTHORS: Irwin Nathan and Stanley A. Rosenthal, Reliability Section, Arma Division, American Bosch Arma Corporation, Garden City, New York

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 3-10, March, 1963

PURPOSE: To present a method of analysis of field failure data where the exponential reliability function can be applied.

ABSTRACT: The method of analysis presented in this paper eliminates the necessity of conducting small-sample-size life tests for extended periods for determining system modal and logistic failure rates when a large population of operational systems with readily available field failure and operating time data is available.

A theoretical treatment is given for the exponential reliability function, including a modified test for exponentiality with a test for its discriminating ability. The mean time between failures is defined and its confidence levels are given.

Several different kinds of failure rates are calculated by selecting appropriate data. For example, breakage during handling of spares does not contribute to mission failure, but does affect the number of spares required.

REVIEW: The authors present a detailed and systematic approach to assessing the reliability of large populations of equipment operating in the field. The keeping track of different types of failure and using them appropriately in calculating failure rates is a good idea. The term "random" in describing certain kinds of failures should be used with caution since it can be quite misleading. It should be noted that the MTBF calculation itself is useful and correct even if the distribution of failure times is not exponential. With regard to worst-case design in analog circuits, such old standbys as automatic gain control and negative feedback can contribute much to allowing such design. ##

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Serial Number 1170 -1
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Empirical parameter variation analysis for electronic circuits

AUTHOR: Stuart Klapp, Battelle Memorial Institute, Columbus, Ohio (present affiliation: SCM Corporation, Data Processing Systems Division, 6701 San Pablo Avenue, Oakland 8, California)

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 11-17, March, 1963

PURPOSE: To present the use of breadboard electronic circuits as a substitute for computer simulation for parameter-variation analysis.

ABSTRACT: Electronic circuits can fail to perform satisfactorily because of a catastrophic failure or a drift failure. The objective of parameter-variation analysis is to improve circuit designs from the point of view of drift sensitivity so that the occurrences of drift failure can be reduced. Variability-analysis techniques combine data on the variation in component-part parameters with information on the sensitivity of the circuit design to such variations in order to determine the statistically anticipated variation in circuit performance. Both mathematical and empirical methods are used in variability analysis. In the usual mathematical methods a mathematical model, or system of equations, is used to represent the behavior of the circuit. Component-part parameters in the model are varied systematically, and the equations are solved to determine the response of the circuit to these variations. A digital computer may be used to mechanize both the parameter-variation procedure and the solution of the circuit-model equations. Physical breadboard circuits are a useful alternative method. A formal method of breadboard analysis is presented here.

The empirical moment method requires component-part parameter-variation data from "life tests" which are expressed in terms of parameter variance at a particular point in time. The information obtained from the technique includes estimates of the variance of the important circuit performance variables such as circuit voltages, currents, gains, etc. The values of circuit performance variances obtained by this method represent estimates of the statistical variability of the circuit performance variables. An excessive variance indicates that the circuit will not behave properly under conditions of component-part-parameter variation. This method assumes a linear relationship between performance and circuit parameters.

The empirical worst-case method differs from the moment method in that it is not statistical in nature. That is, it does not consider the probabilities associated with various possible combinations of component-part parameter drifts. In worst-case

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analysis, all component-part parameters are simultaneously set to their end-of-service tolerance limits in the combination which is most cumulative in effect to obtain worst-case maximum and minimum values for each circuit performance variable. If failure occurs, the circuit may still be good if the particular combination has a low probability of occurring. Worst-case design is rarely suitable for analog circuits because of the overdesign required. It is more useful in the dc design of digital circuits.

In performing the empirical analysis, i.e., evaluating the partial derivatives or the worst-case performance, special mock-up components of which the values can be changed easily are useful. Some are described in the paper. Several circuits were built and analyzed in which these methods were of help.

REVIEW: A good analysis of the empirical moment method and the empirical worst-case method is given. Particular attention should be given to the criticism of the worst-case method applied to circuits other than the switching type. Eight pertinent references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life testing: estimating the parameters of the Weibull distribution

AUTHOR: Jos. V. J. Ravenis, II, The Johns Hopkins University and Westinghouse Electric Corporation, Baltimore, Maryland

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 18-33, March, 1963

PURPOSE: To estimate the parameters of the Weibull distribution by the method of moments and the method of maximum likelihood.

ABSTRACT: The Weibull cumulative distribution function is postulated as underlying the data. The problem attacked here is how to estimate the three Weibull parameters from a set of sample data. When the values of the location, scale, and shape parameters of the Weibull distribution are known, it is quite easy to ascertain the form of the specific distribution and its properties. However, if one is given only the raw sample data and required to find the values of the parameters, the problem becomes rather difficult.

Two methods are presented for estimating the Weibull distribution parameters: the method of moments and the method of maximum likelihood. In the method of moments the first four moments of the data are given as functions of the distribution parameters. Since the third and fourth moments are functions of the shape parameter only, it can be determined by a graphical solution of either of these equations. The location and scale parameters can then be obtained from a solution of the mean and variance equations using the value of the shape parameter already obtained. The method of maximum likelihood is based on the likelihood function which is the joint density function of a sample of independent systems. The equations are difficult to solve; no (closed) analytic solution is available, but iterative techniques have been programmed on a computer. It can be shown that the solutions of the maximum likelihood equations will provide sufficient statistics if they exist. However, when sufficient statistics do not exist, the method of maximum likelihood will always provide asymptotically efficient statistics; that is they are normally distributed in large samples with variances which are no larger than those of any other set of estimators and which decrease as the sample size increases.

When all three parameters are unknown, certain technical complications arise in their estimation, but are not present if the location parameter is assumed known. Two detailed numerical examples are given which show that the method of maximum likelihood gives much better results than the method of moments.

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REVIEW: This is a good comprehensive analysis of two methods of estimation of Weibull parameters. The author is to be commended for clearly stating some of the unsolved difficulties in the analysis. Most engineers will need assistance in interpreting this paper for their own use. While graphical methods are admittedly not precise, much of the data which is analyzed is probably not worth more than the graphical analysis. No mention is made of what to do with the surplus equations in the moment method, i.e., the fourth moment gives a redundant estimate and it may not agree with that from the third.

Other papers dealing with the Weibull distribution and various aspects of its role in reliability analysis have been covered by Abstracts and Reviews Serial Numbers 320, 437, 499, 749, 751, 801, 848, and 1015. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Topological analysis of non-series-parallel redundant networks

AUTHOR: George D. Weinstock, RCA Surface Communications Systems Laboratories, 75 Varick Street, New York 13, New York

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 34-40, March, 1963

PURPOSE: To present a method for mathematically reducing non-series-parallel networks to series-parallel form.

ABSTRACT: This paper presents a theorem which permits the reduction of non-series-parallel networks to series-parallel form. The theorem states that any arrangement of nodes and edges in a linear graph is reducible to series-parallel form and the proof is given for both the planar and non-planar cases. Once the system is in series-parallel form, a number of methods, including one by the author, may be employed to derive the network reliability parameters. The theorem has additional importance since it is not limited to electrical networks. Any problem which involves the flow of information (the format is not important) between two terminals can be analyzed in a similar manner. (Author)

REVIEW: The paper is a mathematical proof of the stated theorem. The author has pointed out in a private communication that since the reduction to series-parallel form is in reality a reduction to canonical form, this result has more than a little significance because the reduction of any network configuration to canonical form is a goal of network analysis as well as synthesis. Extreme care should be used in interpreting the results since the implications of the formalism may not be entirely apparent. The logic "circuit" and the physical circuit may well not have the same form. In fact, a given physical circuit may have several logic "circuits," depending on the kinds of failure. For example, Equation (1) for simple parallel redundancy implies that failure is an open circuit and success a continuous path. Since electrical components other than conductors and insulators operate successfully only when neither opened nor shorted, and have separate probabilities of failure for each mode, the proper logic circuit(s) for the failure analysis must be chosen with care. The quad circuit, so popular in some quarters, is not analyzed properly by using a logic circuit that looks like the quad unless the probability of a shorting failure is zero. (An elaboration on this point will be found in Review Serial Number 1191.)

Engineers would have found the paper more useful if the author had stated the means for obtaining the logic "circuit" from a physical circuit. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Progressive failure prediction

AUTHOR: Walton B. Bishop, Air Force Cambridge Research Laboratories, L. G. Hanscom Field, Bedford, Massachusetts

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 41-49, March, 1963

PURPOSE: To present several common failure distributions and to discuss the meaning of a failure prediction after a period of observation.

ABSTRACT: The probability of failure is considered for a time τ beginning at time t_1 rather than beginning at time zero. The problem is analyzed, and graphical solutions are given for the exponential, Weibull, gamma, normal, and lognormal distributions.

REVIEW: The author's concept of "fallibility" (the conditional probability that an item will fail at some time T in the interval (t_1, t_2), given that it has survived to time t_1) is certainly not new. See, for example, [1], p. 43. If $t_2 - t_1$ is held fixed, and t_1 is varied, the fallibilities obtained are called progressive failure predictions. The curves of these progressive failure predictions may be of considerable assistance to someone who plans to use the analysis.

For systems wherein components are replaced, some components will have an operating time that is different from that of the system. It is then impossible to characterize the system by a single operating time unless the components have an exponential distribution. For example, suppose the system originally has a probability density function (pdf) of time-to-failure that is Gaussian with mean μ, and half of the parts are replaced at time $\mu/2$, then the system may no longer possess the original pdf. Since for the exponential pdf for time-to-failure a shift in the time origin for a part is unimportant, given that the part is operating, the analysis is valid and easy to apply, as shown by the author.

REFERENCE: [1] Reliability Theory and Practice, Igor Bazovsky, Prentice-Hall, Inc., 1961 ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Self-repairing procedures

AUTHORS: D. H. Kramer, MB Electronics, New Haven, Connecticut and W. S. Jarnagin, Minneapolis-Honeywell Regulator Company, Boston, Massachusetts

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, p. 70, March, 1963

PURPOSE: To list the advantages of anisotropic self-repairing materials.

ABSTRACT: The main objective of this paper is the investigation of known and new techniques which can be applied to self-repair procedures for electronic circuits and components. Of the approaches discussed it should be emphasized that several distinct advantages lie in the anisotropic approach to the self-repair of components.

1. The natural behavior of atoms within the material, i.e., their tendency to add onto crystalline structures spontaneously, is capitalized upon.

2. A minimum amount of stand-by material is required, i.e., no baffles, no flux, and no particular atmosphere is absolutely required, since the anisotropy in the materials directs the flow of atoms internally.

3. Excessive regeneration is avoided since the crystals tend to regrow, once broken, in a unique direction, hence will tend to close a given circuit but not grow orthogonally to a given break.

4. Thin-film capacitors, transistors, semiconductors... may be repaired uniquely in the plane of the film vs normal to the plane where short circuits are to be avoided.

5. All the material is utilized during normal operations. For instance, in the alloy variation of the anisotropic approach, both of the metals of the alloy (Al-Cu or Al-Ag) continue to conduct electricity even though the respective metals may be migrating within the component. In short, everything is functional all the time in the anisotropic approach.

6. Anisotropy may be put into components in a straightforward manner, for instance, by designing and zone heating printed circuits, conventional elements or modules of thin films.

7. Repetitive repairs are possible, in fact are the rule, with anisotropy constructed in the elements, as compared with the one-time repair offered by other approaches. (Authors)

REVIEW: Only an abstract is given and is quoted in full above. The authors may be able to provide further information upon request.
##

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Serial Number 1175 -1
Codes 715;782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor reliability after radiation exposure

AUTHORS: Leonard B. Gardner and James R. Coss, Radiation Effects Section, Nuclear Sciences Laboratory, Northrop Space Laboratories, 1111 East Broadway, Hawthorne, California (present affiliation: Consulting Scientists, P. O. Box 103, Toluca Lake Station, North Hollywood, California)

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 71-75, March, 1963

PURPOSE: To report on a study of transistor reliability after irradiation.

ABSTRACT: Transistor reliability after irradiation has not been thoroughly studied, and even the results that are presented must be considered tentative. It is shown that under certain conditions of irradiation almost all of the radiation-produced-damage annealed (self healed) in a period of time following irradiation. However, it is also shown that a portion of the radiation-produced damage did not heal. The type of radiation used in this study was that provided by a steady state research reactor which was suitably shielded so that the spectrum of neutrons would more closely resemble that expected to be found in the instrument compartment of a space probe which has a nuclear propulsion system. The 2N2219 transistor was chosen for this radiation-effects study because of all electronic parts, transistors are the most susceptible to radiation-induced damage. Their mechanisms of damage are (1) atomic displacement and (2) ionization. The parameters studied are the dc signal current gain transfer ratio (measured differentially) and the collector-base leakage current. The storage (switching) time was also measured.

It is shown that the radiation environment associated with this experiment produces no gross changes in transistor reliability; however, it is also shown that at least some permanent damage to the transistors is caused by their exposure to the environment. This is evidenced by the difference in switching time between irradiated and control groups. Thus, it is necessary to suspect that their long-term reliability might be affected. An insufficient amount of operation time and failures have yet been observed to prove or disprove any radiation-induced changes in long-term reliability. The experiment (life test) of these devices is continuing and will be reported in the near future. (Authors in part)

REVIEW: The limitations of the paper are well presented in its section on conclusions. Insufficient data are presented to give a thorough report. It is unfortunate that parts of the paper must be conjecture on what will be found in future data, but these experi-

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ments do take a long time. Other papers concerned with the effects of radiation on semiconductor devices have been covered by Abstracts and Reviews Serial Numbers 1148 and 1149.

The first author, in a private communication, has indicated that the post-irradiation reliability of electronic components and materials is the subject of a recently-initiated study by the Navy Department. Present experimental work is being concentrated in the areas of semiconductors and capacitors. ##

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Serial Number 1176
Codes 775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluation of the effect of X-ray detectable defects on the performance of semiconductors

AUTHORS: Rhoda L. Morris and David Wolin, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 76-81, March, 1963

PURPOSE: To evaluate the use of X-ray techniques in screening semiconductors which are to be subjected to shock, vibration, and thermal cycling.

ABSTRACT: An experiment is described which was performed for the purpose of evaluating the effectiveness of an X-ray program in reliability screening of semiconductors. Seven groups of transistors and nine groups of diodes, of various types, were tested. Each group of approximately forty parts included some which contained defects (such as foreign particles), detected by X-ray, and some which did not. The electrical parameters were recorded before and after exposure to use and qualification stress environments, and the failures counted. The results were analyzed statistically. The data were found to support the conclusion that X-raying, in conjunction with other screening tests, is an aid in determining which semiconductors are greater reliability risks especially as regards intermittents. It is recommended that X-ray procedures be instituted whenever semiconductors are to be subjected to shock, vibration and thermal cycling in use. (Authors)

REVIEW: This paper describes thorough analyses of the data and the applications and limitations of the X-ray program for semiconductor reliability studies. Reference is made to further problems to be pursued, which were not resolved in this experiment. Particularly important among these is the search for correlations between kinds of defects and failure modes. ##

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Serial Number 1177
Codes 833;838;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A proposed use of Zener diodes to improve satellite reliability

AUTHORS: M. Goldstein, D. J. Kovensky, Airborne Instruments Laboratory, A Division of Cutler Hammer, Inc., Deer Park, Long Island, New York and W. Dunham, Fairchild-Stratos Corporation, Hagerstown, Maryland

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 82-87, March, 1963

PURPOSE: To show that shunting cells in satellite batteries with Zener diodes improves battery reliability.

ABSTRACT: If a Zener diode is used as a bypass for each battery cell in a series string, then failure of a single cell does not lead to power failure. Using the Zener in its normal diode (forward) mode, power to the load is maintained while recharging of the battery from a solar array is possible because of the reverse characteristic of the Zener diode.

The analysis of the reliability model demonstrates that the Zener-diode cell bypass technique yields a reliability that is appreciably greater than the series-string configuration (single battery). In addition, it is shown that the Zener-diode cell bypass configuration yields a reliability that at the very worst (failure mode of the diode assumed to be a short circuit) is only slightly poorer than the two-battery redundant configuration at its best (no additional circuits required). The savings in satellite size and weight emphasize the advantages of the Zener-diode cell bypass configuration since the weight of the additional Zeners is considerably less than the weight of the additional cells required in the redundant configuration. (Authors in part)

REVIEW: This paper describes an ingenious use of Zener diodes, including a thorough analysis. (The arithmetical details were not checked, but the results are quite reasonable.) ##

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Serial Number 1178
Codes 720;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A program of quality assurance for welded electronic circuitry

AUTHOR: F. A. Lally, The Boeing Company, Seattle, Washington

SOURCE: 1963 IEEE International Convention Record, Part 6, New York, New York, pp. 88-92, March, 1963

PURPOSE: To present a program designed to establish and maintain effective control of quality in the field of welded electronic circuitry.

ABSTRACT: Welding offers many advantages as a method of connection between component leads and interconnecting wire or ribbon in electronic circuitry. Because the process contains a greater number of potential variables than the more commonly employed soldering techniques, a more thorough understanding of the process is a necessary prerequisite to adequate control. Control in the areas of process and equipment, material, environmental conditions, and human factors, combined with the most effective and up-to-date inspection and test techniques, ensures the subsequent quality and reliability of the assembled circuitry.

The results of the program--designed to determine the effectiveness of the weld process, the relative effects of the variables on the process, and with the overall intent of establishing and maintaining an optimum standard of weld quality--are presented and discussed.

The system includes a quality-assurance program wherein material and product were closely monitored. In-process control is limited to the requirements of the Boeing process specification. However, a complete quality control assurance section is written into this specification. Quality acceptance and initial qualification/certification of all welding equipment is performed according to the procedures and to requirements specified in both the Boeing process specification and an internal quality control document. (Author)

REVIEW: This is not a detailed paper, but it does give a good idea of what is involved in the welding process for high-quality work. Earlier papers on reliable welding were covered by Abstracts and Reviews Serial Numbers 278, 315,365, 522, 777, and 1144. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintenance time specification

AUTHORS: B. L. Retterer and G. H. Griswold, RCA Service Company, Cherry Hill, New Jersey

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 1-9

PURPOSE: To discuss the time specification and demonstration requirements of the Air Force maintainability specification MIL-M-26512.

ABSTRACT: This paper discusses the time specification and demonstration requirements of MIL-M-26512, Maintainability Requirements for Aerospace Systems and Equipment. To accomplish this, the time domain of equipment operation is described and the various classifications of maintenance are given. A system of maintenance indices is presented that will adequately describe system/equipment maintainability in terms of time. A method for determining the underlying distribution of a set of data is given and an observed time distribution is illustrated. Techniques for computing indices and associated confidence intervals are given along with methods for significance testing. In addition, the need for the development of additional indices is discussed. (Authors)

REVIEW: The indices and computation procedures described in this paper constitute effective tools for maintainability specification. As the authors have indicated, however, future research into maintainability measurement may eventually lead to composite measures which are capable of completely describing maintenance consequences. Major problems arise because of the multiplicity of factors involved in maintainability and its dependence on the ever-changing environments of personnel and support.

The reader interested in this topic may wish to see also the papers covered by Abstracts and Reviews Serial Numbers 481 and 1039.

In a private communication the second author has indicated that this paper reflects a portion of the work accomplished for a maintainability techniques study performed for the Rome Air Development Center. Volume II of the final report for this study forms a handbook for maintainability engineering and should provide very useful information for anybody interested in this field. This report is available from the Defense Documentation Center as document number AD 404898. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability--design or support?

AUTHOR: Floyd J. Kreuze, Lear Siegler Instrument Division, Grand Rapids, Michigan

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 10-18

PURPOSE: To describe a practical approach to the problem of organizing maintainability program tasks.

ABSTRACT: Maintainability (M) Assurance can be thought of as one of many product assurance functions. As such, it should be considered from the viewpoint of the tasks required to meet specified qualitative and quantitative M requirements. This leads to the problem of M Program Management. This paper is concerned with the need for and the qualifications of a M Program Manager, with the desirability of separating M Design tasks from Supportability tasks and using the staff-management concept to undertake these tasks most effectively.

Some of the types of M effort likely to be encountered by a typical multi-division corporation, and the organizational levels involved in each, are indicated. Each level must have an adequate M capability. The implementation of this staff-management concept is illustrated, and its advantages are cited. Topics covered include program organization, responsibilities and qualifications of the program manager, and program task descriptions. It is concluded that adequate M Assurance is a mixture of design and support. The importance of having a design-oriented program manager is emphasized.

REVIEW: This is essentially a description of an approach to the organization of a maintainability program which one company has found to be effective. As such, it should be useful to those who are faced with similar problems, to which they may wish to adapt some of the ideas. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimizing the trade-off between reliability and maintainability design

AUTHORS: A. S. Goldman and T. M. Whitin, TEMPO, General Electric Company, Santa Barbara, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 19-32

PURPOSE: To discuss the problem of achieving an optimal combination of reliability and maintainability to yield either maximum availability for given cost or minimum cost for given availability.

ABSTRACT: The availability of a system which is designed to perform a particular task may be described by the reliability and maintainability characteristics of the system and its components. The interest of the systems designer may therefore be viewed as an attempt to determine an optimal combination of reliability and maintainability insofar as they result in either (a) maximum availability for a given dollar outlay or (b) minimum cost for given levels of availability.

While the effect on system availability may be certain, there is always the question whether or not one dollar put into the various areas of reliability will yield more than the same dollar put into areas of maintainability. Decisions along these lines can be made most effectively if information exists in terms of the reaction of system availability to relative combinations of reliability and maintainability, particularly if the data on the particular system are provided in the form of incremental responses or "successive additions" of availability to these combinations. Accordingly, information for decision-making in systems development and management from the support point of view must first be in a form providing an understanding of changes in system availability resulting from the changes and varying combinations of reliability and maintainability. Secondly, technical knowledge requires a complementary understanding of the effects of these changes on costs and, if possible, on the value of the end result.

The basic relationships between availability, reliability, and maintainability at the system level and the economic principles underlying decisions concerning the allocation of resources to reliability and maintainability are discussed briefly. It is demonstrated that the specification of overall system availability and costs of elementary components (for different degrees of reliability and maintainability of the components) determines uniquely the optimum configuration, maintainability, and reliability of the system and its components. Calculations are illustrated for the single component system, systems employing re-

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dundancy, higher order systems, and "supersystems." The possibility of extending the analysis to include spare parts is considered briefly. (Authors in part)

REVIEW: This is a well-written paper on the theory of availability in relation to reliability, maintainability, and cost. The illustrative examples are clearly presented. For those who desire more details, six pertinent references are cited.

It must be emphasized that the trade-off is never between reliability and maintainability in themselves, but is between the efforts devoted to the two fields in the development program. Rarely if ever would one sacrifice a reliability he already knew how to achieve. ##

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Serial Number 1182
Codes 824;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The uncertainty of reliability assessments

AUTHORS: G. R. Herd, R. L. Madison, and P. Gottfried, Booz-Allen Applied Research, Inc., Bethesda, Maryland

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 33-40

PURPOSE: To find bounds on the estimate of reliability.

ABSTRACT: If the failure rate of a system is estimated from the failure rates of its components, uncertainties will occur because the exact component failure rates are unknown. Factors such as inadequate life test data, unknown ambient conditions, complicated calculations, etc. are the cause of the inexactness. While no handbook methods are given, an example is worked out to illustrate the methods that might be employed. Only unsophisticated methods are used in the example, so that complex mathematics does not detract from the presentation. Numerous assumptions must be made, many with inadequate evidence; but this is the best that can be done. The tolerance interval approach is not often used and should prove valuable.

REVIEW: This is an interesting example, but, as the authors state, it should not be taken as <u>the</u> way to solve all such problems. Even trying to estimate some of the required numbers may be almost impossible, thus requiring the use of much "engineering judgment."

The first author, in a private communication, has made the following comment. "We are now using the approach of evaluating the uncertainty to establish test priorities and the relative amounts of testing to be performed. Engineering judgment must play an important role in all such applications. Although the engineers have been using their good judgment in this matter for a long time, we believe that this formalized procedure will aid us in getting more valuable data in the future, and it will currently furnish guidance where intuition has dominated before." ##

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Serial Number 1183
Codes 782;836;838;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of hydraulic controls in space vehicles

AUTHOR: A. B. Billet, Vickers Incorporated, Detroit 32, Michigan

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 69-84

PURPOSE: To summarize the space environment and reliability management techniques, and to give a few examples of improved reliability in hydraulic systems.

ABSTRACT: Reliability of hydraulic controls in space vehicles is now not only a matter of monetary concern, but it is also concerned with human life. The hostile environments of outer space indicate that added and continuous efforts must be placed upon reliability programs. These environments include those found on the moon which are many times more severe than what present equipment is now operating in.

To meet these requirements, new design concepts of fluid power control systems are being used coupled with improved reliability procedures. Some of these concepts include additional redundancy of present design configurations while others, such as the hydrogen-oxygen combustion engine, outline new auxiliary power concepts. (Author)

REVIEW: A major portion of the paper is given over to the space environment and to management concepts. The charts for failure rate imply a constant failure rate over the useful life, even for mechanical components. In response to a question at the symposium, the author stated that seals are the main source of trouble with space hydraulic systems.

A similar paper by the same author was covered by Abstract and Review Serial Number 747. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability in mass produced consumer products

AUTHOR: Edward M. Stiles, Underwood Corporation, Hartford, Connecticut

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 85-96

PURPOSE: To present the Underwood reliability program for electric typewriters.

ABSTRACT: The intent of a general reliability program is to insure that the device or product in question is so designed as to perform under all expected conditions of environment, operation, and maintenance. In the case of a specific product, such as the electric typewriter, these conditions are subject to great variations throughout the world at various points of usage. Like any other complex mechanical product, the basic reliability problem is to establish from a limited number of models the design parameters and predict the probable success in meeting operating criteria for each machine of thousands produced.

Three broad areas are involved in the reliability operation for the electric typewriter at Underwood. These are:

I. Pre-production design analysis and test.
   A. Determine customer requirements.
   B. Determine application and environment for which the product will be sold.
   C. Develop project guide line and control.
   D. Test initial design models for life performance.
   E. Test and evaluate pre-production pilot run.

II. Product reliability verifications.
   A. Quality Assurance in factory operations.
   B. Production reliability test.
   C. Analysis and action on failures in plant.
   D. In-plant usage program.
   E. Product audits.

III. Customer usage and reliability experience.
   A. The application and installation problem.
   B. Transportation versus reliability.
   C. Validity of field reporting.
   D. Reliability of maintenance data obtained from 3,000 mechanics.
   E. Special data reporting point system.
   F. Analysis and application of field data as feedback bias on present and future designs.

A complex electro-mechanical product, such as the electric typewriter, is subject to aging due to frictional wear, continued

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vibration and shock, and exposure to its environment. Maintenance will be required. The key question is, "What is the relationship between the amount of maintenance demanded by the design and the amount of maintenance the customer will accept?" (Author)

REVIEW: This is a very readable exposition on the practical reliability needs and efforts of a consumer-oriented producer. In the oral presentation, the author pointed out that the electrical parts of the typewriter consist largely of a cord, motor, and switch--the rest is mechanical. Perhaps special emphasis should be given to extended guarantees as a means of providing for management the financial incentive to build a long-lived product. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical methods for structural reliability analysis

AUTHOR: Edward B. Haugen, North American Aviation, Inc., Space & Information Systems Division, Downey, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 97-121

PURPOSE: To show how normal (Gaussian) distributions can be combined, and to apply these concepts to the strength of mechanical structures.

ABSTRACT: Presented in this paper is a rigorous statistical approach to the reliability analysis of structure. Such an approach is rendered possible through application of a complete and consistent algebra of normal, or Gaussian, functions. This algebraic system, which is delineated herein, is employed in the statistical description of structural strength and system loads, and ultimately provides the basis from which reliability may be calculated.

Conventional structural analysis is a special case of Structural Reliability Analysis; i.e., the case when variability is zero. (Author)

REVIEW: This paper is not recommended for the casual reader since the emphasis seems to be misplaced. The proofs are not rigorous since the normal (Gaussian) distribution is a continuous function, not a finite sum. Much space in the paper is devoted to proving theorems about the addition and subtraction of variables which have Gaussian distributions. The results are well known, and some of them do not, in fact, require normality for their validity. With regard to the quotient and product of two independent Gaussian variables, the result is Gaussian only if $\sigma_i/\mu_i \ll 1$ for each variable; the further out in the tails one expects to find Gaussian behavior, the smaller σ_i/μ_i must be.

Even though strength is statistical in nature, it may well take more than a mean and variance to describe it (contrary to the author's statement). While the Gaussian distribution is often a good <u>enough</u> description for engineering variables, to forget the ramifications of the word "enough" may lead to gross miscalculations. This qualification is extremely important also in the author's quotation to the effect that other distributions can be transformed to the Gaussian.

The author gives several results implying an unreliability of 10^{-7}, or even less than 10^{-15}; these statements are absurd since no

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statistical model can be presumed to fit any physical situation that well. See Abstract and Review Serial Number 131 for further comments on this point.

The discussion on fatigue (one of the important mechanical failure modes) is rather inadequate. A book such as Sines and Waisman, Metal Fatigue, McGraw Hill, 1959 should be consulted for more information.

The use of standard deviations as well as the conventional means in calculating strength of structures is extremely valuable, but one should not become deluded by an appearance of accuracy in the model when that accuracy does not exist in our knowledge of the physical world. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability engineering disciplines applied to commercial weapons systems--guns and ammunition

AUTHORS: L. W. Kullman and G. W. Phillips, Winchester-Western Division, Olin Mathieson Chemical Corporation, New Haven, Connecticut

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 122-137

PURPOSE: To describe an improved quality control plan for a new model sporting rifle.

ABSTRACT: The design objective was a firearm whose components could be assembled at random without traditional gunsmithing and could fire any combination of three different length cartridges (Long Rifle, Long, or Short) below a specified maximum malfunction rate. The basic components had to be designed in such a manner that, with only a few changes, it would be easily possible to mass-produce a lever action, pump action, or semi-automatic rifle from these standard production components. Traditional final inspection--proof firing--had been performed on a large batch of rifles before the reliability analysis was performed. Design inadequacies were discovered in the rifles and were corrected by a statistically designed and analyzed experiment. An improved field data feedback and correction system was set up. (Author in part)

REVIEW: Articles on the application of reliability to consumer and industrial products are worthwhile, since so much emphasis is on military products. (This particular paper deals largely with the initial quality and little with the failure properties as a function of time.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability prediction in design decision

AUTHOR: John R. Levinson, Propulsion and Vehicle Engineering Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 138-147

PURPOSE: To present some case histories in which reliability prediction has played an important role in design decisions at Marshall Space Flight Center.

ABSTRACT: Developing large, complex liquid-fuel rockets such as the Saturn I and Saturn V space vehicles requires intensive coordination to resolve design problems that affect many design and manufacturing groups at MSFC. Many problems which arise within the design laboratories require study and analysis by other branches and laboratories or the stage contractors. A method which has proved effective at MSFC is to discuss the problems, the proposed solutions, and the impact of the proposed solutions upon a particular engineering discipline or stage subsystem at weekly or special meetings. Representatives from design and other groups describe the problem and make their recommendations for the solution. Each group, including reliability, is expected to present the results of its study and analysis.

The nature of design reviews at MSFC is described, with particular attention to the reliability contribution. Four case histories are presented, in each of which reliability has had an important direct effect on design decisions. The case histories are: Saturn I engine-out capability, Saturn V vehicle umbilical disconnect, S-IC and S-II stage separation, and S-IC and S-II retro and ullage motor-out capability. In each case the system and the problem are described, the method of analysis, the possible solutions, and the recommended solution and results are indicated. (Author in part)

REVIEW: The case histories in this paper are concisely presented, and serve as good illustrations of the beneficial effects of the implementation of a good design review program. It may be that some readers will desire more details than are given in the paper; however, no references to more extensive descriptions of the studies are given.

Other papers on design reviews have been covered by Abstracts and Reviews Serial Numbers 25, 26, 29, 125, 183, 190, 193, 245, 273, 275, 382, 493, 621, 638, 744, 750, 1000, 1021, and 1140. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Satellite system reliability under high radiation

AUTHOR: Richard M. Jaeger, Philco Corporation, Western Development Laboratories

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 148-155

PURPOSE: To present formulas with which one may predict the reliability of a semi-random satellite system from a knowledge of basic system parameters.

ABSTRACT: The problem considered in this paper is as follows: given a knowledge of the reliability of individual boosters, satellites, and dispenser mechanisms, to determine the launch frequency necessary to establish and maintain a given satellite system population. A related question is that of satellite system cost, which may be answered by relating the reliability of major system components to the launch frequency necessary to establish and maintain a given system population.

The following three models of satellite life distribution are considered: exponential, truncated exponential, and joint normal and exponential. Exact solutions are presented for the expectation and variance of the distribution of the number of satellites operating actively in orbit immediately after any given launch. Approximations to the entire probability distribution are also included. A numerical example is given.

REVIEW: This paper poses a straightforward mathematical-statistical problem and presents the solution based on stated assumptions. Only slight reference is made to the practical utility of the results. There is no lack of mathematical detail, most of which is given in an appendix.

There is a minor misprint in Equation (1), in that bnc should read bNc. Also in Equation (1), and in some other places, it would seem that P should carry a subscript j since P is a function of j and is summed over j.

The reference to high radiation in the title of this paper tends to be somewhat misleading since the paper is not concerned with radiation or radiation effects as such. ##

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Serial Number 1189
Codes 824;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability model of a complex system

AUTHOR: Richard V. Bredemann, The Emerson Electric Manufacturing Company, St. Louis, Missouri

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 156-165

PURPOSE: To show that the Weibull distribution gives a good fit to the failure data and to analyze the data using it.

ABSTRACT: Reliability performance measurements for the active tail defense system for a strategic bomber is the basis for this study. In addition to the time-to-failure measurements, considerable engineering documentation of cause of each failure is the basis for grouping the data into various classifications for the study.

Four mathematical models were considered in attempting to establish an expression that would accurately reproduce the measured reliability performance. The models used were the constant hazard, a linearly changing hazard, a quadratic hazard and the two-parameter Weibull. The expressions for each of these models are:

$$\text{Model 1}: \quad R = \exp(-k_o t)$$

$$\text{Model 2}: \quad R = \exp(-k_o' t - k_1' t^2)$$

$$\text{Model 3}: \quad R = \exp(-k_o'' t - k_1'' t^2 - k_2'' t^3)$$

$$\text{Model 4}: \quad R = \exp(-t^c/a).$$

Standard regression methods were used to fit the data and various measures of goodness of fit were calculated. The Weibull was selected as best. The data were analyzed by considering various time periods and various causes of failure. The largest single sub-population of failures is the group caused by maintenance activity. All parts had a decreasing failure rate ($c < 1$). Several graphs and tables are used to compare the behavior of the many sub-classifications.

REVIEW: This is a case-history type of paper with actual numbers. The presentation is well done and furnishes information of use to engineers who want to know what is happening to other people.

While the mathematical methods used are not described in detail, it is possible that not enough care was used in the regression analysis, since cumulative data are not independent, yet independence is a customary assumption in regression analysis. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design analysis: an effective reliability tool

AUTHOR: Arthur C. Littleford, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 166-173

PURPOSE: To present the design review approach used by the Sandia Test Equipment Group.

ABSTRACT: Design time for a Test Equipment designer is often affected by continuous changing of the test requirements and a multitude of other related design responsibilities. As a result, allotted design time often becomes inadequate and the reliability of the system is sometimes jeopardized. To overcome this type of situation, the Sandia Test Equipment Group developed a Systematic Independent Design Review Program.

The primary objective of the independent design review is to verify that the electronic and electro-mechanical apparatus will reliably perform their intended functions. This verification is conducted concurrently with the design in order to be more effective and to be of value to the designer.

The technique discussed in this paper to implement this type of program involves:

1. A detailed analysis of every circuit, sub-system, and system for the "worst case" standpoint,
2. Circuit simplification,
3. Determining and minimizing the electrical stresses on components, and
4. Proper application of individual parts.

This approach has proven to be very practical and successful at Sandia where:

1. Reliable equipment is a necessity,
2. Design time scales are often very short, and
3. The quantity of units to be fabricated from the design are small, usually one to four.

The results of such a reliability program are in evidence by the complete change in the attitude of the majority of the design personnel that want to make reliability an intrinsic characteristic of their designs. Many designers are using the reliability group as consultants on components and circuits while conceiving a design. The effectiveness of the program can also be measured by the small number of field failures that have been reported on designs receiving such a review as compared to the systems designed before the program was initiated. (Author)

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REVIEW: This is another example of how design reviews are conducted. If the design people have become as enthusiastic about the program as the author seems to think, the program must indeed be considered a success. Worst-case design has both advantages and disadvantages. One of the bad parts, for example, is that the circuits may be less "efficient" and more of them may be required, especially in multistage digital systems. Where the disadvantages are not a problem, the worst-case philosophy is very good.

The author, in a private communication, has indicated that the Test Equipment Group at Sandia feels that this approach meets their requirements much better than a statistical approach, which is the best method for designs that are to be fabricated in large quantities.

Other papers on design reviews have been covered by Abstracts and Reviews Serial Numbers 25, 26, 29, 125, 183, 190, 193, 245, 273, 275, 382, 493, 621, 638, 744, 750, 1000, 1021, 1140, and 1187. ##

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Serial Number 1191
Codes 820;837;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of serial systems and redundant systems

AUTHOR: Leo A. Aroian, Space Technology Laboratories, Redondo Beach, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 174-185

PURPOSE: To summarize some of the basic formulas for the reliability of redundant systems.

ABSTRACT: The theory of reliability of systems in series and redundant systems is developed. Formulas for the tolerances of sums, differences, and the product of two or more variables are given, including the quotient of two variables. A short discussion on the evaluation of incentives concludes the paper. (Author)

Twenty-five problems are given at the end.

REVIEW: This is a good summary article on the subject except that more care should have been taken in distinguishing between the logical network and the real network. For example, one might be tempted to analyze the quad circuit, so popular with some people, by using the logical networks (10.6) and (10.7) which look like it. But this will not give correct answers since the elements may fail by opening or shorting and when they operate they are neither shorted nor open. Suppose each element has a probability p of working, a probability q_o of failing open, and a probability q_s of failing short. Then the reliability of the structure represented by the picture of (10.6) is

$$R = p^4+4p^3q_o+4p^3q_s+4p^2q_o^2+2p^2q_s^2+12p^2q_oq_s+4pq_oq_s^2+8pq_o^2q_s.$$

The reliability of the structure represented by the picture of (10.7) is

$$R = p^4+4p^3q_o+4p^3q_s+2p^2q_o^2+4p^2q_s^2+12p^2q_oq_s+4pq_o^2q_s+8pq_oq_s^2.$$

Obviously, neither of these is anything like the equations from the logical networks.

The discussion of combinations of variables with normal distributions is better than that found in the paper covered by Abstract and Review Serial Number 1185. No answers are given for the 25 questions, which is a disadvantage in a tutorial paper. ##

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Serial Number 1192
Codes 612;831;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability simulation model

AUTHORS: B. H. Hershkowitz, M. E. Wheelock, and D. P. Maher, North American Aviation, Inc., Space and Information Systems Division, Downey, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 186-200

PURPOSE: To describe a method of simulation used for making reliability predictions.

ABSTRACT: The Reliability Simulation Model simulates the operation of a vehicle for a large number of missions, and it determines the number of mission successes and mission failures by the application of a Monte Carlo technique.

In applying the simulation model, logic diagrams are constructed to define the combination of components required to complete each function of each phase of a mission. The failure density distribution for each of these components is obtained from test data or estimated failure rates, and the component time of failure is determined by the application of the Monte Carlo technique.

When mission failures occur, the model becomes a decision-making device, as it determines what form of an alternate mission is to be initiated. The form of alternate mission is a function of the combination of component failures at the time of mission failure. The alternate mission may be a continuation of the mission with lesser mission objectives or a return mission to enhance the safety of the crew. Thus the model provides the probability of both mission success and crew safety. (Authors)

REVIEW: This is a good paper on a worthwhile topic. Some of the discussion may not be too clear to those without considerable background in simulation. The absence of figures (which accompanied the oral presentation) makes the paper less easy to understand.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of a basic systems-reliability model

AUTHORS: W. S. Thompson and C. A. Krohn, Research Triangle Institute, Durham, North Carolina

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 201-216

PURPOSE: To present a basic mathematical model for use in reliability studies of an element or system.

ABSTRACT: A fundamental reliability model has been developed to guide improvements in reliability techniques for use in the design of new systems and the evaluation of existing systems. It provides a complete framework within which the variables influencing reliability are included. The performance of the system is considered to be characterized by certain attributes, and the reliability depends upon the behavior over time of these attributes with respect to preselected failure criteria. Performance attributes of the system are related to pertinent attributes of lower-level elements (parts, assemblies, or subsystems). The usual restriction of statistical independence among all the elements is not made. The attributes of the elements are assumed in general to be random variables arising from the combined effects of element structure, signals, power, and environmental stresses. Both catastrophic and drift failures are considered. Reliability is defined in terms of both the probabilities associated with the attributes and some expanded concepts of catastrophic failures.

The model takes the form:

$$R(t) = \int_{\Gamma_{\underline{a}}} \left[e^{-\int_0^t h(\tau|\underline{a})\, d\tau} \right] \cdot \left[\int_{\Gamma_{\underline{v}}} f(\underline{v};t|\underline{a})\, d\underline{v} \right] f(\underline{a})\, d\underline{a},$$

where $\underline{a}$ includes the environmental and input factors, and $\underline{v}$ includes the performance attributes. The exponential term is the time-dependent hazard of catastrophic failure while the second term characterizes the drift beyond acceptable limits.

A limited application of the model is made to the amplifier of an inertial guidance system. Three forms of application are considered: (I) where the critical environmental and input conditions and their ranges are known, (II) where those conditions are unknown, and (III) where they are initially unknown but become known. (Authors in part)

REVIEW: The availability of a sound, usable reliability model to guide

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both the design and testing of systems and their elements is highly desirable. But usable in this context means usable by the practicing engineer. It must be readily understood, have clear-cut statements of the required input information, straightforward methods for handling situations where part of the data is unknown, and readily interpreted results. In short, the model must be attractive to use. Its broad generality and the rigor of its derivation are of secondary importance if the limitations of the model are known.

The basic concept of the model presented is not too difficult to grasp. The application of the model is not nearly so obvious and the examples given offer no help. Discussion of various factors is hedged by such phrases as: "Use of failure rates can therefore be misleading as to the true nature of the amplifier behavior." And after what appears to be a specific statement there is the comment: "Such a situation, however, seldom exists in practice." The authors note, in a classic understatement, that the "combined deterministic and probabilistic multidimensional analysis, considering interactions, readily becomes unwieldy." But there is precious little help for the struggling engineer.

The following typographical errors have been noted: (1) in equation (23) the subscript c should not appear on R(t), and (2) the closed loop static gain of the amplifier (pp. 208 and 209) should be $D/Hk_Sk_Pk_Ak_M$ instead of $H/Dk_Sk_Pk_Ak_M$.

The model appears to be well founded. What is lacking is the translation from theory to practice. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Stochastic evaluation of reliability

AUTHOR: Paul S. Olmstead, Consultant, 1 Lippincott Road, Little Silver, New Jersey

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 217-225

PURPOSE: To consider ways to examine past test data relating to reliability so as to provide more meaningful estimates of what future test data will show.

ABSTRACT: Some historical aspects of reliability and quality control together with a discussion of the philosophies involved are given. Six points which are considered basic are:

1. Most engineers believe that, for a part to be satisfactory, it must be made right.
2. Reliability can be established only by a life test, i.e., by a destructive test.
3. The reliability rating of a product is the reliability rating of the process that produced the product.
4. Test of a sample from a lot tells very little about the quality of the lot, but test of a series of samples representing a series of lots tells a great deal about the quality of the product from a process.
5. Valid prediction from a set of statistical data is possible only when the statistical data meet an appropriate criterion of statistical control.
6. Inspection costs for a given consumer risk when applied to determination of reliability of a particular lot of product are often many times the cost of making the lot.

It is essential that the producer and consumer both know that the process average is good enough so that sampling plans with high consumer's risks actually give adequate protection. If the producer is striving for perfection and if his evaluations are to be meaningful, these four conditions must be met:

1. The producer should have an adequate program for determining the cause of any trouble discovered and for instituting corrective action to prevent its recurrence (or at least to reduce the probability of its recurrence.)
2. The process should be monitored for statistical control.
3. The process should be monitored on a cumulative basis for stochastic approach to a justifiable predicted value subject to appropriate statistical interpretation.
4. Test results should be monitored for conformance to the assumed applicable statistical distribution (e.g., exponential or other appropriate substitute).

The first two points are handled by well-known engineering and

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statistical procedures. The last two are dealt with in the remainder of the paper. If cumulative failures are plotted against total operating time using the scales given in the text, the locus of given failure rates for a given consumer's risk is a family of straight lines with a common intersection point which depends on the risk. Thus cumulative performance can easily be viewed and the demonstrated mean (conditional) failure rate (up to any point) is easily found. It is also possible to test the assumption of unchanging failure rate. Examples are given to illustrate the procedures. (Author in part)

REVIEW: The historical and philosophic parts of the paper are both interesting and adequate. While some of the points have been made before, they need constant reshaping and emphasis.

The exact purpose and use of the charts are not entirely clear. For example, one would be tempted to plot the cumulative results of samples and say that the first crossing of any failure rate line (p_t) at the stated consumer's risk (β) would demonstrate p_t with risk β. On the other hand, one might wish to know what the cumulative behavior would be for a given p_t and β. But the concept of consumer's risk is not defined in this circumstance (as explained below) and the author has not definitively stated what the cumulative behavior will be. Another interpretation is that of confidence growth as compared to reliability growth. See, for example, the paper covered by Abstract and Review Serial Number 1215. For a given low failure rate, one tends to have a low statistical confidence at first because of small sample size. As the sample size increases, we gain confidence that the low failure rate is an accurate description of the product. Thus, by hypothesis, the failure rate remains the same and the confidence level increases; the other way of looking at it, i.e., that the confidence level stays the same and the failure rate decreases seems to violate the assumptions about the process.

The foundation of the graphs is not clearly given nor is the notation properly defined. m is the true value of the Poisson parameter and c is a random variable denoting the total number of failures in any particular sample. The statement "...the distribution of $m^{1/2}-(c+1)^{1/2}$ is asymptotically normal with unit variance" should read "...the distribution of $2[m^{1/2}-(c+1)^{1/2}]$ is asymptotically normal (Gaussian) with zero mean and unit variance." This is true, as the author implies, for the Poisson distribution. The approximation of normality is much better than one would expect offhand, even for values of c equal to 0 or 1. The graph is derived from a plot of $m^{1/2}=(c_\beta+1)^{1/2}+g_\beta$ where g_β is a standard

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Gaussian variable associated with confidence β. For each g_β, there is one line when $m^{1/2}$ is plotted against $(c+1)^{1/2}$; however, when $N^{1/2} = (m/p_t)^{1/2}$ is plotted against $(c+1)^{1/2}$ (as in the paper) there is a whole family of lines for each β--one line for each p_t. The various values of p_t are, in effect, scale changes for m.

It should be noted that the discrete values of c introduce some problems. For example, for a given m and β, it is not always possible to find the c, although for a given m and c, it is always possible to find the β. If the curves are used for estimating the true parameter, the confidence statement will generally read "... at least 1-β confidence ..." and the consumer's risk would be "... at most β ...."

In a cumulative plot across the chart, the concept of consumer's risk is not defined. It is defined for single samples, but in a cumulative plot, successive points are highly correlated and the meaning of confidence levels (consumer's risk) would be quite different from that for single samples. This is the reason for the simulation runs made by the author: to see how the cumulative curve behaves against lines of constant β. Unfortunately, no definitive conclusions were reached and it is not possible to say what this behavior actually is. This, of course, limits the usefulness of the method.

Another point discussed by the author is what to do on the cumulative graph when a poor batch is encountered and the cause of poor quality is subsequently found. His procedure is a reasonable one, as are others--but statistics has little to do with any of them. In this situation, technical judgments about the process are most important.

The method given for comparing the first and last halves of a cumulative sample is correct and is as good as can be done. The concept of checking for the validity of constant p_t is excellent.

The use of N as total operating hours implies a constant (conditional) failure rate--the "exponential" assumption. This is an important assumption and should have been stated explicitly.

In summary, the utility of the author's method is diminished because its probability characteristics are not known exactly. However, the type of plot presented may be helpful. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The relation of engineering to very high reliability

AUTHOR: Major General Leslie E. Simon, USA (Ret.), Consultant, Science and Management, 1761 Pine Tree Road, Winter Park, Florida

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 226-232

PURPOSE: To give a perspective view of the engineering and statistical functions in their roles in the achievement of high reliability.

ABSTRACT: This paper presents a broad view of the various sub-fields of applied statistics and the roles which they play in conjunction with engineering and management in the achievement of practical results and in the creation of new designs with potentially better reliability than previously available. The evolution and the interrelationships of the fields of Statistical Quality Control, Operations Research, and Reliability are briefly considered. The problem of demonstrating very high reliability is discussed. It is concluded that the relation of very advanced engineering to very high reliability is much like that of ordinary engineering to industrial statistical quality control. In both cases it is a matter of teamwork between the engineer who is concerned with getting the job done and the statistician who is concerned with its contemplative, analytical and theoretical aspects. As we move up the scale in engineering techniques from plant operation to design, we must expect the tools of the statistical partner to move from simple statistical quality control to the more sophisticated methods of very high reliability.

REVIEW: This paper is concerned with the broad picture rather than with technical details. It should be useful primarily to managers or other persons who plan organizations, particularly organizations which should be concerned with the interfaces presented by the teaming of diverse disciplines in today's fast-moving administrative, scientific and technical interplay. It should also be useful to persons operating within the respective disciplines, in leading them to understand how and why they should lend help to and receive help from persons of other disciplines. ##

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Serial Number 1196
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860 /

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A reliability management system

AUTHOR: H. Kimel, Re-entry Systems Department, General Electric Company, Philadelphia, Pennsylvania

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 233-249

PURPOSE: To describe a reliability management system which has been developed and used successfully for the implementation of the reliability effort on ballistic missile and space programs.

ABSTRACT: The determination that a required reliability has, in fact, been achieved may be extremely difficult. The customer is not willing, and management cannot afford, to wait until a program is virtually complete to determine whether it will result in success or failure. The development work must be planned and carried out in such a manner that all practical steps are taken to achieve high reliability. Stipulating and monitoring the accomplishment of essential tasks during the program will provide the necessary assurance that the required reliability will be attained.

A reliability management system is an organized effort to assist management in the decision-making process on attainment of reliability of hardware. Its characteristics include the following: reliability event, procedure, scheduled effort, check and balance system of review, and a documented report. Specific management subsystems are discussed, detailing for each the objectives, the flow of work, essential elements and benefits peculiar to the specific subsystem. The subsystems considered include: reliability qualification, reliability design analysis, reliability measurement/demonstration, failure reporting and analysis, design review, supplier reliability, and parts application.

Associated with the reliability management system is a reliability management matrix, which provides management with a comprehensive visualization for monitoring and evaluating compliance with planned reliability activities and events. It is a particularly valuable tool in presenting risk information, thus allowing for reasoned decisions by management. The reliability management system is, in effect, an orderly implementation of the reliability program plan while the reliability management matrix provides visualization to management of progress towards accomplishment of the plan. (Author in part)

REVIEW: This is a fairly comprehensive description of a reliability management system which has been implemented successfully. As such, it should serve as worthwhile reading for those who are concerned with setting up similar programs. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Human factors in design of reliable systems

AUTHOR: Alan D. Swain, Reliability Department, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 250-259

PURPOSE: To discuss the importance of human errors in man-machine systems, to describe ways of reducing such errors to an acceptable level, and to give some pointers on the implementation of good human factors practices in designing reliable systems.

ABSTRACT: Since human reliability is such a major part of system reliability, attention to techniques of reducing human errors should produce great gains in system reliability. First, however, it is necessary that more design engineers and planners appreciate the importance of human errors. Then these men must recognize that the greatest improvements in human effectiveness usually stem from designing equipment and production systems compatible with characteristic human capabilities and limitations. Ordinarily, attempts to improve worker or operator proficiency through changes in motivation have limited payoff.

Engineers can be taught to handle human factors concepts and do much of the required human engineering themselves. But this capability, as valuable as it is, does not eliminate the need for a competent human factors staff. In fact, this staff is needed to instill an appreciation of human factors and a grasp of human factors concepts in design engineers. The small added expense to permit human factors inputs in the design of equipment or production processes is likely to pay for itself many times over. One only has to consider the consequences of human errors in the fabrication and use of systems.

Suggested design practices aimed at reducing human errors include the following: design for the operator in the operator's environment, beware of symmetry, be sparing in the use of man as a monitor, make the task interesting or forget about judgment or memory, conform with populational stereotypes, and minimize or prevent connection errors. (Author in part)

REVIEW: This paper will constitute worthwhile reading for those who are concerned with the effects of human errors on system reliability. It is a cogent presentation and contains good suggestions for dealing with the problem. Other papers dealing with the human element as it affects reliability and maintainability have been covered by Abstracts and Reviews Serial Numbers 188, 196, 240, 248, 267, 480, 502, 565, 567, 712, 840, 841, 842, 843, 854, 910,

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911, and 912.

The author cites documentary evidence in support of the conclusion that "if factors such as motivation and training are in the range of average, as they usually are, only relatively minor improvements in workmanship can be effected by an upward change in such factors," and goes on to say that "frequently these improvements are only temporary." He states further that "it is only when motivation or training for the job are very poor that major improvements in these factors should produce corresponding major improvements in workmanship and therefore decreases in production errors." However, there is some evidence which tends to refute the above "principle." An outstanding case in point is the Martin Company's ZERO DEFECTS Program, which appears to have met with considerable success, and counterparts of which have been implemented by other companies in this country. The program originated from the desire of a company which was already doing well to do better by "motivating people to do their assigned tasks right the first time." Martin Company literature describing the concept says in part "ZERO DEFECTS is a motivation program which has sparked a response far beyond our expectations. The heart of the program is to develop a constant, conscious desire on the part of each employee to perform the job (any job) right the first time." It is suggested that those who desire more information on the program address a request to Mr. Dwayne Gray, ZERO DEFECTS Program Administrator, Martin Company, P. O. Box 5837, Orlando, Florida. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Product assurance training--a tutorial paper

AUTHOR: M. M. Tall, Radio Corporation of America, Camden 2, New Jersey

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 260-265

PURPOSE: To describe a complete training program covering management and product assurance personnel.

ABSTRACT: The need for product assurance management to upgrade available skills and provide their personnel with a thorough grounding in fundamentals is outlined. Many product assurance personnel do not have a basic understanding of the disciplines they are practicing; this is true for some product assurance management as well. A good training program should be aimed at providing each member of the team with the understanding necessary to perform his specific assignment effectively and with a basic understanding of the overall program so that he may be of assistance in other areas when required.

Topics discussed include the following: the importance of understanding the non-absolute quality of the numbers used in practice, the problem of the lack of universal agreement on definitions, the importance of understanding the usefulness and limitations of system models, and the role of the training program in the areas of parts and materials and design. A curriculum for a two-week basic course in reliability is given. The product assurance training needs of management and engineering personnel are discussed. Emphasis is placed on the concept of a basic understanding of the overall program; it is indicated that the stress is on skill training, not on orientation or propaganda.

REVIEW: This is a good paper for the purpose which the author had in mind. The material is concisely and cogently presented.

In a somewhat different connection, two sentences from this paper seem to be worthy of quotation and emphasis. They are the following. "The glib tongue and the slick brochure is inadequate in the atmosphere now pervading government circles. Product Assurance personnel will have to produce if their companies are to remain competitive." ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Total annual cost, a reliability criterion

AUTHOR: Barbara Fox, Bell Telephone Laboratories, Whippany, New Jersey

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 266-273

PURPOSE: To derive and analyze a model of system cost per year vs. reliability of components.

ABSTRACT: Present studies of the cost of reliability tend to concern themselves either with the total cost to the manufacturer of a reliable product or with minimizing maintenance costs. A more meaningful criterion, which would take into account all elements of the cost of a system regardless of when or by whom incurred, might be total annual cost.

Total annual cost consists of: (1) manufacturing cost of a system, installation costs and design costs, all prorated over the number of years of useful system life, plus (2) the annual maintenance cost, plus (3) the annual operating cost.

The following additional assumptions are made: (1) the failure behavior is "exponential," (2) the time value of money is neglected (interest rate on capital is zero), and (3) costs which depend on λ (hazard function) of the average component are linear functions of λ^p or $1/\lambda^p$ depending on whether they are increasing or decreasing. The final expression for annual cost is of the form: Annual Cost = $(A/\lambda^p) + B\lambda^p + C$, and thus has a minimum at $\lambda^p = (AB)^{1/2}$

An analysis of the consequences is given. Some of the broader conclusions from the analysis are:

1. System design must anticipate future needs since the maximum operating life is needed to exploit fully the potentials of low failure rate parts and the maximum number of systems should be manufactured from the same basic design to allow the broadest base for allocation of design costs.

2. In most cases it is economically justifiable to seek the lowest failure rate parts presently obtainable. The optimum level, particularly for long life systems, is almost always lower than the present state of the art provides.

3. A system must be designed to make the best possible use of these low failure rate parts so that their reliability is not diminished by their use in the system. (Author in part)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This is a good analysis of a model, but the conclusions are just a reflection of the assumptions. One unstated important assumption is that there are no down-time (planned or unplanned) costs other than those listed for maintenance. Some of the implicit factors in the various terms are said to cancel out in the expression for optimum λ. Since it is not obviously so, it would have been better to make them explicit. (The use of λ and λ^p--sometimes interchangeably--tends to be confusing.) It will be noted that expressions of the form $f=(A/x)+Bx+C$ have a very broad minimum especially where $A, B, C > 0$. In the figures, for example, a 10:1 change in x produces less than 30% variation in f; thus the location of the exact minimum may not be too important a criterion.

It should be emphasized again that the results from this analysis are a reflection of the assumptions made explicitly and implicitly. Different assumptions might well cause rather different results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Incentives for reliability

AUTHOR: K. A. Frederiksen, Space Systems Center, Douglas Aircraft Company

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 274-285

PURPOSE: To describe some techniques for employing reliability incentives.

ABSTRACT: Fairly sizeable portions of the total incentives are allocated to performance and reliability. This emphasizes the importance of reliability to the customer and gives management a profit motive attached to reliability achievement.

The importance of first establishing a realistic reliability requirement must also be emphasized. In reviewing the various plans presented and referenced, one important characteristic is common to most. This characteristic is in the multiple approach of apportioning the reliability incentives a number of ways. Another important consideration, discussed in several programs, is the establishment of reliability incentives <u>after</u> a period of time during which meaningful data can be accumulated. This, of course, permits a firm base upon which to establish the reliability goals.

Five important considerations are: (1) to establish a realistic and optimum reliability requirement, (2) to allow for a growth factor to provide profit motivation for reliability improvement, (3) to base the program on experience--not conjecture, (4) to provide for several phases and sub-plans to apportion the incentives in many areas, and (5) to negotiate the incentives with subcontractors and vendors to share the responsibility. (Author in part)

REVIEW: This is a rather detailed discussion of some of the reliability incentive programs at Douglas Aircraft Company. These incentives are going to be a very important part of any reliability program since they give managers about the only kind of pressure that can be depended upon to be effective. ##

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815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability incentives in destructive test programs

AUTHOR: Neil E. Hoesel, Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 286-292

PURPOSE: To describe the definition and approaches taken for a CPIF contract for a solid rocket propulsion system.

ABSTRACT: Aerospace contracts are inclined toward a greater application of incentives which reward good performance and penalize poor performance. The shift, which dropped CPFF contracts from 38 to 22.7 percent in 1963, places capability and technology of a contractor directly in balance with profit and loss of the company. In present incentive type contracts, the producer must excel in performance, as well as cost and schedule, in order to receive maximum profit.

To determine accomplishments during the life of a program, both producer and consumer must agree on definitions of performance and the method of measuring achievements. Reliability, as one of the performance incentive factors, requires definition before contract negotiation and accurate measurement after contract award. Reliability definitions vary with the type product and program.

The customer establishes general reliability requirements, design objectives, quantitative requirements, and confidence levels in the request for bids. The contractor defines the method of measurement, failure definitions, reliability estimates and proposes the incentive formula. In negotiation, tradeoffs are made with both customer and contractor aware of the capabilities and risks.

REVIEW: This paper illustrates the importance of tailoring reliability incentives to specific programs, and the necessity for carefully understanding all phases of the incentive.

These incentives may well turn out to be the most important part of any reliability program and optimize consideration for product reliability by both customer and management. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability program plan to implement MIL-R-27542

AUTHORS: E. S. Dean and E. A. Polgar, Lockheed Missiles & Space Company

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 293-309

PURPOSE: To present a reliability program plan in response to MIL-R-27542.

ABSTRACT: This paper compares the paragraphs of a Lockheed Reliability Program Plan for a highly successful research satellite vehicle with the Military Specification on Reliability Program Requirements for Aerospace Systems, Subsystems, and Equipment, MIL-R-27542. The paper gives an interpretation of the reliability tasks, and discusses the problems encountered at contract negotiations and the problems in implementing the program. Accomplishments under similar Reliability Program Plans are referenced.

A Revision A to MIL-R-27542, dated 21 May 1963, was issued subsequent to the establishment of the subject Reliability Program Plan. The Revision A is now being reviewed by Lockheed Space Systems for applicability to current and follow-on programs. A preliminary review indicates that the contractor reliability program under the revised military specification would not vary significantly from the program discussed herein. (Authors)

REVIEW: This is a detailed paper, presenting both a complete reliability plan for MIL-R-27542, and a discussion of the tasks contained in it. As MIL-R-27542 is apparently becoming the standard Air Force reliability specification and the included program plan was actually negotiated, this paper is a useful reference. It can serve as a model for reliability program plans for smaller companies, and as a basis of comparison for programs for larger companies. Both the military specification MIL-R-27542 and this program plan reflect considerable experience, and are a vast improvement over their earlier counterparts. Although these approaches reflect growth and encourage reliability improvement, they will not absolutely ensure reliability. In the absence of meaningful reliability measures and contractor financial responsibility, a specification and plan are only as effective as the collective intentions and knowledge of the contractor and the government procuring agency. There can be costly reliability programs that make little meaningful contribution to improved reliability. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design review

AUTHOR: Marion P. Smith, Honeywell Aeronautical Division, 13350 U. S. Highway 19, St. Petersburg (33733), Florida

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 310-313

PURPOSE: To provide a review of techniques and principles recommended in setting up and carrying out a sound design review program.

ABSTRACT: Design review, when handled properly, can provide a major contribution to the creation of a reliable design, and can also provide management organizations with assurance that proper design principles, insofar as it is possible to measure them, have been followed. Major hazards can be avoided by recognizing the need for both formal and informal types of design review in a design and development organization. Design review cannot, of course, take the place of adequate design supervision. The design supervisor must provide for conservative derating practices and assure the use of adequate stress analyses as designs progress, thus providing a climate for good initial designs which no amount of design review can replace.

The need for well-identified policies and procedures for design review is emphasized. The features of formal design reviews are described. The value of internal or informal design reviews is indicated. Recommendations are made regarding some of the basic items which should be included in well-constructed design review policy statements. Suggestions are made regarding the timing of reviews at appropriate points in the design and development cycle. While the listed suggestions are presented from the point of view of an electronic system supplier, they can be adapted to meet the design review planning needs of most organizations.

REVIEW: This is a concise presentation which accomplishes its purpose quite well. As the author remarks, the subject of design reviews has been treated extensively in the literature. He cites seven references to documents containing checklists, recommendations for methodology and selection of participants, and discussions of techniques and philosophy. Two of the references cited were covered by Abstracts and Reviews Serial Numbers 26 and 493 respectively. Other papers on design reviews have been covered by Abstracts and Reviews Serial Numbers 25, 29, 125, 183, 190, 193, 245, 273, 275, 382, 621, 638, 744, 750, 1000, 1021, 1140, 1187, and 1190. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability testing and assessment

AUTHOR: W. T. Sumerlin, McDonnell Aircraft Corporation, St. Louis, Missouri

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 314-329

PURPOSE: To provide a tutorial recapitulation of the sequential assessment methods of AGREE.

ABSTRACT: This paper is a tutorial summary of the statistical methods associated with the testing and assessment of the reliability of complex units of hardware. Situations in which the exponential distribution of times between failures is applicable are emphasized, since they occur most frequently in dealing with complex equipment. However, testing of one-shot items which follow the binomial distribution is briefly covered, and the test of parts with failures normally distributed and Weibull distributed is also mentioned for reference. Emphasis is placed on sequential testing because this method also takes into account the variation between successive failures (or between successive tests in the binomial case) and thus is more efficient. Furthermore, the sequential tests described are truncated at an early point in order to guard against the principal drawback of the sequential test, the possibility of indecision. Finally, the consideration for the retest, which usually follows an unfavorable decision, is examined for effect on the assurance provided, and a revised type of sequential test is suggested to eliminate the penalties of retest. Evaluation of sequentially observed failures by a sequential yardstick to maximize the inference drawn is described in the concluding remarks. (Author in part)

REVIEW: This paper should be very worthwhile reading for those who are concerned with the statistical aspects of the evaluation of the reliability of complex equipment. While the paper is in the nature of a summary, some 26 references are cited for those who may desire more details.

Particularly commendable is the author's discussion of random failures; it should be helpful in dispelling the misconceptions which sometimes exist concerning the meaning of this term. In this connection, the following two sentences from the paper are worthy of quotation and emphasis. "All failures have a cause based in physics and engineering, even though in many cases we are unable to determine the cause or the mechanics of failure. It is the nature of these causes, or the mixture of characteristics produced by mixed causes, that permits a given statistical distribution function to adequately represent the physical situation

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for the purpose of calculation."

It may be worthwhile also to draw attention to the qualification implied by the word "adequately" in the above, with the reminder that the degree of adequacy will vary from one situation to another. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure from a materials point of view

AUTHOR: Charles F. Bild, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 330-337

PURPOSE: To discuss some ways in which materials fail, and some approaches to the choice of materials so as to minimize failures.

ABSTRACT: Incorrectly chosen materials and poor processing result from design and manufacturing mistakes and ignorance of how materials age. Materials failures may result from such factors as excessive mechanical/electrical stresses, return to an equilibrium state (stress relaxation, etc.), thermal effects, evaporation, chemical/biological reactions (fungus, etc.), wear, and radiation damage.

These failures can be minimized during the design phase by such means as thorough analysis of functions vs. failure mechanisms, using known materials in known ways, testing materials under use conditions (life tests, etc.), tests to destruction to find safety margins, and analyzing last-minute changes and their effects. During manufacturing one should control and analyze incoming materials and define, control, and check all of the processes. Lastly one should check stocks for aging effects.

REVIEW: This is a rather qualitative paper to acquaint designers with the general problems of materials. Materials analysis is part of the need for infinite attention to detail in every phase. ##

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Serial Number 1206
Codes 740;831;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating control computers

AUTHORS: G. C. Hendrie and R. W. Sonnenfeldt, The Foxboro Company, Natick, Massachusetts

SOURCE: ISA Journal, vol. 10, August, 1963, pp. 73-78

PURPOSE: To discuss and compare important characteristics of on-line industrial computers.

ABSTRACT: Evaluation of on-line control computers is based on three characteristics: (1) reliability, (2) speed margin with respect to worst-case demands, and (3) storage size margin with respect to worst-case demands. There is no single, simple measure of overall machine speed in problem solving. In comparing control computers, add and multiply times, memory access time, and time required for double precision arithmetic must be considered in view of the proposed application of the machine. The manufacturers' specifications for ten control computers are given, and a speed comparison is given for an example arithmetic problem and for a series of logical manipulations. The SDS 910, the Daystrom 636, and the PDP 4 are also compared on the basis of a more realistic on-line control problem.

The required memory or storage size is more easily determined. Choice of the ratio of size of high-speed storage to size of low-speed storage is a problem, however, as is transfer time between the two stores.

Reliability, in terms of mean time between failures (MTBF), can be calculated from known diode and transistor failure rates, or can be determined from failure history of the actual machine. The latter method is preferred insofar as accurate prediction of MTBF is concerned, although a great many failures must be observed before a prediction can be made with confidence. All in all, conservative design appears to enhance reliability, and could be used as one basis for reliability comparisons in the absence of field data.

REVIEW: This is a semi-technical article recommended for the reader who desires an introduction to the characteristics and comparisons of industrial control computers. The topics discussed are all worthy of consideration, and the problem of predicting system reliability is well illustrated. Some of the authors' conclusions appear to be aimed toward some unspecified particular application, and are not universally applicable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Increasing service life of L3 repeaters

AUTHOR: Mrs. D. M. FitzGerald

SOURCE: Bell Laboratories Record, vol. 42, pp. 21-26, January, 1964

PURPOSE: To describe modifications necessary for improvement of the service life of the L3 transcontinental coaxial carrier system.

ABSTRACT: About one quarter of the long haul message service mileage of the Bell System is carried by the coaxial carrier systems, primarily L3. A single coaxial L3 carrier system can carry 1860 message channels in one direction. Most routes are capable of carrying three times this many messages or about 5600 message circuits in both directions. One of the biggest problems from the standpoint of service and cost is maintenance. Maintenance and servicing of line equipment alone cost approximately three million dollars per year. The major item affecting maintenance expense is the repeaters, spaced about every four miles. There are approximately 1800 such repeater stations on L3 systems, of which about 85 percent are unattended huts. Each station contains at least eight amplifiers. Each amplifier contains five long-life electron tubes and the feedback circuitry required to ensure high amplifier stability. In addition, regulators to control amplifier gain automatically and power supplies to provide proper tube voltages are located in the stations. The complex circuitry at each station requires a schedule of routine maintenance visits that are presently made at three-month intervals.

New developments in electron tubes (such as improved pumping and cleaning, double carbonate cathode coating, and high purity nickel anodes) are expected to double their service life. Better heat conducting shields will allow the tube envelopes to operate at much lower temperatures. Some circuit changes were made and some newer type components were introduced to alleviate some of the problems. Service and installation procedures were reviewed and upgraded where necessary.

By this means of circuit and component analysis, study of service procedures (in the field) and records, and engineering attention to detail, the amplifier life has been increased to an estimated 20 years (exclusive of tubes) and to an estimated 3.5 years (including tubes). (Author in part)

REVIEW: This is a case history type of article and shows the attention that must be paid to all sorts of details to effect an improvement in existing equipment with a redesign. Many of the failure origins had their roots in human frailty--a not uncommon circumstance. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability problems of electronics in space

AUTHOR: S. W. Herwald, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania

SOURCE: 6 pp., presented at the Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, November, 1962

PURPOSE: To give a philosophical discussion of the new challenges to electronic reliability in space, and some of the potential solutions.

ABSTRACT: Space reliability of electronics is a tough challenge because of the exceptionally long maintenance-free life desired. On the other hand, there is a rapidly expanding body of knowledge growing relative to individual component behavior and mode of failure in the space environment. Similarly, there is new knowledge coming to the fore on really useful redundancy techniques. It is this kind of detailed understanding that has led to apparently successful initial Telstar and Minuteman reliability. It is my belief this base is solid enough to build reliable space electronics from, as long as we don't let our voracious appetite for increased performance overbalance our real knowledge. The human race has done a pretty good job so far in technically conquering each new medium in which they develop a hand hold. I don't think space electronics will be the exception. (Author)

REVIEW: This is a rather general qualitative paper on the challenges of space and as such will be of limited use to designers. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The EIA established reliability program as it relates to electronic component parts

AUTHORS: Leon Podolsky, Sprague Electric Company and J. Howard Schumacher, EIA Engineering Department

SOURCE: 7 pp., presented at the Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, November, 1962

PURPOSE: To summarize the background leading to the EIA Established Reliability Program, and the basic policies and quality assurance guide lines provided for the task forces drafting the program.

ABASTRACT: In June, 1957 the AGREE Report was issued, and was followed in May, 1960 by the Darnell Report, published by DOD. The EIA set up task forces in conjunction with users to implement these recommendations in the form of suggested specifications. (The background on these forces is given in some detail.)

It was decided to use 60% confidence (40% consumer's risk) rather than the 90% suggested in the Darnell Report. Four failure rates are specified: 1, 0.1, 0.01, and 0.001 percent per 1000 hours. A nomogram is provided, giving confidence limits vs. test time and defect levels (assuming zero defects observed).

The EIA Established Reliability Program is considered to be one of the finest examples of industry-military cooperation designed to improve and insure adequate reliability in vital military electronic equipment. In addition, it has been estimated that the completion and acceptance of this single central specification-writing activity can save as much as two hundred millions dollars per year, as opposed to the repetitive reliability specifications written by individual military equipment contractors. It is anticipated that the single basic set of established reliability specifications developed by this program will prove to be adaptable to all military electronic equipment.

REVIEW: This is a good summary of the EIA program and its background. More than a year has passed since the paper was written, but the first author, in a private communication, has indicated that a later presentation on this subject was made at the 1963 National Electronic Components Conference. The latter presentation contained later and more accurate information, bringing the subject up to date as of May 1, 1963. The author has also indicated that the output of this program is being effectively used by the Defense Electronics Supply Center in the preparation and issuance of new Established Reliability Specifications on electronic components. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Lot by lot and process control

AUTHOR: Frank J. Ruther, Defense Electronics Supply Center, Dayton 20, Ohio

SOURCE: 10 pp., presented at the Northeast Electronics Research and Engineering Meeting, Boston, Massachusetts, November, 1962

PURPOSE: To show how a simple reliability test can be set up using MIL-STD-105.

ABSTRACT: As an example of a simple reliability test and specification the Air Force bought the 6AH6 to a failure rate specification, viz. 1%/1000 hours (failure being defined by change in transconductance or heater current, opens, shorts, etc.). The lot was defined and the sample size was set at 75 tubes for 1000 hours. This gives adequate producer's risk and, at a 7%/1000 hours level, adequate consumer's risk.

MIL-STD-105 is used. A cumulative chart is also kept and 95% Gaussian limits are set, within which the process is presumed to stay the same. If it goes out on one side, the specification can be up-graded; on the other side, delivery is stopped, even if the lot-by-lot results are good.

In this case the manufacturer up-graded his line to a 0.65%/1000 hours failure rate, raised the sample size to 110,000 tube hours with no change in accept/reject number, and did not raise the price. It costs, now (1962) less than 10% extra for the reliability specification. The cause of each failure is ascertained to see if process changes are called for.

Reliability programs must be based on practical mathematics. Many people know and understand MIL-STD-105--why not use it?

REVIEW: This seems to be a good application of "acceptance testing." While it is true that the mathematics should be kept simple for the everyday workings of a plan, it may pay to have competent opinions on what the risks really are. In the example plan, for instance, the cumulative or sequential plan may have risks associated with it that are different from those expected. The exponential distribution is also more or less assumed; that is, the failure rate is assumed to be reasonably constant during and appreciably beyond the test time of 1000 hours. If the failure rate does not behave in this way, a supplier would be rewarded for making tubes with a low failure rate before 1000 hours (the length of the test) even if they had a higher failure rate after that. Therefore some long-time tests should be run in addition to those stated here.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

But in any event, simple programs such as this can materially assist in up-grading the reliability of parts at a low cost.

The author, in a private communication, has indicated that the technique defined in this paper is now used in tri-service coordinated specifications for four (4) vacuum tube types, and an additional twelve (12) types are in the final coordination stages.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A closed loop failure analysis corrective action system--A reliability tool

AUTHOR: Jerome Bakalish, Quality Engineering Department, Denver Division, Martin Marietta Corporation

SOURCE: 12 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To give the principal features of a failure analysis corrective action system.

ABSTRACT: Failure Analysis, which includes problem investigation, laboratory testing, dissection, and CORRECTIVE ACTION is under the Quality Engineering Department. At Martin Denver, Failure Analysis is considered the vital link in the feedback loop which translates actual experience into increased reliability via improvements in design, manufacturing, testing and quality control. Effective implementation and control of such a program is predicated on timely, accurate information; and meaningful corrective action with attendant follow-up surveillance to maintain achieved goals. (Author)

REVIEW: This paper describes the workings of the system rather than the details of any one phase. As such it is useful reading for anyone involved in a similar system. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mission profile analysis technique for space-age reliability prediction and trade-off

AUTHORS: Norbert S. Jagodzinski and Hugh McIntyre, Sylvania Electronic Systems, A Division of Sylvania Electric Products Inc., Williamsville 21, New York

SOURCE: 19 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To describe a system of reliability analysis wherein the profile of stresses during the mission is emphasized.

ABSTRACT: A discussion of a reliability technique successfully implemented as a means for effectively assessing or establishing reliability requirements of specific spaceborne electronic equipment design is presented. The technique is called "Mission Profiles," and it is optimally utilized in the initial stages of system synthesis. Additionally, it is an invaluable tool in making reliability tradeoff decisions during the course of the program.

A mission profile is defined as the actual stresses the equipment is subjected to, from conception (i.e. manufacture) to final mission accomplishment. The conditions include delivery, ground checkout environment and the various stages of boost, separation, and operation. By analyzing and tabulating the specific influence of the expected operating environments upon the individual equipment, a means of integrating high reliability into the basic design of electronic equipment is effected.

The need for a reliability goal as a basic reference is demonstrated and some key reliability principles and techniques are briefly explained. Most significant among them is the discussion of the value and limits of redundancy as applied to failure-tolerant design, where failure tolerance is defined as an ability to permit one or more catastrophic chance failures and still maintain operation within performance limits. A profile is constructed and it is shown that it can be constructed from a detailed operational specification, or a hybrid combination of the environmental specifications, operational procedure, and reliability goal.

Upon the completion of the profile it is shown how it is analyzed in detail by the design and reliability engineers to produce the first logic diagram and mathematical model of the physical, electrical and reliability aspects of the design. It is during this

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phase that the major tradeoffs can be made. The basic functional block diagram, which will dictate the entire program philosophy, is then constructed. The program schedule, the design plan, the reliability program, the costing and maintainability philosophy, and even the basis for value engineering are some of the benefits derived from this effort. Although the examples for the technique are presented for electronic components, it can be applied to non-electronic equipments. It is additionally adaptable to other areas (e.g. contract and subcontract control, costing, human factors, training and specifications). (Authors in part)

REVIEW: This is a good technique, although the amount of detail presented in the paper is insufficient to really show how the authors intend it to be used.

The first author, in a private communication, has indicated that this technique has been applied and details are presented in a second paper by him entitled "Dynamic reliability instantaneous forecasting technique." Figures 12, 13, and 14 in that paper constitute an application of mission profile analysis. The paper also contains an application to reliability of finite Markov chains (absorbing barrier type). Copies of the second paper are available from the author. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Implementation of a design review program

AUTHOR: Arthur S. Winthrop, Space Technology Laboratories, Inc., Redondo Beach, California

SOURCE: 14 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To describe the design review program in the Electronics Division, Space Technology Laboratories, Inc.

ABSTRACT: This design review program was set up to have teeth in it. It includes the following four phases.

1. Review of the conceptual design
2. Evaluation of the reliability of the proposed design
3. Consideration of the integration of subsystems, the environmental performance, and methods of manufacture
4. Review of any difficulties that show up during testing

The program has been quite successful and the design engineers accept and profit by the reviews.

REVIEW: This is another description of a particular design review program. It is this great attention to detail that is required for high reliability.

Other papers on design reviews have been covered by Abstracts and Reviews Serial Numbers 25, 26, 29, 125, 183, 190, 193, 245, 273, 275, 382, 493, 621, 638, 744, 750, 1000, 1021, 1140, 1187, 1190, and 1203. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Man/moon/machine reliability relationships

AUTHOR: Edgar Peirce McDowell, Hughes Aircraft Company, Culver City, California

SOURCE: 10 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To assess the factors that must be considered for the reliability of a manned moon craft.

ABSTRACT: The designers of vehicles and equipment for manned space flight must provide future astronauts with realistic predictions of the probability of mission success. This paper examines some trends in average part failure rates since 1952 and projects these trends into the time period of anticipated manned flights to the moon. The impact of these projected failure rates on operator activity and equipment design is discussed.

Realistic trends in reliability are encouraging, but do not point to a high probability of success for nonredundant systems for manned lunar missions by 1967. Redundancy at carefully selected levels of design is feasible and offers attractive possibilities for success. The presence of one or more men in a lunar vehicle can significantly and advantageously affect the design of redundant systems, and greatly enhance the probability of mission success. (Author)

REVIEW: This is a qualitative review of the factors to be considered in a manned moon shot. Much progress in this type of analysis has been made since May 1962 when this paper was written. The author, in a private communication, has indicated that the paper was first presented at the Sixth National Convention on Military Electronics, sponsored by the Professional Group on Military Electronics, IRE, at the Shoreham Hotel, Washington, D. C., June 25, 26, and 27, 1962. However, the conference proceedings contain only the five hundred word abstract, since the paper was cleared too late for publication. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Confidence growth: a concept for the development of reliable systems

AUTHORS: Robert S. Swanson, Aerojet-General Corporation, C. E. Roth, and I. Doshay, Space-General Corporation, El Monte, California

SOURCE: 25 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To introduce the concept of growth in confidence rather than growth in reliability, and to indicate how this concept can assist in the design and development of a highly reliable complex system.

ABSTRACT: A successful period of testing a given component grows only confidence, not reliability, since successful tests result in no failures (and thus yield actually no change in reliability). As soon as the first failure occurs, a redesign of the part must be started immediately. The new part will presumably be better than the part that failed, and this is the true meaning of "increased reliability." However, we have less confidence, in a statistical sense, than we had before, since we have increased only our engineering (or "intuitive") confidence by this redesign. As the tests proceed, we will grow statistical confidence in the new design. In reality, what happens after the first failure of a given part is not that we actually lower the reliability, but that we now know, with a high degree of confidence, that the reliability is lower than we had at first estimated. The redesigned part then should bring the reliability back up to the intended level; that is, to the reliability design goal that had originally been established for the particular part or overall system.

The really important advantage of the "growing confidence" concept over the "growing reliability" concept lies in correlative concepts which are associated with a positive approach (i.e. "growing confidence") to the reliability problem.

If the "growing confidence" concept is adopted by the project manager and applied at all levels of the project, it will result in the performance of a careful design for high reliability from the very first. It will result in internal specifications for higher reliability design goals than specified by the contracting agency. It will keep the early portions of the development test program specifically aimed at solving problems and the demonstration testing for growing confidence, and will result in a reliable design in a shorter time period and with less expense than will

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a project managed under the more "happy-go-lucky" philosophy of "growing reliability." (Authors in part)

REVIEW: The idea introduced here is important, although it need not supersede the one of reliability growth. Certainly, complacency about poor designed-reliability should be eliminated. Papers have been published about the probability of finding all the possible sources of failure during a limited test (see, for example, Abstract and Review Serial Number 914).

The paper contains the unfortunate term "random failure" and implies that this may be different from a caused failure. This is generally considered now to be an untenable concept for highest reliability. The approach here also points up some of the inadequacies of classical statistics as applied to reliability prediction. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic part failure rates in space environments

AUTHOR: John A. Connor, Astro Reliability Corporation, Sherman Oaks, California

SOURCE: 13 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To derive a suitable expression for failure rate as a function of stresses.

ABSTRACT: Much conjecture exists regarding the special effects of space environments as reliability stressors on common electronic parts. To understand the unique risks associated with these additional factors, it is useful to envision their presence as superimposed sources of activation energy. This, in turn, demands a general mathematical model for part failure rate synthesis which relates statistical risk with energy level. Such a model has been developed and is worthy of close examination from the viewpoint of additional space environment risks. Thus, an energy-level concept affords an analytical model from which the statistical risks in "unproven" operational environments can be inferred from an extrapolation of a wealth of conventional operational experience. In addition to these general concepts, factors which will guide space environment tests of electronic parts are discussed.

It is contended that advances in the art of space material test and evaluation must have their roots in a comprehensive understanding of terrestrial tests and statistical failure rate criteria. Any useful comprehension must be based upon a rank order of part stressors where ground environment factors are essential prerequisites. Once examined from an energy viewpoint, failure tendencies and their underlying material mechanisms can be usefully modeled using energy as a helpful common denominator. It remains then to deliberate upon the appropriate material test evidences to establish tables of response and part usage risk for space environments with the same level of completeness as has been established for terrestrial operating conditions. (Author in part)

REVIEW: The derived expression does have a reasonable basis in that presumably it fits the failure behavior of some parts. The use of energy as the basis for the derivation is questionable since it is not clear what energy is meant. Activation energy of a particular failure or degradation mechanism is not specifically related to the energy converted into heat by a device. (See also Review

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

Serial Number 976.)

The terms "chance failure" or "random failure" should be used with caution. It is true that the occurrences of failures can be adequately represented in many cases by statistical formulas (models) of chance/random occurrences. But this does not necessarily mean that we cannot ascribe real physical causes to these failures, nor does it mean that they cannot be prevented. Other authors have tended to imply that when the conditional failure rate became constant during the life of a device, all the "caused" failures had been eliminated. See the paper covered by Abstract and Review Serial Number 1204 for a further discussion on this point.

The occasions for the use of statistics of random numbers to describe events can be put roughly into three classes as follows: (1) situations in which we cannot know anything more detailed about the process than the statistical description, e.g., quantum mechanics; (2) situations in which it is hopelessly involved to evaluate individual behaviors and effects, e.g., statistical thermodynamics; and (3) situations in which we do not want to be bothered with details and are willing to lump things together into a few numbers, e.g., a census. The use of statistics for failures falls somewhere in classes (2) and (3), depending on the application. Thus the use of the term "chance" failure describes our attitude rather than the ways of nature. ##

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Serial Number 1217
Codes 770;816;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Procurement of extremely reliable semiconductor devices for space applications

AUTHOR: H. R. Lambert, Quality, Reliability and Standards Division, Autonetics, A Division of North American Aviation, Inc.

SOURCE: 6 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To discuss a proposed method for procuring small quantities of state-of-the-art semiconductor devices which would prove to be highly reliable in actual circuit operation.

ABSTRACT: The necessity of procuring extremely reliable, state-of-the-art semiconductor devices in relatively small quantities has arisen with the development of complex electronic systems for space vehicles, satellites, and other "few-of-a-kind" projects demanding the ultimate in reliability. Techniques employed in the past for obtaining highly reliable semiconductor devices in large quantities are not necessarily attractive or feasible for procuring these devices in small quantities. For example, extensive reliability improvement programs were successfully employed to obtain highly reliable Minuteman semiconductor devices in large quantities; however, the unit cost of a program of this type applied to the procurement of small quantities of devices would be prohibitive.

The proposed method of procuring the desired devices consists of three steps:

1. Selection of the most qualified supplier available to assure at least some inherent device reliability.
2. Repeated, one hundred-percent screening of devices to eliminate potential failures, as well as sampling tests to avoid substandard lots.
3. Continual updating of techniques to assure optimum screening.

Supplier selection and screening procedures are discussed briefly. (Author in part)

REVIEW: The point made is good and the method in part has found increasing use since the time of its presentation. However, as a complete solution to the problem, there is an apt comparison to "belling the cat." The big problem is to find the screening tests that will do the complete job. If these were in hand, the whole reliability effort could be radically modified. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Parts reliability as a function of system design

AUTHOR: J. J. Seidman, Space Technology Laboratories, Inc., Redondo Beach, California

SOURCE: 4 pp., presented at the Third Annual Seminar on the Reliability of Space Vehicles sponsored by the Professional Groups on Reliability and Quality Control, Component Parts, and Electron Devices of the Los Angeles Section, IRE, Los Angeles, California, October, 1962 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price: $6.50)

PURPOSE: To discuss the problem of using the inherent reliability of parts to produce systems which show a corresponding reliability on the systems level.

ABSTRACT: The fundamental concept essential to the design of highly reliable systems is predicated upon a trio of design characteristics. These are: (a) the inherent reliability of a system based upon its component parts; (b) the design efficiency of the system based upon the techniques using the inherently reliable parts; and (c) the control which is predicated upon the suitable use of the highly reliable parts with the right set of design characteristics and incorporating the correct controls in the purchasing, manufacturing, fabrication, testing, and delivery of the systems. To design a system in today's complex world, neglecting any of the three fundamental areas or only emphasizing one or two of them, leads to an unbalanced system with subsequent unreliability in the final product.

The same attention should be given to problems and procedures at the system level as during the manufacture of high-reliability parts. For example, a weapons system should be subject to extensive screening tests and "burn-in" before delivery. (Author in part)

REVIEW: This is a short philosophical paper and many of the points in it are quite valid. The mechanism of transforming some of them into engineering reality may be rather difficult. ##

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Serial Number 1219
Codes 717;773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A statistical approach to test equipment reliability

AUTHOR: H. L. Mirick, IBM Corporation, Kingston, New York

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, November, 1962, pp. 20-30

PURPOSE: To show how to handle variations in readings of testing (inspection) equipment.

ABSTRACT: A test instrument may not give the "true" reading for reasons related to such factors as scale resolution, tester stability, product-under-test stability, accuracy of the meter, and environmental effects. An analysis of variance technique can be used to separate and estimate the variability between parts and that between measurements. It is then possible to calculate the repeatability variance which can be used to estimate the uncertainty in any test reading. This is particularly useful in acceptance testing where parts are close to the limit.

REVIEW: This is a discussion of quality rather than reliability as it is usually defined; however it is a worthwhile paper. The ASTM has discussed the measurement problem at length in some of its publications.

It should be noted that the deviation due to the error may well not have zero mean and the changes in the error will be much slower in time than are the changes in other factors; thus care must be exercised in evaluating and combining the variances due to the error term. ##

Serial Number 1220
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Techniques and applications of failure mechanism studies

AUTHOR: Myron A. Wilson, Senior Reliability Engineer, Burroughs Corporation, Military Systems Division, Paoli, Pennsylvania

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, November, 1962, pp. 31-37

PURPOSE: To describe the results of a statistical analysis of many failed missile components.

ABSTRACT: This paper describes a statistical examination of more than 2500 missile component failures. Failure mechanisms and causes were classified and studied using contingency-table analysis as the basic tool for identifying significant interactions. More than 63 percent of failures comprising the sample were of the catastrophic type involving material failures under fluctuating impressed loads, supporting a concept of the underlying mechanism as action by peak loads on material flaws. The effects of MIL-E-5272 environmental tests were also evaluated, the data indicating that several tests are of minimal significance for much space equipment. The field environment was appraised and the principal hazards identified as mechanic's error and prolonged exposure to atmospheric humidity.

The study provided information on responsibilities for equipment failures. Manufacturing defects were the commonest causes (30 percent), followed by design defects (25 percent), defects in test equipment, handling errors, etc. The results were of significant benefit in elimination of failure causes, as well as refinement of testing programs and improved design of several of the components studied. (Author)

REVIEW: The author makes an excellent point in his statistical analysis of failures and their causes. Few papers of this sort have appeared; perhaps this one will be a good example for others to follow.

The discussion concerning physics of failure is not a vital part of the analysis. The discussions of largest flaw and rate reactions are rather invalid generalizations. A more complete critique may be found in Review Serial Number 976. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weibull distribution analysis--short method

AUTHOR: Robert K. Ruzicka, Quality Assurance Engineer, Space Systems Division, Martin Company, Baltimore 3, Maryland

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, November, 1962, pp. 38-54

PURPOSE: To show how to plot life/failure data on Weibull paper and how to estimate the important parameters.

ABSTRACT: In this society of high-speed computers and automation, simplified methods for the manual solution of analytical problems still bring relief to the overburdened engineer, statistical practitioner and statistician. This paper presents a simplified method for the graphical solution of the Weibull probability distribution. In applying this method, the limitations of a graphical solution should be kept in mind. Accuracy is sacrificed for ease and speed of solution, but the sacrifice is quickly outweighed by the practical application. (Author)

REVIEW: This is another of the papers which try to give the practicing engineer tools which tend to make him no longer wary of the Weibull distribution. It succeeds in this purpose. Two points should be brought out, however. First, there is by no means universal agreement on what probability value to assign to a particular failure--although if the graphical solution is treated as the "quick and dirty" calculation it really is, there will be no problem. Second, the use of more than one straight line to reproduce the curve tends to overextend the utility of the Weibull approach. After all, by the time six or nine adjustable parameters are allowed, almost any function can appear to provide a reasonable fit for given data. Where one straight line does not do the job well enough, perhaps some other technique should be used.

Once an engineer has used these graphical methods enough to be at home with the Weibull distribution, he should make some effort to read about its fundamentals. Above all, he should always keep in mind that the mathematical model he uses do not necessarily tell him what "really" is happening; they just provide an adequate, convenient summary of the data.

Other papers dealing with the Weibull distribution and various aspects of its role in reliability analysis have been covered by Abstracts and Reviews Serial Numbers 320, 437, 499, 749, 751, 801, 848, 1015, and 1171. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Advances in reliability prediction

AUTHORS: Irving Bosinoff, Richard M. Jacobs, and Juliette Herman, Sylvania Electronic Systems, A Division of Sylvania Electric Products, Inc., 100 First Avenue, Waltham 54, Massachusetts

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, November, 1962, pp. 4-19

This paper is the same as the one covered by Abstract and Review Serial Number 563.

TITLE: Reliability analysis equipment--electromagnetic switching elements

AUTHOR: Francis J. Soychak, International Business Machines Corporation, General Products Division, Burlington, Vermont

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, November, 1962, pp. 55-69

This paper is the same as the one covered by Abstract and Review Serial Number 667. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Specifying reliability in military contracts

AUTHOR: Major General O. J. Ritland, Commander, Space Systems Division, USAF, Los Angeles, California (presented by Col. Richard E. Sims, then Chief, Technical Requirements and Standards Office, Space Systems Division)

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 13-17 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss Air Force experience in contracting for reliability, and to present some new contract requirements.

ABSTRACT: The author presents some concrete experience of the Air Force during several years of contracting for reliability in ballistic and space systems. Topics covered include basic reliability concepts, brief history of contractually specifying reliability requirements, quantitative requirements, management requirements, control of piece parts, and current trends in specifying reliability requirements.

Relatively new requirements which the Air Force is either employing or considering for inclusion in future contracts include participation in the Interservice Data Exchange Program (IDEP) and modification of MIL-Q-9858 to provide more specific direction to industry. The author states in conclusion that "through the collective efforts of the military services and industry, we have made significant strides in fielding reliable systems. The performance requirements and operational environments of tomorrow's systems will require greater strides. We must be continually aware of system reliability requirements and reflect this awareness in every technical, cost, time, or other management decision."

REVIEW: The discussion of reliability contracting experience and plans by high-level government officials is very desirable. These presentations serve as guides for the establishment of industry reliability policy and approaches. Broad areas such as specifications, management concepts, quantitative reliability requirements, and controls over the selection and application of piece parts, which are briefly discussed, are certainly pertinent to achieving higher reliability. However, government contracting measures in these areas have often not been successful in achieving the intent of the specifications. Contractors have found that conscientious implementation can have a detrimental cost effect, and that a meaningless or casual response is sometimes acceptable to the government procuring agency. The government has in some instances purchased a reliability program that had no effect on achieved

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RELIABILITY ABSTRACTS
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equipment reliability. Difficulties in meaningful quantitative reliability requirements and measurement, and lack of financial motivation to contractors continue as deterrents to fulfillment of the intent of reliability specifications. The objectives of the new contract requirements for the reduction of test duplication, the supplementing of MIL-Q-9858, and the engineering classification of inspection characteristics should be well received by industry. Some difficulties can be anticipated in arriving at mutually acceptable details of implementation for these new requirements. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Procurement practices for reliability

AUTHOR: William W. Thybony, Colonel, U. S. A., Office of the Assistant Secretary of Defense (I&L), Washington, D. C.

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 19-22 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To describe DOD incentive contractual procurement approaches for acquiring highly reliable weapons and equipment.

ABSTRACT: The ability of DOD to contract for reliable equipment has been improved by the reduction of cost-plus-fixed-fee contracts, the increased use of incentive-type contracts, and emphasis on value engineering. The Armed Services Procurement Regulation has been reworked to change the emphasis on the selection and use of the various types of contracts employed by DOD. It is expected that this effort will result in improvement of the quality and reliability of procured material, as well as lower costs.

The system outlined rewards risk-taking, efficiency, and the surpassing of performance and reliability goals. It has been coordinated with many industry associations, which may be depended upon for support. Progress will depend on the acceptability of incentive contracts to individual firms. Adequate understanding must be developed, and the details of the program and its objectives must be adequately communicated to the individuals who will be directly involved, both in the government and outside.

REVIEW: It is very desirable for government agencies to disseminate their plans for changes in procurement practices for reliability. Such papers as this are of particular interest to reliability and management personnel. Procurement practices have an extremely important effect on the actual reliability of equipment supplied to the government.

The procurement approaches discussed in this paper include the increased use of incentive-type contracts and emphasis on value engineering. The proposed practices of rewarding high or penalizing low reliability may or may not result in reliability improvements, depending on the ability to develop meaningful methods of measuring equipment reliability that are both economically feasible and acceptable to suppliers. Also, when several different supplier characteristics such as schedule, cost, reliability, and performance are each related to incentives, a supplier may place emphasis on those characteristics which are easiest to achieve and not strive to obtain the difficult ones. Similar difficulties are

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also pertinent in applying value engineering concepts, where the deleterious effects on reliability of cost reduction measures may not be readily apparent.

Certainly past procurement practices which placed little financial responsibility for unreliability on equipment suppliers have fostered much unreliable equipment. Whether or not the cited procurement approaches, if implemented, will improve the current situation remains to be demonstrated. It is very doubtful, however, if significant improvements in the reliability of government-procured equipment can be achieved without changes in procurement practices; responsible government officials are to be encouraged to continue such studies. ##

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Serial Number 1225
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability specifications and their effects

AUTHOR: A. H. Drayner, Martin Company General Offices, Friendship International Airport, Maryland

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 23-32 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present and discuss the currently significant reliability specifications.

ABSTRACT: This paper covers in brief form the currently significant reliability specifications, and includes a reliability specification "tree" for ready reference. Management requirements for effectively complying with these documents are discussed, and one multi-division systems manufacturer's organization for reliability management is briefly described. Cost implications of reliability specifications, as well as reliability considerations of incentive-fee contracts are mentioned and several of the current reliability management problems in these areas are reviewed.

There is a need for reducing the current number of reliability documents. It is also important that reliability groups be fully aware of their interrelationships with other departmental functions. Engineers operating in interdisciplinary areas such as reliability and maintainability require cross-education beyond traditional disciplines; if possible, there should be a reduction of the extreme specialization that exists in reliability organizations today. Methods of funding must be reviewed and revamped in those areas that create "blanket" reliability improvement, such as engineering standards, test facilities, and data centers. Acceptable methods must be developed for measuring the efficiency of reliability organizations without the necessity of waiting for final hardware deliveries. (Author in part)

REVIEW: This summary of reliability specifications provides a useful reference, and will be particularly helpful to personnel in smaller companies and newcomers to reliability activity. The term "specification" is used broadly, and various related documents are included. The mild criticism which is made of the myriad of pertinent documents could justifiably have been more severe. The concluding discussion is good, and calls attention to the need for cost justification of various reliability activities. Both government and industry reliability management personnel may be interested in the latter part of this paper, in which the cost implications of these specifications are discussed. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability analysis and prediction

AUTHOR: G. Ronald Herd, Booz, Allen Applied Research, Inc., Bethesda, Maryland

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 33-36 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To emphasize the importance of realistic reliability evaluation and goals.

ABSTRACT: We have the analytic tools to analyze the reliability of a design; we have demonstrated their application; we know their weaknesses--now it is time for all levels of management to apply reliability analysis and prediction to the difficult job confronting them--controlling the design of a complex system. My plea is that we incorporate system reliability analysis into our PERT programs and begin to control performance rather than allow the deterioration of performance to resolve all of the scheduling obstacles identified by PERT. (Author)

REVIEW: The problems presented here are knotty ones, and the suggestions for solving them are good. Unfortunately, the message in this paper needs constant repetition. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design reliability measurement and evaluation

AUTHOR: W. T. Sumerlin, McDonnell Aircraft Corporation, St. Louis, Missouri

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 37-44 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To review some of the analysis problems involved in demonstrating reliability.

ABSTRACT: Reliability measurement by data collection and evaluation is considered. Parameters are defined and restrictions established. Reliability estimation of sub-systems and parts as a preliminary to system estimation is reviewed, and rules are established. Confidence levels of sub-systems and parts versus combined system are analyzed. Estimation planning is discussed. Tests planned for accept-reject reliability decision are very briefly considered. (Author)

REVIEW: This presentation is more for the person who is quite familiar with the problems rather than for a beginner. While not all of the examples were checked, it is noted that "exponential" behavior is assumed in virtually all cases. The term "random failure" is reasonably well handled, but the term itself is unfortunate, since to many people it connotes a failure from an unexplainable cause and about which they can do nothing. The same author has provided a more extended treatment of this subject in the paper covered by Abstract and Review Serial Number 1204. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Service evaluation of weapons system reliability

AUTHOR: Captain Mark W. Woods, U. S. Navy, Operational Test and Evaluation Force, Norfolk 11, Virginia

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 45-48 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To show the kinds of tests used by the Navy in evaluating the reliability of a weapons system.

ABSTRACT: Due to budget and time limitations, equipment is installed in ships before it is completely debugged. Even during the early phases of testing at sea, it is essential to gather meaningful reliability data. Thus ships being built during the shake-down period can have the benefit of that experience. The series of tests for a surface-to-air missile system might include a Development Assist Test, a Technical Evaluation, and finally an Operational Evaluation.

The Navy has many problems with the sea environment, some of which are more obvious than others. Unfortunately, many designers make the same mistakes as their predecessors--at great cost to everyone.

During the tests, many other factors besides reliability are being measured. A series of forms has been developed for optimum use during recording and analysis of data. The use of these forms continues during the life of the equipment, so that evaluation is not confined solely to early experience. The objective of testing in the sea environment is to simulate during peacetime, all the requirements that can be foreseen during war--to give everything a chance to happen that could happen.

REVIEW: This is a good paper for designers of Naval equipment since it is a summary of the Navy's philosophy with regard to the testing of weapons systems. ##

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Serial Number 1229
Codes 720;760;836

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability techniques in production

AUTHOR: B. L. Lubelsky, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 49-50 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To summarize some of the efforts required in the production of high-reliability hardware.

ABSTRACT: The first step in the production of reliable hardware is a design definition review to ensure that production understands the intent of the design. Most people not closely connected with production activities, and this includes most designers, are under the illusion that manufacturing people work directly and only from the engineering design. Production activities have their own special "family" of planning and process paper which is used to convert the engineering design into the detailed instructions necessary for manufacturing. This may include substituting "equivalent" standard manufacturing process specifications for the design-produced process specifications. While these manufacturing specs may start out as "equivalents," changes and necessity may soon cause significant differences. These should be reviewed. Production must have adequate facilities to do the job. Unusual things, such as clean rooms, should be checked carefully. Testing and inspection are important. There should be a material review to ensure that unacceptable material is not used. As nine hundred and ninety-nine departures from the designer's intent will degrade quality as compared to one or two which might improve it, the production product quality function is to insure and assure full design conformance. (Author in part)

REVIEW: The points made in this paper are all quite worthwhile. The reader interested in this topic should see also the paper by the same author covered by Abstract and Review Serial Number 992. It is also important, and not usually the case, that designers know what really goes on in production. Many of their designs would be much better if they did. ##

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Serial Number 1230
Code 814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Economic considerations of reliability

AUTHOR: F. E. Wenger, AFSC, Andrews AFB, Maryland

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 51-56 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To dramatize the expense caused by unreliability which leads to high maintenance costs.

ABSTRACT: Several examples of costs are given in the paper; two are summarized here. It costs the Air Force between 5 and 350 dollars per maintenance action when all factors are included. The Air Force uses almost 1 million type 5814 electron tubes per year in maintenance. The present failure rate is 1%/1000 hours for a cost of $1.00 per tube. The total costs for replacing 5814's is over 5 million dollars per year. If the failure rate were 0.1%/1000 hours or less, consider what the Air Force would save, even paying between 5 and 10 dollars per tube.

The TACAN equipment has gone through models A, B, and C. The MTBF has been increased from 17.5 hours to 150 hours; the performance has been increased and the initial cost decreased. The Air Force thus saves about 120 million dollars per year. Reliability is cheaper than unreliability--any way you look at it.

REVIEW: These sentiments are refreshing after being exposed to "trade-offs" involving reliability which have been described in the literature. The big problem, and it is being tackled now by incentive contracts, is how to really give a manufacturer a heart/pocketbook-felt reason to produce high reliability parts and equipment. ##

Serial Number 1231
Codes 840;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability research needs

AUTHOR: E. J. Nucci, Office of the Director of Defense Research and Engineering, Washington, D. C.

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 57-59 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To point out certain reliability areas which are in need of research.

ABSTRACT: The reliability areas in need of research may be divided in two parts: (1) systems and equipment and (2) parts. The specific areas include reliability prediction for electronic and mechanical systems, methods of assuring specified life, reliability demonstration, accelerated testing, failure mechanisms, self-healing parts, assurance of reliability in small lots. The ones deserving highest priority are:

Predicting and demonstrating reliability,
Accelerated testing,
Self-healing design, and
Assurance of reliability in small production lots.

Reliability is the key to advanced weapon technology and success in space operations. In our defense, in our economy and in the prestige we enjoy among the world's nations, it is of the utmost significance that our systems of all kinds function dependably. And it will take the combined efforts of our government and our industry to achieve the required reliability. (Author in part)

REVIEW: As the author says, some may disagree with the assigned priorities. However, it is difficult to disagree with his discussion of the needs in the field.

Perhaps one peripheral, although vital, area missing is how to really convince management that reliability is important or, perhaps equivalently, how to tie high reliability to high profits and low reliability to high losses. Incentive contracts are a step in this direction. ##

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Serial Number 1232
Codes 813;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Three lessons from the reliability verification program

AUTHOR: David B. Christian, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 61-67 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss three important lessons that resulted from a Reliability Verification Program.

ABSTRACT: The verification program was concurrent with actual flight test of the Mod III A system. Problem areas indicated by the verification program agreed very well with those brought to light by the ground and maintenance tests of the Mod III A equipment in the field. This correspondence added confidence in the program and with it an urgency and sense of need to eliminate the problems revealed. In this sense, information was obtained that did aid in improving the reliability of the guidance equipment.

This paper presents three significant lessons learned from the Mod III A/B Reliability Verification Program. It discusses the significance of these lessons and how they have affected the planning of subsequent evaluation. It goes on to discuss in a new light what the program has added to our knowledge of the behavior of complex electronic systems.

Briefly stated, the lessons are:

1. This type of Reliability Verification Program can and should be a valid means for demonstrating the reliability of a system.
2. There are relationships between time, cycling, and vibration.
3. The time required to perform such a program may limit its value. (Author)

REVIEW: This paper discusses problems of point of view as well as of mechanics of testing and planning. It does a good job on both. The problems of Production Environmental Testing (PET) are handled well. (All of the figures referred to in the text are missing.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The successful application of a repeated test-to-failure program on Sergeant missile assemblies

Part I. The design, application, and results of the combined operating temperature vibration test for missile assemblies reliability

Part II. Statistical techniques applied to the Sergeant repeated test-to-failure program

AUTHORS: Richard H. Brashear, Jr. and Larry Blundell, Sperry Utah Company, Salt Lake City, Utah

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 69-98 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present the Sperry Utah Company test philosophy and the results of a reliability test program which led to the achievement of many of the reliability goals of the Sergeant System.

ABSTRACT: The tests discussed in this paper are the results of the practical application of a test-to-failure program based upon Latin square and regression analysis models. The statistical theory was presented in a Sperry Utah paper at the Sixth Joint Military-Industry Guided Missile Reliability Symposium at El Paso in 1960 [1].

Early in the R & D program the reliability efforts were directed primarily to component evaluation. As the R & D program progressed and production hardware became available, the emphasis was placed on assembly and subassembly evaluation. This test program was designed and put into effect to assess the capabilities of the Engineering Model to meet its expected environment, including allowance for variations in environmental extremes. The program included reliability tests as well as type approval environmental tests. The Sperry Utah approach to reliability testing utilizes a repeated test-to-failure model to verify quantitatively the ability to the system to satisfy the number one military characteristic, reliability. The type approval tests determine assembly design limitations.

The test program is discussed in three parts. Part I discusses the testing aspects, Part II discusses the mathematical analysis aspects, and Part III discusses the conclusions and recommendations which are: (1) The basic statistical test philosophy proved to be readily adaptable to practical test application on Sergeant missile assemblies, (2) To preclude biasing reliability indices too conservatively for "no-failure" type assemblies it was necessary to develop a new statistical analysis, (3) Results of the

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test indicated that Sergeant missile assemblies are not subject to wearout effects from the environmental tests, (4) The repeated test-to-failure program identified design, component, and quality control type defects that were not discovered by previous type-approval and flight acceptance test programs, and (5) The computed in-flight reliability calculated from the repeated test-to-failure program agreed with the reliability as demonstrated in the R & D missile flight test program. (Authors in part)

REFERENCE: [1] White, D., Operational Reliability and Maximum Safe Operating Levels for Expensive Equipment, Proceedings of the Sixth Joint Military-Industry Guided Missile Reliability Symposium, presented February 15-17, 1960, El Paso, Texas

REVIEW: This is a descriptive paper which discusses not only the results and principles of the program, but some of the problems as well. The actual examples of failure are helpful.

(While no details of the regression analysis are given, care should be used in weighting all data equally--especially after the data have been transformed.) ##

Serial Number 1234
Codes 353;814;863

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A method for determining the cost of failures

AUTHOR: David E. Van Tijn, ARINC Research Corporation, Washington, D. C.

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 99-110 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present and discuss a procedure for cost allocations of support operations.

ABSTRACT: Cost predictions for weapons systems are based on the same general principles, and developed by the same general techniques, as reliability predictions for equipments. Therefore, the step-by-step procedure for developing a mathematical model for cost allocation -- on which the cost predictions are based -- is analogous to the well-established procedures for developing reliability allocation models. This paper presents a sequential set of rules for establishing a cost model, exemplified by application to an actual Air Force weapons system.

The model developed for a particular support system will allocate the various expenditures for the equipment being supported. Expenditures fall within the categories of Investment, Manpower, Supplies, and Time. A discussion of the theory behind cost allocation and predictions precedes the presentation of the rules for development of a cost model. (Author)

REVIEW: The procedure that is presented for establishing a cost model for the support or maintenance of operational equipment is timely and pertinent to the current emphasis being placed on cost effectiveness. The model and example presented would be of primary interest to operational or logistics cost analysts. Primary uses of the model are for management types of decisions for the optimization of the cost of supporting an operational system after some initial related support experience is obtained. The parallel between reliability modeling and cost modeling that is discussed in the first part of the paper only tends to distract the reader from the presentation of the cost analysis procedure, and has no real bearing on the substance of the paper. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Results of a test-to-failure program on electronic parts

AUTHOR: Louis M. St. Martin, Army Weapon Systems Management Reliability, General Dynamics/Pomona, Pomona, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 111-120 (U. S. Government Printing Office, Washington, D. C. 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To describe the use of test-to-failure on the MAULER weapon system.

ABSTRACT: General Dynamics/Pomona as the prime contractor for the MAULER Weapon System is conducting a strong reliability program according to policy established by AOMC. One of the requirements of this policy is that reliability testing of components to failure be conducted in order to determine safety margins. The safety margin is a statistical relationship between the strength of the component and its use environment. The USAOMC policy was implemented by a MAULER Weapon System Test-to-Failure Plan. This plan established the objectives and scope of the test program, the basis for selection of candidates and test environments, a list of the candidates and environments, uniform test-to-failure language, uniform test method, criteria for judgment of test results, initiation of corrective action on failed items, test reports, and test schedules.

Forty-two tests on twenty-three parts and seven assemblies have been completed; some items were tested in more than a single environment. The environments were high and low temperature, vibration, shock, and acoustic noise. Twenty-six of the tests disclosed adequate safety margins. The other sixteen tests resulted in corrective action ranging from reducing the stress on the item to replacing the item with one of adequate strength.

The lead time gained by this program on the potential problems has been one of its direct benefits. Of indirect benefit has been the increased confidence the designer has in the items passing the test, which allows him to dismiss doubts and concentrate on other unknowns. The author recommends the use of test-to-failure by designers in selecting and evaluating components, determining the failure modes of parts, materials, and assemblies, identifying "weak links" in a system, and as a prelude to the design of a life test. (Author in part)

REVIEW: Test-to-failure and calculation of safety margins is, as the author claims, a valuable adjunct to any reliability program. This paper adequately describes the philosophy and results of the particular tests. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The demonstration of telemetry reliability

AUTHORS: Edwin D. Karmiol, W. Thomas Weir, and John S. Youtcheff, General Electric Company, Missile and Space Division, Philadelphia, Pennsylvania

SOURCE: Paper Number 3.6.1, 1 p., presented at the Tenth Annual East Coast Conference on Aerospace and Navigational Electronics sponsored by the Baltimore Section of the IEEE and the PTGANE, Baltimore, Maryland, October, 1963 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price $9.00)

PURPOSE: To establish analytical techniques to provide telemetry equipment reliability predictions.

ABSTRACT: This paper discusses the analytical techniques which can be utilized in the demonstration of telemetry reliability in a system development program. Analytical techniques have been established to provide telemetry equipment reliability predictions at periodic intervals as functional and environmental test data are accrued. A mathematical model has been developed which allows for a realistic and sound approach to the problem. The equations allow for the calculation of telemetry equipment reliability, at any desired confidence level, in both individual and combined operational environments. These expressions have been programmed on the IBM 7090 Computer to provide a completely mechanized reliability data handling and processing system. Equipment reliability status reports are issued periodically to provide management with a quantitative measure of telemetry equipment reliability, and offer the design engineer an opportunity for any needed redesign early in the program. (Authors)

REVIEW: Only the abstract reproduced above is given in this source. Perhaps the authors will be able to provide copies of the full text to those who request them. ##

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Serial Number 1237
Codes 612;782;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Environmental resistance evaluation through analytical simulation

AUTHOR: I. Doshay, Space-General Corporation, El Monte, California

SOURCE: Paper Number 3.6.2, 15 pp., presented at the Tenth Annual East Coast Conference on Aerospace and Navigational Electronics sponsored by the Baltimore Section of the IEEE and the PTGANE, Baltimore, Maryland, October, 1963 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price $9.00)

PURPOSE: To describe the use of analytical techniques in simulating environmental effects and incorporating environmental parameters into a design procedure.

ABSTRACT: Analytical simulation through a computer program is used for incorporating in design procedures the actual or predicted environmental resistances of aerospace equipment. Through prior environmental testing, the relationships between component parameters and environmental levels may be established. Data may also be analyzed through statistical methods or by physical considerations and resulting parametric relationships. By utilizing the statistical and parametric models of component-environment relationships in connection with analog design analysis methods, environmental factors can be included in design considerations. For the purpose of demonstrating the feasibility of the design system a fine attitude control system in a polar orbit through the outer Van Allen Belt has been chosen. Evaluation of environmental effects completed to date, as well as analog computer runs on the nominal system, show great promise of this technique to minimize costs of systems testing and to accelerate space programs. From the results obtained to date it is anticipated that system test costs may be reducible by a factor of 1/3 and time to develop new space systems shortened by as much as 1/2 if this technique is adequately applied in early design analysis. (Author in part)

REVIEW: This is a description of a technique for evaluating design adequacy, which existing reliability techniques do not cover. The paper discusses the mathematics of the methodology, including the programming of the computer. The demonstration of the method is extensively illustrated with figures.

Each application of this method is likely to be tedious, but the results may well be worth the effort. Those who are interested in more details may request a copy of the final report entitled "Development of an analytical model for environmental resistance inherent in equipment (Project ERIE)," Technical Documentary Report No. RTD-TDR-63-4101, January, 1964, prepared under Contract No. AF33(657)-9949 by Space-General Corporation, El Monte, California. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Introspective in-flight checkout techniques for manned space vehicle electronics systems

AUTHORS: E. R. Campbell, Jr., H. B. Goldman, and P. D. Stahl, Aerospace Communications and Controls Division, Radio Corporation of America, Camden 2, New Jersey

SOURCE: Paper Number 3.6.3, 12 pp., presented at the Tenth Annual East Coast Conference on Aerospace and Navigational Electronics sponsored by the Baltimore Section of the IEEE and the PTGANE, Baltimore, Maryland, October, 1963 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price $9.00)

PURPOSE: To compare the effectiveness of several introspective in-flight checkout techniques for the electronics systems of a manned space vehicle.

ABSTRACT: This paper discusses the application of introspective testing techniques (involving checkout equipment which is self-contained in the device or equipment to be tested) to in-flight checkout of a postulated manned space vehicle. The advantages of introspective testing techniques are shown through comparisons with other in-flight checkout methods. Finally, the principles of introspective testing as applied to checkout of typical radar and communication subsystems are described.

In particular, three checkout techniques are discussed: automatic computer controlled, semiautomatic, and passive monitoring. An automatic system has a weight penalty of 50% over a semiautomatic system. Also, while limited with respect to the level of confidence achieved in assessing system performance, passive monitoring, when combined with some form of active testing using various kinds of stimuli, contributes not only to performance evaluation but also to fault isolation capabilities. (Authors in part)

REVIEW: After a general analysis of the checkout techniques, three subsystems: the communications subsystem, the radar sensor, and altimeter are analyzed. The paper gives a good general idea of the comparative merits of the checkout techniques discussed.

These considerations are very real with regard to the actual reliability of the manned mission, and this paper does a good job of analysis on them. ##

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Serial Number 1239
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A reliable earth sensor for attitude sensing

AUTHOR: Barbara Kegerreis Lunde, Stabilization and Control Branch, Goddard Space Flight Center, Greenbelt, Maryland

SOURCE: Paper Number 3.6.4, 6 pp., presented at the Tenth Annual East Coast Conference on Aerospace and Navigational Electronics sponsored by the Baltimore Section of the IEEE and the PTGANE, Baltimore, Maryland, October, 1963 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price $9.00)

PURPOSE: To describe an infrared earth sensor for attitude sensing which will have a higher reliability than former sensors.

ABSTRACT: An earth sensor for determining the orientation of a space vehicle with respect to the earth with a mean time to failure of 29 years, far higher reliability than former sensors, is being developed. The sensor uses a new approach of detecting the earth. This method requires no moving parts and only about ten per cent of the electronic parts required by existing earth sensors. The far infrared radiation from the earth is imaged on temperature sensitive elements which absorb infrared radiation and are heated by it. The sensor uses the difference in temperature between elements to determine the offset angle.

The aim of the program is to develop and test an earth sensor which will have a 90% probability of operation in space for three years without failure, that is, a mean time to failure of 29 years. By comparison, the calculated estimate of the mean time to failure of the Orbiting Geophysical Observatory earth sensor system is 2.7 years. To achieve the better reliability the accuracy of this sensor is less than for previous earth sensors, but it is sufficient for the mission of orienting long term operational satellites. (Author in part)

REVIEW: The paper is a discussion of the sensor and is reasonably complete. If the hopes for this instrument are borne out, it will be a big improvement.

Two figures in the paper are difficult to interpret. Figure 1, evidently taken from a color map, has a legend which is impossible to decipher with the result that it is little more than a fancy picture. Figure 3 is highly idealized to the point of conveying little information. It is stated that "the radiation from the earth should be more uniform at the wavelengths of absorption bands of molecules which occur high in the atmosphere, such as CO_2." More elaboration on this point might have been helpful. ##

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Serial Number 1240
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The application of redundancy to achieve a fail-operative flight control system

AUTHOR: H. Moreines, The Bendix Corporation, Eclipse-Pioneer Division, Teterboro, New Jersey

SOURCE: Paper Number 3.6.5, 13 pp., presented at the Tenth Annual East Coast Conference on Aerospace and Navigational Electronics sponsored by the Baltimore Section of the IEEE and the PTGANE, Baltimore, Maryland, October, 1963 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price $9.00)

PURPOSE: To discuss the use of redundant subsystems with passive signal selection from the redundant elements.

ABSTRACT: A design concept for implementing triple-redundant flight control equipment is presented. Redundancy is required to achieve fail-operative performance in critical flight regimes. A method for passive signal selection in analog control systems is described which utilizes the amplitude-selective properties of conventional digital logic gates. It is shown that an overall improvement in reliability and tolerance spreads can be achieved using this technique in a parallel-series array of functional elements. An "off-line" monitoring method is described to permit failure warning indication for cockpit display, and which facilitates fault isolation when used in conjunction with self-test circuits and a maintenance panel display. (Author)

REVIEW: The paper is a good mathematical account of the theory of redundancy with voter selection.

The following points in the article are worth emphasis. The voter (passive signal selector) selects the signal of intermediate amplitude, and the selection involves no switching. Signals not selected by the voter are monitored for malfunctions, and faults can be isolated within subassemblies which are easy to replace.

The author, in a private communication, has advised that complimentary reprints of the paper are available. These may be obtained by requesting Publication #6311-14 from Mr. Robert Johnson, Sales Department, Eclipse-Pioneer Division, The Bendix Corporation, Teterboro, New Jersey. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic management of subsystems in the supersonic transport

AUTHOR: M. A. Paradiso, Douglas Aircraft Company, Long Beach, California

SOURCE: Paper Number 3.6.6, 1 p., presented at the Tenth Annual East Coast Conference on Aerospace and Navigational Electronics sponsored by the Baltimore Section of the IEEE and the PTGANE, Baltimore, Maryland, October, 1963 (Proceedings available from Western Periodicals Company, 13000 Raymer Street, North Hollywood, California, Price $9.00)

PURPOSE: To review an electronic management system for supersonic transport aircraft.

ABSTRACT: The Douglas Electronic Management System (EMS) is presented in this paper. The requirements and the approach to an efficient electronic management of the subsystems of supersonic transport aircraft are reviewed.

A method for assisting the crew by monitoring, controlling, and recording functions automatically or as specified by the crew is discussed. Tasks considered from pre-flight checkout to landing include: display of processed data; control of various subsystems; self-test features for pre-flight and in-flight checkout; and recording of flight performance, equipment status, and engineering data. It is shown that the potential of the EMS allows the introduction of a cable multiplexing system which permits the handling of more than one signal per wire. (Author)

REVIEW: Only the abstract reproduced above is given in this source. However, copies of the complete paper (Douglas Paper 1703) are available from Douglas Aircraft Company, Inc., Aircraft Division, Long Beach, California. The paper describes the effort required to develop the EMS, and the exploratory work accomplished by Douglas in association with major electronics manufacturers. In its role as a method for integrating the man/equipment functions for future aircraft, the EMS has connotations of interest to those concerned with the design of reliable man-machine systems. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: NASA list of preferred parts is key document

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement, vol. 3, December, 1963, pp. 1-2

PURPOSE: To explain to contractors supplying electronic gear to NASA the meaning of a Marshall Space Flight Center document entitled "Preferred Parts List, Electrical."

ABSTRACT: In order to have parts with a demonstrated reliability for meeting space vehicle reliability requirements, NASA is classifying parts by these definitions:
Hi-Rel Parts: Parts conforming to a high reliability specification consisting of the total spectrum of space vehicle environments, reliability and quality control requirements for each family of parts, and acceptable reliability limits for each part within a family. The specification includes requirements for manufacturing process control, inprocess inspection, 100% qualification and acceptance testing and failure rates at maximum rated stress not to exceed 1%/1000 hours at 90% confidence level. Life tests must be conducted for at least 2000 hours.
Preferred Parts: Parts that do not meet all requirements of a Hi-Rel part, but conform to a MSFC (Marshall Space Flight Center) approved specification, qualify to Saturn environments and have proof of qualification in properly documented format. This data may come from various sources but must be approved by MSFC. Vendor data are acceptable if tests are 100% monitored by NASA. Failure rates at maximum rated stress for preferred parts are not to exceed 1%/1000 hours at 60% confidence level. Life tests must be conducted for 2000 hours minimum.
Selected Parts: Parts in process of being qualified for the Preferred or Hi-Rel categories.

Wayne Wagnon, Reliability Coordinator at Huntsville's Astrionics Laboratory, reported on the MSFC's Parts Reliability Information Center (PRINCE) at the 12th Annual Convention of the Standards Engineers Society. The objective of PRINCE is to gather and make available in a usable form all the technical information that can be useful in a parts program. Collection of data started in early 1961. Use was made of the existing facilities such as IDEP (Inter-Service Data Exchange Program) and ECRC (Electronic Component Reliability Center at Battelle Memorial Institute).

Data are provided with no restriction as to vendor, date of the reports, environments, values (such as capacitance or resistance unless a particular part number was given), etc.; however, requests may be restricted to a particular part number, vendor,

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

environment or test data. If the parts user chooses, he may request additional information as it becomes available on any part. Output information is on three basic levels. First, a summary is given of all test data for a particular part that has been reduced from the available reports. This summary will reference reports from which this abstract has been made. Second, a summary of the individual reports is available. Third, if additional information is required, such as the test procedure itself, curves, or raw data, the entire test report may be obtained. It is EEP's understanding that this service is available to all contractors. A tabulation of the frequently used parts is maintained to determine similar items capable of performing the same function. A survey of available information determines if these parts should be used in future design. After better parts have been selected, a study is made to fill the gaps in the parts spectrum.

Hi-Rel specifications must, as a minimum, meet the following major stipulations:
(1) All special test and measuring equipment, special set-ups, and environmental test methods used in part testing must be adequately described.
(2) Relative to each test method, the specification includes inspection levels, showing end-point limits and the number of failures allowed, to assure maintenance of the stipulated reliability index.
(3) Each specification includes life test requirements. The allowable number of failures from a stated size lot is specified, together with the allowable minimum quantity to be tested.
(4) Each specification requires a definite number of hours or cycles of functional operation of all units to detect any changes in the product and to cull out early failures ("burn-in" tests).
(5) Each specification imposes requirements on vendor management to maintain high-level quality control over production and to monitor design, process, or test changes to assure uniform quality.
(6) Each specification requires that vendor records showing performance of the part or failures in daily lot-sampling tests be available for review.
(7) Individual part markings are required to completely identify each part, lot, date and manufacturer. (Author in part)

REVIEW: The article is a useful summary of MSFC's efforts to provide its contractors with reliable parts and to improve the nation's manufacturing capabilities. Mr. James A. Lippke, EEP Editorial Director, has pointed out in a private communication that the preferred parts list should always be identified as the MSFC list. There is no overall "NASA" list. The PPL referred to is identified as M-ASTR-TSR-PPL-1. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Microelectronics at what cost?

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement, vol. 3, December, 1963, pp. 18-20

PURPOSE: To evaluate the use of microelectronics from the viewpoint of procurement.

ABSTRACT: Microelectronics is not yet the best buy on a price-per-circuit basis, but does make possible advanced systems. Tipping point when price can beat conventional circuitry is near if buyers and standards work together to get both designers and vendors to agree on what to build. Microelectronic devices are being bought today for improvements in size, reliability, power demand, and cost.

For the last half of 1963, availability was perhaps the chief consideration in evaluating integrated circuits. Only four suppliers were available. More suppliers now have the capabilities; several of these are reviewed. Included is a list of sources for five types of microelectronic circuits.

Volume production is the key to lower costs for integrated circuits and thin film circuits because of the high tooling costs, and the obvious approach to achieving the benefits of high volume is to standardize on a few circuits. (Author in part)

REVIEW: This is a good review-type article on the procurement of microelectronic devices. Examples of costs in procurement and information on suppliers and various types of circuits are useful features. So far, these devices seem to be living up to the reliability hopes expressed for them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability engineering and quality assurance in the U.S.A.

AUTHOR: H. C. Hamaker, Philips Research Laboratories, Eindhoven

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, April, 1963, pp. 5-9

PURPOSE: To present a survey report on reliability engineering and quality assurance in the United States.

ABSTRACT: After the Eighth National Symposium on Reliability and Quality Control (January, 1962) the author visited a number of large manufacturers of complex electronic equipment, for the purpose of studying their approach to the problems of reliability and quality assurance. He was impressed with the importance ascribed to these considerations in areas in which high reliability is vital and cost secondary. This paper is a report of his findings in the following areas: general approach to reliability and quality assurance, failure reporting, failure rate data, failure analysis, and organizational structure.

REVIEW: This paper was undoubtedly prepared originally for a European audience, and does a good job of presenting a general picture of the American approach to reliability and quality assurance. The list of references is rather limited, but it does include some of the most fundamental items in the field. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Computer simulations of man-machine systems

AUTHOR: Arthur I. Siegel, Applied Psychological Services, Wayne, Pennsylvania

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, April, 1963, pp. 10-27

PURPOSE: To describe a psychological model for simulation of the human operator in a one- or two-operator man-machine system.

ABSTRACT: The purpose of the model described here is to predict the success or degree of success with which a given task is completed by the operator or two-man team. The given task is composed of several subtasks, some of which are non-essential, and a total time is allotted for the completion of the task. Parameters which may be adjusted are operator average speed, standard deviation of speed, probability of success for each subtask and operator, the essentiality of each subtask, idle time and subtask sequence information, and operator stress thresholds. During digital simulation runs, random values of subtask execution times are selected by the computer, in agreement with the desired mean speed and standard deviation for the operator.

The program computes the urgency of each subtask and stress placed on the operator as a ratio of time needed for completion of the task to time remaining. The operator stress is utilized to modify the effective average speed and standard deviation for the operator. Both speed and standard deviation are decreased with increasing stress until the threshold stress is reached, above which they are increased (disorganizing effect). The probability of successful subtask execution is treated in a similar manner.

The model has been used with reasonable success to evaluate situations involving aircraft carrier landings, in-flight missile launching, in-flight refueling, and intercept. No general claims are made as to the effectiveness of the model, although it would appear to be useful in other similar situations.

REVIEW: The paper provides a comprehensive summary of the simulation model, and should be useful to investigators in this field. The model appears to be quite flexible, and permits simulation of systems requiring communication or proper sequence of actions between two operators. The model contains no provision for selecting any best operator or machine, but on the basis of the output of the model changes in equipment design or required operator characteristics may be inferred. This type of work should result in ideas for improved reliability. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability assurance of military electronic equipment through effective reliability control

AUTHOR: Stanley A. Rosenthal, Arma Division, American Bosch Arma Corporation, Garden City, New York

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 1, April, 1963, pp. 28-52

PURPOSE: To review Arma's reliability program for the Atlas ICBM Inertial Guidance System and to discuss the effectiveness of such a program in assuring the reliability of complex military electronic equipment.

ABSTRACT: Assurance of the reliability of complex military electronic systems necessitates a reliability control program covering all phases of the specification, design and production of this equipment. Emphasis must be accorded to: (a) obtaining high inherent equipment reliability through review of design configurations and control of parts and parts procurement, (b) assuring the maintenance of this inherent reliability level by surveillance of manufacture and test operations and review of shipping, handling, and operating environments, and (c) evaluating the level of reliability achieved, identifying reliability deficiencies and failure modes, and effecting appropriate corrective action and improvements.

This paper reviews the reliability program of the Arma Division of the American Bosch Arma Corporation under the headings:

1. Reliability planning and organization,
2. Reliability design control,
3. Parts reliability specification and procurement,
4. Reliability surveillance and reporting,
5. Reliability evaluation, and
6. Reliability investigation and corrective action.

REVIEW: This is a detailed description of a reliability program which one company has found to be effective. The material is clearly presented, and extensive use is made of illustrative graphs, charts, and figures. Those who are concerned with the implementation of reliability programs for complex systems should find this to be worthwhile reading. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to get at the causes of unreliability

AUTHOR: Ervin F. Taylor, General Electric Company, Philadelphia, Pennsylvania

SOURCE: Journal of the Electronics Division, American Society for Quality Control, vol. 2, September, 1963, pp. 21-26

PURPOSE: To cite various causes of unreliability in design and hardware, and to suggest appropriate cures for them.

ABSTRACT: Unreliability in designs and in hardware has meaning and can only be detected if three things are present: (1) reliability requirements or reliability design objectives, (2) reliability estimates, and (3) reliability measurements. The causes of unreliability can only be eliminated or minimized through corrective action -- changes in the design, the hardware, or hardware associated processes and practices. Testing has little direct influence on reliability of design or hardware. Increased testing provides increased confidence in a reliability statement. The key factor in getting at the causes of unreliability is a dynamic reliability program, organized and integrated with all other project activities, whose major tasks are to establish reliability standards, detect reliability variances, and to secure prompt and effective corrective action.

The paper takes the form of a listing of some of the causes of unreliability in design and hardware, together with suggested cures for them. (Author in part)

REVIEW: The listing of causes in this paper is not intended to be complete or detailed, although some of the major considerations are included. Similarly, the proposed cures are presented in general terms, leaving the reader to look elsewhere for details. The main value of a paper of this kind would appear to lie in the area of indoctrination of novices to the field. It will be useful for this purpose, as it stresses some of the most fundamental considerations. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability Bulletin No. 3: Component Parts Failure Data Compendium

AUTHORS: Ad Hoc Group on Component Parts Failure Data, Subcommittee on Reliability (M-5.2), Engineering Department, Electronic Industries Association, 11 West 42nd Street, New York 36, New York

SOURCE: 111 pp., published by Electronic Industries Association, 11 West 42nd Street, New York 36, New York, December, 1962, price $2.50

PURPOSE: To present factual reported data on the gross failure rates of electronic parts as observed in operation.

ABSTRACT: The data included in the compendium constitute documentation of close to an estimated 100-billion component part hours operating time. The diversity within the field of electronics represented by the research and industrial, as well as military, organizations contributing the data provides a broad cross section of airborne, ground, shipboard, and laboratory equipments and systems experience. The failure rate figures compiled herein are gross failure rates observed on equipments and systems in use. The wide variance in these figures can be attributed to the many factors affecting the rate of failure. The criteria for definition of failure are a basic factor. Other basic factors include the wide range of applications within the ratings of the component parts, and applications which exceed specification ratings (misapplications). The data compiled cover failures observed in equipments over a rather long period of time. Some of these equipments were designed and built years before formal reliability programs were employed. Also, there may be cases where the equipment use-environment stresses exceeded the original design criteria.

There is no significant trend readily apparent in the data to show either the improvement or worsening of component parts failure rates when operating at equipment and systems levels, as a function of calendar time during the period from 1954 to 1960. This might indicate that state-of-the-art improvements at the materials and higher levels may be counteracted by more-stringent design or application requirements, and by the process of miniaturization. The received data which included cycling versus continuously-on information for operation at systems level indicate quite conclusively that component parts fail more frequently when cycled (at systems level) than they do in continuously-on operation.

As might be expected, the absence of generally agreed upon definitions for reliability terminology results in an added uncertainty concerning the validity of conclusions drawn from comparing documented failure rates from widely differing sources. Accordingly, it is recommended that specific analyses be based only upon fail-

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ure rate data whose origin and significance is completely known and understood by the persons conducting the analyses. (Authors in part)

REVIEW: When taken for what it claims to be, this compendium can be a valuable source of information. Before any of the data are actually used, the introductory qualifying remarks (some of which are quoted above) should be studied very carefully. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Discussion of paper: Fatigue of metals: Part 3--Engineering and design aspects

AUTHORS: M. R. Raghavan, Mechanical Engineering Department, Indian Institute of Science, Bangalore, S. India and R. E. Peterson (author of original paper--See Abstract and Review Serial Number 946)

SOURCE: Materials Research & Standards, vol. 4, p. 80, February, 1964 (original article: Materials Research & Standards, vol. 3, p. 122, February, 1963--See Abstract and Review Serial Number 946)

PURPOSE: To discuss the size effect in fatigue.

ABSTRACT: If large specimens are fatigued, the internal heating may be appreciable. This can cause enough strengthening of the part--well above the endurance limit--to strengthen the large part relative to the small one. Near the endurance limit, this is not true and the large parts tend to fail at lower stresses than do small ones.

REVIEW: This discussion is an excellent rebuttal (without intending to be so) of the fallacy of "the largest flaw" so popular with those who are trying to generalize the physics of failure. The failure of a part is usually due to several interacting factors; to isolate one on the basis of a simple inadequate model and make a general assumption about it does little for a failure theory. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Problem number one--reliability

AUTHOR: A. I. Berg

SOURCE: Tekhnika Molodezhi, no. 10, 1960, pp. 7-10, Translation prepared by Translation Division, Foreign Technology Division, Wright-Patterson Air Force Base, Ohio, FTD-TT-63-40/1, 18 March, 1963 (Astia Document No. 402445)

PURPOSE: To summarize the need for high availability and reliability of machines and systems.

ABSTRACT: The conventional concepts of reliability and availability are introduced. Another ratio--what you can get compared to what you need or would like--is also introduced. The product of these three ratios, all less than one, is called a quality coefficient or effectiveness, K.

There is a general discussion of evolution and adapting. Man attempts to simulate and aid the brain by creating and using machines. These machines must have high K. Microelectronics and redundancy are areas of promise. Quantitative measures of quality are needed so that we know what we mean by improving quality.

The ordinary person or technical manager does not have a sufficient grasp of these things to be effective.

REVIEW: This is appropriately labeled a rough draft translation. The paper is general and philosophic in nature, but it does show that industry everywhere has its problems with quality. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Predicting system reliability

AUTHOR: Harold M. Gordy, Reliability Assurance Department, Guidance and Control Systems Division, Litton Systems, Inc., Woodland Hills, California (present affiliation: Giannini Controls Corporation, 1600 South Mountain Avenue, Duarte, California)

SOURCE: International Science and Technology, no. 19, July, 1963, pp. 72-76, 78

PURPOSE: To provide an expository discussion on the prediction of system reliability.

ABSTRACT: The causes of specific failures can usually be determined; however, the reliability of systems is best described statistically. After an initial wear-in or burn-in period, and until the onset of wearout causes an increasing failure rate, subsystems usually experience a period of relatively low constant failure rate. In this period time-to-failure is described by an exponential probability density function. The normal (Gaussian) density function is correspondingly appropriate in the wearout period.

The prediction of the reliability of series systems is described. Discussions and equations are also given for the reliability of systems involving parallel non-switched redundancy, multiple standby replication, and voting logic.

REVIEW: This is a very readable paper on the statistics involved in the "classical" approach to the prediction of system reliability. Pertinent formulas are cited; mathematical derivations are avoided. None of the material is "new," but the paper has value for the novice or one who wishes to get a grasp of the main ideas without becoming too involved in the technical details. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The human as a missile system component

AUTHORS: R. F. Chaillet and A. Steinberg, Army Ordnance Missile Command, Redstone Arsenal, Alabama

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 121-123 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To report on human problems associated with missile firings.

ABSTRACT: About 1000 flight tests of Army missiles were studied at various locations. The test conditions were much less severe than tactical conditions, but nevertheless the results do provide useful information. Failures are difficult to pinpoint as to cause--human as opposed to machine, but the attempt was made to do so.

Designers, in their comfortable habitat, do not readily realize the ramifications involved in severe environmental specifications and thus tend to design inadequately.

In general, human error can be classified into three groups: maintenance errors, pre-firing adjustment errors, and operator error introduced at/after launch.

Design should be simple with a minimum of test requirements and a maximum of replaceable units. Training of maintenance persons should be a supplement to good design, not a substitute for it.

It is very difficult to get good data on human error and the extra effort devoted to ways and means of making it easier and to doing it will be well worth the effort.

REVIEW: This is a short paper on the subject, but it does make its points rather effectively. The suggestion that the investigation of human error should receive the same order of attention as do the detailed reconstructions of commercial aircraft accidents is well taken. The important question is not the cost of such investigations, but rather the cost of the poor performance sustained as a result of failure to identify and correct the difficulties. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The role of human factors in white room manufacturing reliability

AUTHOR: Edward I. Gavurin, General Electric Company, Missile and Space Vehicle Department, Philadelphia, Pennsylvania

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 125-131 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To describe techniques and procedures used in studying human factors affecting the performance of white-room workers, and to make general recommendations for maximizing human performance in white-room settings.

ABSTRACT: The unusually restrictive nature of the white-room environment and the exacting nature of the critical manufacturing tasks performed within it justify a careful study of human factors which affect the overall reliability of equipment manufactured in the white-room setting. Special indoctrination programs for preparing new employees to meet the demands of this totally unfamiliar setting have usually been developed wherever white rooms exist. However, indoctrination and training programs alone, although very valuable, are inadequate steps on the part of management. A major reason for this is the fact that certain workers may be highly unsuited to white-room work as a result of either personality factors or skill factors. The requirements for the successful performance of a particular job are different inside the white room than they are outside it. For example, glove-handed finger dexterity may be quite different from bare-handed dexterity. Persons with tendencies toward claustrophobia or hypochondria are obviously unsuited to white-room work and are, in addition, harmful to general white-room morale.

A good screening program, therefore, is essential in choosing white-room personnel. Such a program must consider both skill factors and personality factors. The author has found that useful selection criteria can be derived from the General Aptitude Test Battery, developed by the U. S. Employment Service, and the Thurstone Temperament Schedule, a personality test measuring seven personality traits. Past experience provides the necessary guide for correlating the results of such tests with probable white-room performance.

REVIEW: The human factor in attaining highly reliable parts and equipment, while always important, becomes particularly significant in the unusual environment of the white room. This paper provides a good discussion of some of the factors which contribute to the motivation and general job attitude of the white-room worker as

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well as pointing out various steps through which management can reasonably hope to improve the quality and quantity of the work done by its white-room personnel. This paper is aimed primarily at the persons within manufacturing facilities who have the responsibility for organizing and directing the activities within white rooms and for dealing with the concomitant personnel problems. Its scope is not such as to make it of particular interest to the general engineering reader. ##

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Serial Number 1254
Codes 613;863;871

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Resources to support a man-machine system

AUTHORS: E. W. Pickrel, Life Sciences Section, Missiles and Space Systems, Douglas Aircraft Company, Inc., Santa Monica, California, and W. W. Haythorn, Rand Corporation, Santa Monica, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 133-140 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To describe an information model for use in estimating resources to support a man-machine system.

ABSTRACT: The needs for early estimates of support requirements for weapon systems are well known. Personnel plans must be made well in advance of weapon system acquisition in order to get necessary budget approval, to develop training procedures, to construct equipment and facilities, and to select, recruit, and train personnel. Some estimates must be made at least three years in advance of system acquisition; details on skill types and levels are needed two years in advance.

An objective commonly stated in personnel-requirement estimates is that of minimizing the required number of personnel. By contrast, the objective stated in this paper is that of increasing an effectiveness-to-cost ratio. A model is presented for gathering information. A sample problem is used to describe the manipulation of the information to derive a manning document.

REVIEW: This paper is a rather brief description of a procedure used for estimating maintenance personnel requirements. The topic has indirect bearing on the reliability of maintainable systems. The ideas will require perhaps considerable adaptation in order to meet the needs of systems other than those to which they have already been applied. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the application of linear programming techniques to human factors in space programs

AUTHOR: Paul A. Young, Sperry Utah Company, Salt Lake City, Utah

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 141-145 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present a mathematical model which provides optimal crew task scheduling.

ABSTRACT: The functional representation of the probability of mission success, or reliability of a space vehicle is defined in terms of two implicit reliability functions: (1) the reliability of the equipment and (2) the reliability or proficiency of man. In general these two functions are not independent, but are in turn, functions of each other. Estimates of equipment reliability can be made through the use of testing procedures on the equipment and statistical models to evaluate the data from the tests. The evaluation of human proficiencies can be made in much the same way. Testing procedures consistent with objectives can be devised and statistical models consistent with the tests can be applied.

Once these reliabilities or proficiencies have been established it is possible to optimize the reliability of the mission. One aspect of this optimization is to optimize crew selection, scheduling, and task assignment.

The model presented in this paper employs linear programming techniques in defining an objective function to be optimized subject to individual task proficiencies. The first step in optimizing human proficiency is the assignment of a proficiency index for each crew candidate for each expected task. This index is a number c_{ij} which is a measure of the i th man's capability in the j th task, and is assigned according to the results of specific tests. The fraction of the time that the i th man spends on the j th task is denoted by x_{ij}. Using the general linear programming model, an assignment model is formulated in terms of the x_{ij} and c_{ij}. A simple illustrative example is given. Some extensions of the basic model are discussed briefly. (Author in part)

REVIEW: This paper serves a good purpose in calling attention to the usefulness of the linear programming technique for the solution of the type of problem considered. However, the paper provides no real detail on how the technique would be applied to a relatively

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complicated problem. As the author has indicated, the example given is so simple that it can be solved by enumerating the six possible combinations of assignments, together with the effectiveness of each, and then selecting the combination yielding the optimum effectiveness. This approach requires no knowledge of linear programming as such. Thus while the basic idea of the paper is good, it is not carried far enough to demonstrate the real utility of the technique. ##

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Serial Number 1256
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundant adaptive flight control systems as used in space vehicles

AUTHORS: John N. Mitchell and Allyn J. Forsman, Minneapolis-Honeywell Regulator Company, Aeronautical Division, Minneapolis, Minnesota

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 147-156 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss flight control systems for use in space vehicles, and the means of achieving high reliability in such systems.

ABSTRACT: In recent years, the role of the automatic flight control system has changed. Originally considered an accessory item, it has reached the point where success of the intended mission depends upon its satisfactory operation. Present-day high-speed aircraft, for instance, exhibit poor stability characteristics at certain flight conditions, making it very difficult for the pilot to control the craft, much less perform his intended mission, without a stability augmentation system. In manned space vehicles the need is even greater.

Naturally, this growing dependence on the automatic control system has focused greatly increased attention on its reliability. While performance demands upon future systems are great, reliability requirements are the most difficult to meet. In comparison with present capabilities, it is perhaps the single area in which the greatest improvement over existing techniques must be made to satisfy projected future control system requirements.

Methods of improving reliability include system simplification, the use of high-reliability parts, derating, redundancy, and in-flight maintenance. The operation of a conventional control system is compared with that of an adaptive control system. The approach taken in the development of the adaptive control system for the X-15 vehicle is described. (Authors in part)

REVIEW: This is a qualitative discussion of the means available for achieving reliability in flight control systems. No actual reliability data are given. The authors refer to an improvement in reliability "by an order of magnitude or more." Such wording is unfortunate since reliability is a probability usually having a value close to but less than unity. Thus it cannot be increased by an order of magnitude. No doubt the reference is to an order of magnitude decrease in failure rate; if so, it should have been stated as such. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: SNAP reliability program

AUTHORS: W. R. Vaughn and C. J. Brous, Compact Systems Division, Atomics International, A Division of North American Aviation, Inc., Post Office Box 309, Canoga Park, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 157-177 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To describe a program which makes use of available test and performance data in the analysis of the reliability of systems for nuclear auxiliary power (SNAP) for space payloads and propulsion.

ABSTRACT: The reliability of nuclear power systems for space applications is one of the important factors that will make this energy source practical. The study of environmental effects on the reliability of these space systems and their electronic payloads involves not only the usual conditions of space but adds to it the requirements for long-term endurance and radiation resistance. The study of these effects can be expensive and time consuming. A simplified analytical technique has been developed at Atomics International which uses available test and performance data and requires limited additional testing. This program should provide reliable systems for nuclear auxiliary power (SNAP) that will be suitable for the space payload and electrical propulsion requirements of the larger systems of the late 60's and 70's.

Prediction of the life capability and functioning characteristics during the component life, as well as failure probability, lies within the technical framework of the reliability analyst; and it is in this area that the usefulness of the statistical method can be demonstrated. Binomially or exponentially based demonstration plans for long-lived reactor power equipment are simply not reasonable in terms of time and money. Therefore, new techniques are required both in analysis and in demonstration. The analysis and testing procedures in use at Atomics International represent one approach. Others are undoubtedly available. In any event, it is believed that the solution will constitute a joining of engineering design analyses and statistical hypotheses.

The approach for including the effects of the radiation environment in the reliability analysis involves first a determination of the gross effects in terms of percent change in the parameters of the components. These values are inserted in the circuit formulae and the change in circuit output is calculated. This value is then compared with the circuit failure/success criteria for a determination of category. Repetitive selection of sets

of component values from an assumed rectangular distribution of values is made, and in each case the circuit output is calculated. This output is then compared with the circuit failure/success criteria. At least 1000 such sets are computed. The result is a ratio of success to total trials for each circuit for a specified operating time (t). The system radiation reliability is then determined by a series multiplication of the individual circuit reliabilities. In turn, the standard reliability analysis values are then multiplied by the radiation reliability for a combined system reliability. The approach is illustrated through application to a simple circuit with resistive, inductive, and capacitive loads. The time-dependent effect of radiation on the circuit current flow is calculated through the use of available data. (Authors in part)

REVIEW: This is a good discussion of the problem faced by the reliability analyst in relating data on environmental effects to the reliable life of the system. The idea of making optimum use of the data available from limited tests is very worthwhile. As the authors have indicated, a limitation on the utility of the approach is imposed by the availability of substantial data gathered in a systematic manner, enabling individual factor effects to be isolated and interactions to be determined. In this connection there is no substitute for well-designed test programs. (The absence of the identifying numbers on the figures in the paper is a source of inconvenience and possible confusion to the reader.)
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Serial Number 1258
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy as applied to analog circuitry for Project Relay

AUTHORS: E. L. Bolden and R. A. Smith, Radio Corporation of America, Astro-Electronics Division, Hightstown, New Jersey

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 179-198 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To illustrate the redundancy techniques applied to a portion of NASA Relay spacecraft electrical system.

ABSTRACT: The use of redundancy in analog circuitry should be carefully weighed to determine the suitability of the level of application within a system. Criteria dictating this level are circuit unreliability, circuit criticality to system's operation, weight, space, and cost. The use of redundancy, standby operating, will result in larger net gains in reliability over the standby inoperative technique when automatic switching of the latter is required. When earth-controlled switching is provided, the latter technique is desirable, especially at the function level. The incorporation of redundancy in Project Relay results in a predicted reliability of 0.95.

The system described is NASA's Relay. For the purposes of this paper, it has been broken down into four major areas: (a) the system power supply; (b) the wide-band repeaters; (c) the command control circuitry; and (d) the telemetry circuitry. Each area is broken down to illustrate the redundancy incorporated in the design and the effects of this redundancy on reliability numerics. (Authors in part)

REVIEW: This is strictly a case study of one spacecraft system. Each of the various circuits is treated separately, and no unusual problems or techniques are encountered. There appears to be some confusion between the terms reliability and life. For example, the statement to the effect that a reliability of 0.95 for the redundant case represents an increase in reliability by a factor 1.5 over that of a non-redundant system literally means that the reliability of the non-redundant system is approximately 0.64. This, however, is not the meaning which the authors intended to convey, judging by the figures given in the paper. (Giving a reliability to 4 significant figures, e.g. 0.9508, tends to give a misleading idea of the precision of the estimate.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Predicting space mission success through time-stress analysis

AUTHORS: I. Doshay and H. L. Shuken, Space-General Corporation, El Monte, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 199-225 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present a technique for reliability prediction by analytically reproducing the time stress events related to specific missions.

ABSTRACT: A technique of reliability prediction is introduced which encompasses the review of vehicle components, their periods of active and passive performance, and the schedule of operational stresses involved in the mission. This methodology is applied to Ablestar space program upper stage vehicles, where component reliabilities are established from prior experience using ground test criteria. This is interpreted as the unity stress level, upon which basis the reliability of the vehicle is constructed. It is accomplished by tracing each significant vehicle function and accompanying operational time-stress through the progress of the intended vehicle mission. After the vehicles are fabricated, comparisons are made of the prior published predictions and subsequent tests on the actual vehicles. The results are seen to be very encouraging for further application of this technique.

The details of the analysis of propulsion system and electronics portions of the vehicle are given. These include establishing failure rates, operational stresses and the resultant reliability calculations for two pre-defined levels of mission success. An appendix is provided disclosing the determination of confidence limits and the calculation of same. Twelve tables are included listing failure expectancies of propulsion and electronic components, duration of operational time stresses, functional breakdown of Ablestar stage, list of critical items and their failure rates, expected failure rates under non-firing tests and failure rates of components experienced in Ablestar systems produced subsequent to the pre-hardware prediction. (Authors)

REVIEW: This paper is difficult to read critically when one does not possess a more complete knowledge of this specific program than will usually be the case. The general methods seem reasonable but the exact meaning of the results is difficult to interpret from the paper. However, the first author, in a private communication, has indicated that the analysis on which the paper was based has been revised. The revised analysis [1] should be consulted by the reader who desires further clarification of the

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technique.

The formula for 95% confidence limits is an approximation and is true only for a large number of failures. The first author, in the private communication cited above, has indicated that the confidence limit approximation should be quite satisfactory for data like that in the paper having 25 or more failures.

A misprint has been found on page 200 in the paper. In this connection the authors have supplied the following erratum: On page 200, last sentence of first paragraph change "times to failure, T" to read "number of failures, x" and replace the remainder of the paragraph with the following: "It has been shown in the literature that where the hazard of failure is constant throughout the time, t, of the mission, we have:

$$f(x) = \frac{(t/M)^x}{x!} e^{-t/M}$$

where M is the mean time to failure. This leads to the reliability model for the non-failure condition:

$$R = f(0) = e^{-t/M} = e^{-tF}$$

where F ..."

REFERENCE: [1] "Revised reliability analysis of the Ablestar stage," Report No. 111R-6, April, 1963, Space-General Corporation, El Monte, California ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability analysis of redundancy mechanisms

AUTHORS: Nathan Lichter, Grumman Aircraft Engineering Corporation, Bethpage, New York and Gilbert Friedenreich, Fairchild Stratos Spacecraft Systems, Bay Shore, New York

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 227-241 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss in a qualitatively and quantitatively useful manner the results of a study of the reliability to be achieved through the use of redundancy techniques in a two-channel system.

ABSTRACT: Reliability expressions are derived for two basic redundancy techniques as applied to a two-channel system: active redundancy (both channels operate simultaneously prior to any failure) and standby redundancy (one channel operates; the other is switched in upon failure of the first). Each expression is investigated for the effect of the following: (1) failures of a channel which cause the redundant channel to fail, (2) failures of a channel which do not affect the redundant channel, (3) load sharing, and (4) reliability of the switching device.

Solutions to the reliability expressions for these redundancy techniques were examined over a wide range of variables with the aid of a digital computer, and an analysis of the results leads to the following observations and conclusions:

1. Active rather than standby redundancy should be used whenever technically feasible due to its simplicity and the added reliability which potentially results from load sharing (derating).

2. The traditional reliability expression for active redundancy,

$$R_{system} = 2R_{channel} - R^2_{channel},$$

may provide erroneous conclusions since it does not allow for the negative effect of short-type failures or the beneficial effect of derating resulting from load sharing between the two active channels. Taking these factors into account, the reliability provided by standby redundancy, assuming perfect decision and switching devices, is only slightly greater than that provided by active redundancy.

3. As the probability of short failures increases, the reliability of the active redundant system decreases. When the ratio of short to open failures is unity, system reliability is approximately equal to that of a single channel.

4. Assuming short failures to be negligible, the reliability of active redundancy will exceed that of standby redundancy, even

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

with perfect switching, when the ratio of open failure rate at half load (derated operation) to open failure rate at full load is 1/2.

5. The obvious disadvantages of standby redundancy are the complexity resulting from the decision/switching device and the possibility that this switching device itself may be a source of system failure.

6. Neglecting the open-type failure of the switching device, the reliability of the standby-redundant system will always exceed $2R_c - R_c^2$ provided the probability of successful switch-over from the failure channel to the standby channel is greater than the reliability of the channel itself. (Authors in part)

REVIEW: This paper presents in a very clear manner the results of the application of some of the fundamental laws of probability to basic redundancy techniques. The discussion is limited to the exponential failure distribution and to second-order redundancy. The primary value of the paper would seem to be, not in the presentation of new information, but rather in the effective way in which it illustrates the effects of a variety of factors and alternatives in the achievement of reliability through redundancy. Despite the inclusion of some highly idealized situations and results, the authors have succeeded in orienting the discussion in such a way as to make the information useful from a practical point of view. ##

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Serial Number 1261
Code 821

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Graphic solution of reliability logic equations

AUTHOR: William E. Marshall, Minneapolis-Honeywell Ordnance Division, Hopkins, Minnesota

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 243-249 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

This paper is virtually the same as the one covered by Abstract and Review Serial Number 882. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: MTBF apportionment in reliability control of the MAULER design

AUTHOR: Leonard R. Doyon, Raytheon Company, Wayland, Massachusetts

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 251-263 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To describe the technique for apportioning MTBF requirements to various levels of subassemblies.

ABSTRACT: One of the more important tasks for the reliability engineer is translating a reliability system specification requirement into subassembly design requirements that have meaning for the design engineer. But the performance of this task alone does not ensure that the reliability design requirements will be met, particularly when the state-of-the-art is being taxed to its limit. The task of translating reliability system requirements into subassembly requirements, called "MTBF Apportionment," must be complemented by firm management reliability policies and effective control procedures.

This paper describes the technique used by reliability engineers in apportioning the MAULER Acquisition and Track/Illuminator radar-subsystems MTBF (mean-time-between-failure) design requirements down four levels to the subassemblies. This paper reveals how the MTBF apportioned values, when made specific design requirements enforced by MAULER Systems management policies and key reliability procedures, evolved into an effective tool for controlling the reliability of the MAULER radar subsystems design presently in its initial R&D phase at Raytheon Company.

The "exponential" assumption with regard to unit failures and other engineering approximations with regard to system failures were made in order to simplify the calculations. The active-element-group (AEG) was used as the basis of failure probability, with modifications made when an AEG was known to have radically different failure probability. For example, digital AEG's were counted as only (1/10)AEG and a klystron amplifier AEG as 8AEG. (Author in part)

REVIEW: This is a rather qualitative but good paper. The engineering approximations are stated explicitly and without apology. For those who are interested in the reliability apportionment phase of system design, this paper is worthwhile reading. ##

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Codes 710;770;835;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability evaluation and environmental testing of printed-wiring-board solder joints

AUTHOR: Mark L. Hinkle, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 265-283 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present the results of accelerated tests on printed-circuit solder joints.

ABSTRACT: During the last three to four years, the Reliability and Maintainability Engineering group of General Electric's Light Military Electronics Department has conducted a series of reliability tests of solder (tin, lead; 60-40) joints on printed-wiring boards. The discussion in the paper presents a few highlights of this testing and evaluation. In particular, the results and conclusions are given from an extensive test configuration that evaluated the effect on solder-joint reliability of some eight different factors. These results have provided definitive quantitative solder-joint failure rates upon which can be based availability-cost tradeoffs and preferred printed-wiring-board solder-joint configurations for ultrahigh reliability even with high rates of temperature cycling and temperatures of 100°C.

The following conclusions (further qualified in the text) were reached.

1. The plated-through-hole type of joint is by far the best at 50 to 100°C with temperature cycling.
2. If eyelets are used, the board quality (best to worst) is 1/16 inch epoxy glass, 1/8 inch XXXP phenolic, 1/16 inch XXXP phenolic.
3. Hand touch-up of joints did not improve reliability.
4. Removal and replacement of components before test improved the reliability.
5. Repairing failed joints (by removing all old solder) improved the reliability of the redone joints.
6. The environments from most to least severe were high temperature cycling, medium temperature cycling, high temperature aging and room temperature aging. A room temperature vibration during the course of the tests caused failures to occur during the vibration.

A field failure rate of 0.3×10^{-9} joints/hr was obtained in a Polaris subsystem. The environment was less severe than the medium temperature cycling. (Author in part)

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REVIEW: Papers on topics such as this are always welcome because they are needed so badly. The actual statistical planning of the tests is not given extensively in the paper; thus it cannot be commented upon. It does appear, however, that the conclusions are more limited than one would have hoped for, because the variety of test combinations was so limited. No comparisons are made with welded joints nor was the soldering process itself one of the variables. (The absence of the identifying numbers on the figures in the paper is a source of inconvenience and possible confusion to the reader.)

Other papers on reliability in soldered connections were covered by Abstracts and Reviews Serial Numbers 724, 942, 987, and 988.
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Codes 541;612;824;
831;840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Experimental evaluation of predictions of probable circuit performance

AUTHOR: M. A. Young, International Business Machines Corporation, Space Guidance Center, Owego, New York

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 285-296 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To report the results of analyzing the time behavior of six circuit types and their comparison with actual circuit behavior.

ABSTRACT: Predictions of probable circuit performance appeal to those factors in a circuit design which are of direct concern to the designer. These predictions take into account the particular design configuration and interaction of part parameters on operating points, plus the effects of part parameter drift and their joint probabilities of occurrence. This paper reports the results obtained when six digital computer switching circuits were analyzed for probable performance at 2000 hours life, compared with measured performance at about the same age based on a controlled life test of circuit samples. Three of the more common techniques covered in the literature are applied: the Combination method (designating the analytical combination-of-distributions for functions of random variables), the Monte Carlo method (synthetic sampling), and regression analysis. The three analysis techniques employed allow certain conclusions to be drawn about relative accuracy, ease of use, etc. The Monte Carlo method possesses over-all advantages which make it the most attractive for general applications. The Combination method proved to be relatively easy to use after circuit equations were simplified. The regression method produced good results for the analysis of two transient terms which contribute to circuit response time. The method appears to have special application when defining equations are not easily obtained from a circuit analysis or when circuit equations cannot be written in terms of the distributed parameters which are commonly measured for component parts. It should not be compared directly with either of the previous methods for these reasons. In more complex applications the use of a Monte Carlo analysis of the regression equation should not be overlooked. (Author in part)

REVIEW: This is a good paper on the subject of circuit performance as a function of the component parameters. If a greater degree of standardization of circuits can be obtained, this type of analysis will become less expensive since it need not be repeated each time a similar circuit is needed. Its use can help to improve the design, performance, and life of circuits and systems. ##

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Serial Number 1265 -1
Codes 815;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The specification and assurance of large MTBF's typical of spacecraft electronic equipments

AUTHOR: Clifford C. Petersen, Motorola, Inc., Military Electronics Division, Western Center, Scottsdale, Arizona

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 297-301 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75) (has been printed in Military Systems Design, April, 1963; reprints are available from the author)

PURPOSE: To discuss some of the complexities of the problem of specifying and assuring reliability in equipment which is to exhibit large MTBF's, and to suggest ways for dealing more successfully with this problem.

ABSTRACT: The primary question stated and discussed in this paper is: "How is reliability best specified and assured?" Reliability assurance is the logical basis for making many decisions in the genesis of a space system. However, whereas actual life-testing of equipment usually gives the most confidence, time schedules are typically much too short to enable the adequate demonstration of equipment reliability by such long-term testing. Moreover, the present state of the art of accelerated test techniques is too undeveloped to alleviate the situation.

Suggested means of mitigating these problems and gaining time include: (1) extending the contract given to an equipment developer beyond the delivery dates to the latest possible time when a firm reliability assessment is required, (2) asking manufacturers who supply basic equipments with minor modifications to be able to show evidence of long-duration life tests previously conducted by them on their basic product, and (3) calling for the performance of life tests of whatever duration is feasible in instances in which time does not permit sufficiently long testing to provide full confidence. The system manager, in requiring a demonstration by test under a contract, should specify the duration of the test, conditions of test, number of equipments to be tested, the number of allowable failures, and otherwise ensure that compromised interpretations of this costly task are not reflected in bids and projected time schedules. Parts standardization should be implemented on a system-wide basis whenever possible. Designers of principal systems should be thoroughly oriented and given a retainable picture of the operating, handling, and checkout abuse to which their equipment will be subjected. The equipment manufacturer should play a major role in field failure removal and analysis activities.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Evidence suggests that a decreasing failure rate up to the time that wearout mechanisms take effect is characteristic of both parts and equipments. This evidence supports the argument for reliability assurance by life-testing and longer burn-in for equipments. Because of the considerable cost in dollars and hours for doing this, however, it is imperative that through study and research we devise means to accelerate tests, improve the accuracy of our predictive estimates of reliability, and gain the capability of identifying parts having shorter than average potential lifetimes. (Author in part)

REVIEW: As the author states, this paper may be regarded, in a sense, as an open letter to systems managers from one of many electronic equipment suppliers. The problem discussed is one that is constantly becoming more widespread, more costly, and more acute: the adequate specification and assurance of reliability. Though the problem is too complex to permit simple answers, the author has nevertheless made some discerning observations and offered some specific, constructive suggestions.

Primarily an expression of the author's opinions and philosophy on this systems problem, this paper presents no new factual data. However, the paper does present a stimulating discussion of means for improving the specification and assurance of reliability at the systems level. ##

Serial Number 1266 -1
Codes 740;770;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Saturn systems automatic checkout

AUTHORS: P. M. Hughes, NASA, Marshall Space Flight Center, Huntsville, Alabama and R. W. Milkie, The Boeing Company, Huntsville, Alabama

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 338-344

PURPOSE: To highlight the test criteria pertinent to the evolution of the Saturn system automatic checkout and to present the good and bad factors derived from its implementation.

ABSTRACT: Automation has a definite role in vehicle development and qualification testing. The concept and implementation of automation technology is still in its infancy. However, through the implementation of automation at the Quality Assurance Division (QAD), Marshall Space Flight Center, invaluable knowledge and experience have been obtained. Through utilization of the present equipment, test personnel have demonstrated the feasibility and advantages of automatic systems checkout. This experience has provided the test organization with greater capability to better define future concepts for automatic checkout programs.

QAD is convinced that this area of technology not only applies to, but is a necessity in, present and future programs. It is our conviction that we have confirmed the feasibility of the Saturn automation concept through implementation of automatic checkout techniques on the Saturn I program.

These efforts have shown that the advantages of computer-controlled checkout equipment as originally projected were essentially correct. Some of these advantages in their relative order of importance are:

1. Repeatability of measurements.
2. Accuracy of measurements.
3. Ability to compare measurements with a "standard" or calibration curve to determine acceptability prior to going to the next step. (Using manual checkout, the results of certain tests could be evaluated only after laboriously hand-reduced and compared to calibration curves.)
4. Ability to make numerous samples rather than just a point calibration.
5. Reduction in running time of components.
6. Reduced vehicle checkout times.
7. More even distribution of work load, better utilization of personnel due to advanced preparation and planning.

Certain systems of the Saturn I vehicle do not lend themselves to automation; therefore, continued coordination with the design

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divisions is necessary in order to incorporate automatic features into all systems. Continued exploration of new and improved methods and techniques is required.

Automation has a promising and necessary future in the test and checkout of multi-stage space vehicles. It will validate vehicle systems with a thoroughness and accuracy not possible under manual testing within the same time duration. In essence, automation will increase the validity and enhance the reliability of the present and future manned space flight programs. (Authors in part)

REVIEW: This is a general paper, dealing essentially with the philosophy of the situation--as stated in the PURPOSE. As such it contains worthwhile information. Few of the disadvantages are given, nor are the inevitable troubles in such an undertaking discussed. The gradual use of automation is probably an important factor in the success of this program. For other recent papers on automatic testing see Abstracts and Reviews Serial Numbers 1032 and 1034. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Choosing optimum system configurations

AUTHOR: Lee Webster, Republic Aviation Corporation, Electronic Products Division, Farmingdale, New York

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 345-359

PURPOSE: To present a procedure that can be used to optimize reliability subject to constraints on a system-wide basis.

ABSTRACT: Several theorems are given concerning the increase in system reliability due to logically parallel redundancy of some of its parts. Some of these theorems are based on the work of M. Sasaki (see Abstracts and Reviews Serial Numbers 496 and 978). These theorems are extended to other types of redundancy: quad, majority voting, and sequential. The work is based on the theorem that a low-reliability part, when made redundant, causes a larger numerical increase in system reliability than does a high-reliability part. Therefore, within the allowable constraints of cost, weight, etc. the redundancy is applied first to the low-reliability parts of the system, then gradually to the more reliable ones until a system constraint is reached.

REVIEW: In general the method is presented so that it can be followed with a minimum of study, although careful attention to the explanation is necessary. Within the context of the purpose of the method, it is good; but it may not be applicable in all cases.

There are several "editorial" errors in the paper. There are also some important omissions and debatable points. For example:

1. The failure events are implicitly assumed to be statistically independent. This should have been stated explicitly. (See the paper covered by Abstract and Review Serial Number 199 for a good discussion of the nature of statistical independence.)
2. There is no obvious explicit distinction made between "a" and "A". A minor omission is the perhaps trivial requirement for some theorems that the probability of failure $\neq 0,1$.
3. The term "functional redundancy" is used to denote parallel redundancy in the logical sense. There is some confusion in the paper between the logic network and the circuit network in discussing redundancy. For example, two series capacitors which may fail only by shorting are "logically" in parallel. See Reviews Serial Numbers 1167, 1172, and 1191 for further discussion of this point.
4. The discussion of the quad circuit is not too clear because of ambiguity in the word "OR". The complete equations for the reliability of the quad when both open and short failures can occur are given in Review Serial Number 1191.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

5. The discussion of the majority voting circuit is not up-to-date since the reliability is a function of how the device fails. See the paper covered by Abstract and Review Serial Number 1268 for further discussion.

6. The items in the listing of nine system considerations in the appendix may well be true, but some would benefit by a proof. ##

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Serial Number 1268
Codes 838;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effects of failure modes on redundancy

AUTHOR: L. J. Rhodes, Minneapolis-Honeywell Regulator Company, Aeronautical Division, St. Petersburg, Florida

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 360-364

PURPOSE: To show that the reliability of the majority voting circuits is sensitive to the mode of failure.

ABSTRACT: This paper is an investigation of possible reliability improvements by considering the effects of failure modes on redundancy (in particular, majority-voted redundancy) when such redundancy is employed in a digital system. The investigation includes optimum voter-logic reliability relationships and practical reliability-complexity trade-offs in these optimum regions.

Important assumptions are: (1) the probability of a voter or logic failing to "0" (given that it fails) is the same for both, denoted by p, (2) the most "chaotic" state is characterized by $p = 1/2$, and (3) the relative failure probability of the logic network without redundancy to that with redundancy is the parameter of interest. (Author in part)

REVIEW: The principle introduced here is important although the value of the analysis itself is restricted by the assumptions. Obviously "chaotic" is not "pessimistic" since $p = 1/2$ is the most optimistic value of p possible (i.e., $p(1-p)$ is a maximum for $p = 1/2$).

The real contribution of this paper lies in the author's being able to rise above the common assumptions in logic circuit analysis and to make more realistic ones. ##

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Serial Number 1269
Codes 612;882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Availability analyses--a realistic methodology

AUTHORS: W. E. Faragher and H. S. Watson, Planning Research Corporation, Los Angeles 24, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 365-378

PURPOSE: To present a methodology evolved in the course of conducting availability analyses of a number of complex systems.

ABSTRACT: The various approaches which have been used for availability analyses of complex systems possess varying degrees of lack of realism. Some are inflexible with respect to configuration changes, thus being unsuitable for the study of optimization of availability through equipment redundancy. Others concentrate on the mathematical aspects of the simulation and neglect the engineering aspects that are essential to obtaining a realistic evaluation of availability.

This paper presents a flexible methodology which incorporates an appropriate blend of engineering and mathematical analysis to provide more realistic availability analyses than were previously possible. Three major aspects of the methodology are discussed, viz. (1) its development, (2) its application to the numerical evaluation of the availability of a specific system, and (3) its use as a tool for optimizing availability. The introduction of the concept of "availability matrix" is a unique feature which greatly facilitates the analysis.

The method involves three basic steps: (1) engineering description of the system, (2) formulation of the simulation model and programming it for the computer, and (3) computer exercises and engineering analysis. The various tasks involved in these steps are described and illustrated.

REVIEW: This is a fairly comprehensive description of a methodology for availability analyses developed by the Planning Research Corporation. It would appear from the references cited that details on its application to specific systems are contained in classified documents. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Management of the reliability effort

AUTHOR: Col. W. F. Stevens, HQ AFSC, Andrews AFB

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 379-385

PURPOSE: To discuss the elements of an adequate reliability management program, the management problems being encountered by the Air Force, and the efforts being directed toward their solution.

ABSTRACT: This paper analyzes and partially answers three questions, namely: (1) What constitutes a good weapon system management program? (2) What are some of the problems encountered by the Air Force weapon system program manager? and (3) What current Air Force efforts are being made to improve the weapon system management program?

A good management program has many features. It must establish realistic objectives, provide personnel, money and other facilities. It must contain the capability of evaluating current status in terms of objectives and of determining and pinpointing areas that have veered off course, and indicate what to do about it.

Problems encountered by the Air Force weapon system manager include reliability requirements that cannot be attained without a major breakthrough in the present state-of-the-art, compressed time schedules, and inadequate data documentation and analysis. Recognizing this, the Air Force has activated within its own organization and contracted with others to improve the weapon system management program. (Author)

REVIEW: This is a rather comprehensive description of the approach being taken in the management of reliability programs associated with Air Force procurement. As such, it will be of most interest to those who are concerned with the implementation of reliability assurance provisions in Air Force contracts. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Program costs vs. reliability

AUTHOR: B. T. Colandene, International Business Machines Corporation, Space Guidance Center, Owego, New York

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 386-394

PURPOSE: To discuss the relationship between program costs and reliability as experienced on a missile guidance computer program.

ABSTRACT: This study deals with a specific program based upon a set of requirements related to that program. Three major phases of the program are discussed: research and development, production, and operational use. Each phase is developed to show the impact of reliability upon costs; these are then combined to show total program costs versus reliability. By trading off operational costs with R&D and production reliability costs, optimization can be accomplished. The unique aspect of the information reported here is that empirical data are presented based on a program from its inception through production. To supplement the cost data, a complete breakdown of the Missile Guidance Computer Q&R program with related costs is given.

From the results obtained several basic observations may be made: (1) Q&R development costs for a given equipment and comparable hardware delivery schedules increase with an increase in the reliability requirements. The rate of increase becomes pronounced for increases substantially in excess of the levels of reliability generally observed. (2) Within limits, operational cost can be reduced by increasing product reliability. By trading off these costs with development and production reliability costs optimization can be accomplished. (3) The optimum reliability is influenced by the quantity of hardware in production. (Author in part)

REVIEW: This is a fairly detailed presentation of the program and the associated data. It will be of interest to those who are concerned with the cost and reliability aspects of other programs, and associated trade-off evaluations. The author's "basic observations" are quite in line with reasonable expectations; the important thing is to be able to associate specific numbers in a totally realistic way with the increases in cost and reliability in order to effect optimization.

For other papers in this general topic area see Abstracts and Reviews Serial Numbers 1199, 1297, and 1298. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Is a commercial reliability program feasible?

AUTHOR: Miles Davis, Xerox Corporation, Rochester, New York

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 395-398

PURPOSE: To describe the commercial reliability program at Xerox.

ABSTRACT: A reliability program is needed at Xerox for the following two main reasons:

1. The machines are leased and service calls represent a large expense.
2. There is a direct relationship between dependability and saleability.

Throughout the design of a machine, components and subsystems are analyzed and tested. Some of the samples are small by QC standards, but they are large enough to supply valuable information. There is considerable interaction between the desires and needs of the reliability, maintenance, and design groups. After the machines are built, the whole operator-machine system can be tested and further changes made as necessary to help make the system "foolproof."

To the question in the title, the answer is yes. This answer requires that important corporate attitudes be established in order to sustain a reliability program. Xerox recognizes the fact that service costs are real costs and also that saleability depends on dependability. These are the corporate attitudes that are the foundation of our reliability program. These basic attitudes are not unique to our lease business; they apply to both military reliability programs and extended commercial warranties. (Author in part)

REVIEW: This is a rather general description of the reliability program, problems, and attitudes of a commercial (as opposed to military) manufacturer. More of this type of paper is necessary in order to convince others in the consumer market that long trouble-free life is a reasonable goal for their products.

Other papers dealing with reliability programs for commercial products have been covered by Abstracts and Reviews Serial Numbers 677, 818, 1184, 1186, and 1282. ##

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Serial Number 1273
Codes 720;813;825;
833;853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: "Built-in" reliability for the skybolt computer

AUTHOR: Frank A. Applegate, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 399-414

PURPOSE: To describe the special features of a reliability program for the Skybolt Computer.

ABSTRACT: The Skybolt Ballistic Missile Guidance Computer was developed by GE's Light Military Electronics Department. The reliability program developed for that computer had to do much more than predict or measure reliability. Its goal was to "design" reliability into the computer in the face of both limited funding and a one-year prototype-delivery cycle. The story of how this program was used to achieve a prototype computer with average mean-time-to-failure in excess of 450 hours is the subject of this paper.

Some of the important distinguishing features of this program were the following.

1. It is more important to design reliability in than to run numerous tests to see if it is there.
2. Many circuits and components were standardized heavily. This allowed economies in time, costs, and testing and gave more useful information for each test.
3. All parts tests were statistically designed and analyzed. A maintenance and upgrading part-test program was planned.
4. Worst-case design and statistical analysis of circuits were performed.
5. Prototype assembly was done directly in the factory, rather than in the model shop. This helped train production personnel right from the start.
6. All failures were assumed to have a cause and this cause was tracked down insofar as possible, and corrective action was initiated. (Author in part)

REVIEW: This is a good brief summary of what appears to be an effective reliability program. Certainly the author makes several good points. Perhaps the moral that comes through most strongly is to be sure you know why a reliability function is being performed and what good it may actually be expected to do. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Part application cells definitize reliability risks

AUTHOR: Donald H. Ross, Astro Reliability Corporation

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 415-433

PURPOSE: To define an Application Cell Matrix which provides useful criteria for selection and application of component parts.

ABSTRACT: The purpose of this paper is to establish the basic concepts and explore the technical factors which relate the specific boundary definitions to each Application Cell. The result is a Matrix which may be described by two major coordinates. The abscissa denotes "Mission Levels," which, in turn, are defined in terms of (1) representative equipment types, (2) pertinent environmental conditions, (3) sequence and time-based mix of mission phases, and (4) those mission objective factors which must be accounted for in the definition of a part-survival environment. The ordinate categorizes reliability risk influences in terms of the responsibilities, technological concepts, and disciplined techniques required of the component part producer, as well as the part user, and is expressed as discrete "Industrial Practice Grades." The assignment of part reliability-risks is facilitated by reference to a unique coordinate combination or Application Cell within the Matrix. The result is that only within a given cell is a failure rate numeric deemed to be meaningful for a given functional application. Two discrete Industrial Practice Grades have been defined and labeled as Conventional and State-of-the-Art.

The Application Cells, as defined, aid in the orderly interpretation of parts' test data which may be further reduced to synthesized part failure rates. This technique assures a more rigorous interpretation of the failure rate data which is used in the process of modeling electronic system reliability expectations. Thus, it is made absolutely clear that a component part is <u>not</u> to be considered universally "reliable" without considering the control of operational stresses and industrial practice disciplines. (Author)

REVIEW: While many of the concepts explained in this paper are worthwhile, the utility of this explicit presentation may be low due to the very specific nature of the mission levels. It should be noted also that the surfaces shown in the figures do not actually exist due to the discrete nature of the intervals and that the direction of the arrow for mission level does not necessarily mean increasing severity. ##

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Serial Number 1275
Codes 837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dual-phased failure mode evaluation

AUTHOR: Fulvio E. Oliveto, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 434-448

PURPOSE: To show how circuits were analyzed both on paper and in the laboratory for worst-case conditions.

ABSTRACT: This paper describes a failure mode evaluation technique which consisted of the following two phases: Phase I, a theoretical appraisal entailing an analytical analysis to determine and evaluate circuit failures and degradation limits; and, Phase II, laboratory tests performed to verify these limits and to uncover other failures not predicted by Phase I.

The failure mode evaluation was considered complete only when the causes of the failures were resolved and corrections made to the circuit. These corrective measures made it possible to achieve the low failure rates specified for the equipment. The end result of this dual-phased evaluation was the design and manufacture of a highly reliable missile system.

Thirty-two digital and analog circuits were analyzed using the dual-phased failure mode evaluation technique. Of the thirty-two circuits, twelve failed during Phase I analysis or Phase II testing. The theoretical analysis was worst-case of a conventional type. The laboratory analysis was also worst-case and used the AIL 90 Circuit Design Reliability Tester.

This type of failure mode evaluation is of great importance and a powerful tool for the design engineer to apply as a fundamental step in the development of new circuits. Using this technique, the effects of environmental conditions and parameter variations could be evaluated, and therefore any shortcomings and circuits operation malfunctions could be overcome during the preliminary design stages. The finished circuit would be an optimum design and many retrofitting redesigns would be eliminated. (Author in part)

REVIEW: This is a good article on the application of worst-case analysis. The experimental checking of the worst-case situation is quite valuable; as the author indicates, it is also usually much simpler. It should be noted that while worst-case analysis is usually worthwhile, there are situations in which worst-case design may not be. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Accelerated life testing

AUTHOR: Hauw T. Go, Transitron Electronic Corporation, Diode Division, Wakefield, Massachusetts

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 449-457 (see also Electrical Design News, vol. 9, January, 1964, pp. 98-105)

PURPOSE: To describe the design, evaluation, interpretation, and application of accelerated life testing in improving semiconductor reliability.

ABSTRACT: The time element in conventional life testing hinders the providing of quick corrective action to improve reliability on the basis of observed performance. A means of overcoming this difficulty is accelerated or high-stress testing, in which the occurrence of failure is accelerated by subjecting devices to stresses in excess of those encountered in normal use. Its main purpose is the derivation of a relationship between device failure behavior, stress and time. This relationship may then be used to extrapolate device behavior from a test result at a predetermined condition to predicted results at various test or operating conditions. It is assumed that equivalent failure mechanisms are activated at the different operating conditions. Two methods of accelerated testing are described, viz. (1) the step-stress test in which each test lot is subjected to a series of stress increases, and (2) the stress-sampling test in which each test lot is stressed at only one predetermined level.

The bulk of the paper is devoted to a description of a large-scale test on three diodes: SV-3321, SV-424, and SV-425, for the purpose of evaluating the technique in terms of its practical application in deriving screening techniques, in the comparative evaluation of new device design, and in predicting potential failures. The test design and the data recording and reduction procedure are described briefly. The evaluation of the data is discussed. The results are depicted in some 13 graphs in an appendix.

REVIEW: This paper stresses the practical application of high-stress testing in an actual production line. The method of evaluation is not restricted to a given product type and should have rather general applicability. Those who desire more detail on the background for the procedures will no doubt want to consult the references cited by the author. Sources for these are not given in the paper, but the following information may help. The first one was covered by Abstract and Review Serial Number 165; the second is an internal publication of Transitron Electronic Corporation, Wakefield, Massachusetts; the third is to be published in the 1964 ASQC Convention Transactions. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of microwave tubes

AUTHOR: R. Strauss, ARINC Research Corporation, Washington, D. C.

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 458-466

PURPOSE: To discuss failures in microwave tubes and specifications for guaranteeing procurement of reliable tubes.

ABSTRACT: Although production and use of microwave tubes has flourished, a wide disparity exists in the reliability of tubes. Since microwave tube manufacture is essentially a custom business with quantity requirements for the same tube usually less than 500 units, the causes of the disparity in reliability are difficult to analyze. Some contributing factors are that the microwave circuit is part of the electron source and beam, performance requirements are difficult to achieve or describe, and specifications are lengthy and have a limited common test terminology.

A wide disparity in the life performance may appear to be natural, but evidence exists that it need not be so. Commercial applications of traveling wave tubes, reflex klystrons, high and low power klystron amplifiers, and magnetrons are given as supporting evidence for the possibility of reliable tubes. A brief review of the various types of tubes is given.

Most of the data given on removal rates are for the magnetron, but data are also given for milliwatt reflex klystrons, and klystron power amplifiers. For magnetrons studied the mean time between removals (MTBR) is 500 to 1000 hours, and ground radar performance is four times better than that of pulse airborne or shipborne radar. The latter are subject to more operating cycles and different maintenance methods. The MTBR for milliwatt reflex klystrons was about 5000 hours, and the MTBR for high power klystron amplifiers was about 1000 hours.

Information on MTBR for newer types of tubes is presented as trends indicated in collected data. Carcinotrons are expected to be similar to CW magnetrons of comparable power output. Low power klystrons and wave tubes including the milliwatt level backward wave oscillator should be similar to reflex klystrons at similar frequencies. Medium power klystrons, voltage tunable magnetrons, and watt level wave tubes should have no less than a 500-hour MTBR and half the MTBR of milliwatt reflex klystrons. A 100-300% improvement is anticipated for pulsed kilowatt and megawatt magnetrons, primarily through the introduction of coaxial cavity-type structures. Kilowatt or megawatt pulse klystrons should show a twofold improvement. Comparable performance

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

may be expected for forward wave amplifiers.

The defects analysis indicates, in a general way, that tremendous improvement is possible if greater care is exercised in (1) field maintenance and testing, to prevent removal of good tubes, (2) application of the tubes, and (3) the design of tubes.

In recent years great emphasis has been placed on "physics of failure." Specific work on microwave tubes with regard to heat-transfer problems and electron-interception analysis has been limited. Most basic internal tube failure mechanisms or causes are associated with undesirable or inadequately understood electron motion. Field data on some of the more expensive military tube types should be studied in detail. Their failures should be analyzed and a study supported which would permit evaluation of prediction techniques in relation to these failures.

In procurement several specifications seem to be attractive. The use of 100% life tests for less than 100 hours on life-sensitive parameters would reduce infant mortality. A life sampling plan for small lot production known as the Group S Life Test Plan proposed by Committee JT-11.1 (EIA) includes initial acceptance and short and long life test criteria. The inclusion of application data in tube specifications would reduce misapplication.

REVIEW: In view of the cost of microwave tubes, action on the author's recommendations is justified. In addition to the study of tubes after manufacture, it may be worthwhile to relate failures and manufacturing procedure. The analysis of application cannot be emphasized too much. One manufacturer of commercially available tubes provides free analysis service to tube users when early failures have occurred. Usually the fault is found to be in auxiliary equipment. Also, certain types of tubes coming from one manufacturer are sometimes found to be unreliable. When this is found to be the case, these tubes should be avoided if alternatives are available.

The review of microwave tubes is taken from the first reference cited in the paper. The author, in a private communication, has indicated that this reference makes available to the reader a simplified and good description of microwave tube types--for which the British are noted. ##

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Serial Number 1278
Codes 844;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some methods for accelerating failure modes in receiving tubes

AUTHOR: Louis Gomberg, Astro-Electronics Division, Radio Corporation of America, Princeton, New Jersey

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 467-477

PURPOSE: To show how receiving tubes may be checked for satisfactory performance with regard to non-specification parameters.

ABSTRACT: The tube user is often faced with a choice of vendors. Generally, there are several possible qualified vendors for each tube type, all of whom are essentially equivalent in price. The similarity ends here; vendors employ different trade-offs, some of which may have long-term undesired effects in the circuit. The circuit designer usually does not have sufficient time or resources to evaluate the different manufacturers' products in terms of life and other long-term parameters.

Several methods are presented for accelerating long-term potential failure modes. With these methods, additional insights into the construction and trade-offs which went into the design and fabrication of the tube may be obtained. Data are presented showing correlation between heater power and heater-cathode leakage; total tube power dissipation and interelectrode leakage, grid current measurements and ultimate life; cathode alloy and heater-cathode leakage; and heater design and life.

A case history is outlined which illustrates the application of some of the techniques. Accelerated tests for incipient heater-cathode leakage and marginal heater designs are also discussed. The relationship between manufacturing techniques and the physics of operation are related to the failure modes. The influence of these factors on long-term electron tube performance is discussed. (Author)

REVIEW: In a time when the popular emphasis is on semiconductors, such a paper as this on tubes is a good idea. The paper is well written on a good subject. One wonders, however, why some of the critical tests and parameters described here could not be made part of high-quality tube specifications. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability assessment of liquid rocket engines

AUTHOR: Alvin Steinberg, Marshall Space Flight Center, NASA, Huntsville, Alabama

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 478-484

PURPOSE: To describe various techniques for evaluating static firing test data on liquid rocket engines.

ABSTRACT: Reliability assessment of NASA development programs is essential in order to provide information for management decisions. Although a great effort has been expended over the years to standardize scorekeeping techniques, satisfactory methods are not yet available. For rocket engines the technique developed by Lloyd and Lipow [1], for evaluating static firing tests has been widely implemented. However, shortcomings of their system makes it mandatory for NASA to investigate better techniques. The most promising approaches are by using test objectives as a criteria, by comparing performance variables data on a probability of conformance to specification limits, or by special treatment of overstress test results.

Contractual engine reliability requirements are indicated. The purpose of the assessment of reliability levels is outlined, the current demonstration procedure is described, and the new techniques aimed at overcoming its shortcomings are indicated. Brief reference is made to related studies on the rate of testing, frequency of malfunction occurrence and cumulative malfunction cost, and unit cost per static firing test. Display charts used in summarizing the results of assessment are illustrated in an appendix. (Author in part)

REFERENCE: [1] Reliability: Management, Methods, and Mathematics, David K. Lloyd and Myron Lipow, Prentice-Hall, Inc., 1962, Chapter 16

REVIEW: This paper is a rather brief discussion of some of the problems encountered in using ground-test results to establish a confidence related to flight reliability, together with some of the means adopted to solve them. For those who may desire more details, five references (in addition to [1], above) are cited in the paper. ##

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Codes 715;770;782;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Pulse radiation reliability of passive electronic parts

AUTHORS: Charles P. Lascaro and William Schlosser, U. S. Army Electronics Research and Development Laboratories, Fort Monmouth, New Jersey

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 485-493

PURPOSE: To discuss the methods and results of pulsed nuclear radiation testing.

ABSTRACT: Experimental Techniques: The state of the art of pulsed radiation testing has proceeded to a level of proficiency such that increasingly reliable and quantitative data for individual parts can be accumulated. At present, the weapon environment can best be simulated by a combination of tests at three facilities namely; LINAC, SPRF and TRIGA or DRF. The use of these facilities is complex and should be limited to a need to confirm the predicted behavior of selected parts that are expected to contribute significantly to malfunction in a circuit. Based upon the current knowledge of radiation effects on parts, the performance of the part can be estimated, and tests should then be accomplished to confirm predictions. In this connection, utilization of the latest prediction techniques being developed by Boeing and IBM is suggested. There is a need for simplification of the test procedures so that qualification and service-life data can be accumulated in order to establish radiation reliability indices for electronic parts. The techniques for making accurate measurements are rather difficult, especially with regard to influences on/from the connecting cables and the instrumentation.

Radiation Reliability of Parts: Under the effects of a pulsed nuclear radiation environment, no permanent effects have been noted except "memory" effects in dielectrics, which may store a charge for delayed release. Sufficient data on which to base a relative reliability index exist mainly for capacitors, resistors, cables, memory cores and tapes. These have been selected because they are considered to be important in critical circuit functions. Other type parts may be similarly affected but their expected transient malfunction in a circuit has been of such a nature that this has not been a cause for major concern to date. None of the five items listed is considered as susceptible to radiation as semi-conductor devices (such as transistors). Capacitors are considered to be the most critically affected of the passive parts, providing an induced current which is dependent upon dielectric constant, the dose rate, capacitance, geometric configuration and the shape of the radiation burst. Resistors are less affected and, if adequately potted, should cause little, if any transient difficulties in circuit usage. Cables will introduce an increase

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in attenuation of RF signals, but this is only a transient and may be ignored in many applications. Magnetic cores and tapes for data processing use have been thoroughly checked at the SPR facility and are considered inherently radiation resistant under these conditions.

Air and Surface Effects: Air and surface ionization will cause the most profound effect in parts by forming a leakage resistance path that may be as low as 10 to 100 kilohm (at SPRF). Heavy coating of the part or potting of the assembly will, however, minimize this effect. Pulse currents may also be expected in the dielectric materials, and these are not as readily controlled as yet. (Authors in part)

REVIEW: This is a specialized paper and deals largely with the transient effects of nuclear radiation--simulated to be from a nuclear explosion. The material is of interest to this field and shows the progress that is being made in these difficult measurements.

The paper contains 20 pertinent references. Other papers on the topic of pulsed-radiation effects have been covered by Abstracts and Reviews Serial Numbers 108, 823, and 826. A listing of Abstracts and Reviews covering other papers on the effects of radiation and other environments is found in Review Serial Number 821. This list should now be updated through the inclusion of Abstracts and Reviews Serial Numbers 1128, 1138, 1148, 1149, 1152, 1155, 1156, 1175, and 1257. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimates of error for design reliability

AUTHORS: Bruce L. Baird and William N. McLeod, Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 504-509

PURPOSE: To show how uncertainties of individual parts of a function are combined to evaluate the uncertainty of the function.

ABSTRACT: The proper procedure for estimating variation of dimensions or performance of an assembled product from component parts is based on propagation of error from mathematical relations. This technique should be used to provide proper weights of the variation of each component part and also to avoid indiscriminate use of rules of thumb.

The subject of propagation of error is introduced by a simple example of the generally understood linear equations and summation of variances. The weighting of variables, simple products, quotients, and finally complex multivariable equations with correlated variables is then discussed. The general procedure consists of the summation of products of partial differentials and standard deviations.

The Monte Carlo or model sampling procedure is presented as an alternate or auxiliary technique. This consists of simulating data representing a random sample for each variable or component, followed by combination simulating the assembled product. This procedure is particularly useful if the mathematical equation is complex and/or variables are correlated. (Authors)

REVIEW: This is a rather brief standard discussion of the problem of combining uncertainties. The treatment of the Monte Carlo procedure is too abbreviated to have instructive value. ##

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Serial Number 1282
Codes 720;813;814;
860

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Industrial reliability programs must produce reliability plus cost reductions

AUTHORS: Harmon S. Bayer, Bayer, Kobert & Associates, Inc., Management Consultants, Detroit 26, Michigan and Gayle W. McElrath, Industrial Engineering Division, University of Minnesota, Minneapolis 14, Minnesota

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 510-516

PURPOSE: To discuss the problems associated with the establishment of reliability programs for non-military industry.

ABSTRACT: The development of reliability programs for commercial (as opposed to military) products is curtailed by the necessity of avoiding prohibitive costs. However, programs for commercial products can benefit by the experience gained and the methods developed by producers of military equipment. Adaptations with a view to reducing costs are necessary. The commercial program must not only assure adequate reliability; it must also produce cost reductions for the company. The survival of the individual company in a competitive market will depend on recognition of this economic fact.

Military and commercial reliability are contrasted. The following topics are discussed briefly: costs of reliability, the identification of priorities for reliability program action, responsibilities and authorities, solving the problems of reliability, statistical engineering methods, design reliability problems, product development, effects of process on reliability, process development, process improvement, process problem solving, process controls, improvement of maintenance, testing, screening, 100% inspection, engineering laboratory reliability tests, and field experience with warranty costs. It is concluded that approaches such as extensive screening which have been used in military programs are not feasible for commercial programs; emphasis must be greater on process controls.

REVIEW: This paper will be of interest to those who are concerned with reliability programs for commercial products. From the range of topics included, it is evident that they are covered briefly in broad generality rather than in specific detail. However, the authors cite some 15 references, in which additional discussion and information may be found.

Other papers dealing with reliability programs for commercial products have been covered by Abstracts and Reviews Serial Numbers 677, 818, 1184, 1186, and 1272. ##

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Serial Number 1283
Codes 837;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Apollo reliability by demonstration or assessment

AUTHOR: Roy B. Carpenter, Jr., North American Aviation, Inc., Space and Information Systems Division, Downey, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 517-524

PURPOSE: To describe the problems associated with the achievement of reliability assurance in the Apollo program without conventional demonstration.

ABSTRACT: Apollo Program reliability objectives are stated as (a) the probability attached to a successful mission, and (b) the probability of a safe crew recovery. The problem presented is how to achieve reliability assurance without conventional demonstration. This paper defines the problems attached to the demonstration of Apollo objectives and presents what is believed to be a realistic and practical solution. The solution involves a combination of two simple test principles: NAA's "off-limit" and "mission simulation life" tests. A form of these tests is applied to the development, qualification, and flight test phases. Application varies and acceptance criteria including all levels of assembly is fully controlled. Practical examples of test application are discussed. Concluded is that test planning and reliability engineering are one integrated engineering responsibility from development through acceptance. This organization is the key to Apollo's reliability demonstration by assessment to assure complete mission success and safe crew recovery. (Author)

REVIEW: This is a good description of the problems associated with the demonstration of reliability objectives in a specific program, and the steps taken to achieve a solution. The absence of sufficient data on which to base valid statistical conclusions is a fact with which the engineer must live in such situations, and it becomes necessary to resort to engineering judgment. It is important to be sure that the engineering judgment is based soundly on all of the information which is available. The application of less conventional statistical techniques (such as Bayesian analysis, for example) may prove to be helpful. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Achieving circuit reliability with linear programming

AUTHORS: H. J. Jelinek and F. R. Frola, Autonetics, A Division of North American Aviation, Inc., Anaheim, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 525-537

PURPOSE: To describe an application of linear programming to the design of a circuit which dissipates minimum power, while satisfying all the circuit functional constraints.

ABSTRACT: Circuits are designed to perform given functions, which are ordinarily stated as a set of specifications. Constraints which specify performance in terms of circuit variables such as voltage and current are set in advance and are usually determined by system requirements. For a fixed circuit topology, the designer selects components whose parameter values satisfy the constraints on the performance variables. Similarly, there are several functions of the parameters which one attempts to make optimum; these functions might be cost, weight, power dissipation, etc. By applying the technique developed in this paper, the circuit may be made optimum with respect to any one of these. This type of problem can be handled by linear programming and the solutions can be obtained by use of a digital computer. The solution in addition to being optimum, satisfies all of the constraints on performance.

REVIEW: This paper can serve as a useful introduction to linear programming for circuit design, but it is not detailed enough to actually teach one how to apply it. Even though computer programs are available for effecting the calculations, the user must understand the principles in order to set up the problem properly. It is particularly important to be sure that the solution represents a physically realizable circuit. (The equations and examples in the paper were not checked in detail but they do appear to be reasonable.) ##

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Codes 713;720;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluation of the effects of manufacturing processes on structural design reliability

AUTHOR: P. Kluger, Aerojet-General Corporation, Sacramento, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 538-544

PURPOSE: To show how to calculate reliability as a function of stress, strength and their variabilities.

ABSTRACT: The safety margin, (mean strength-mean stress)/(combined standard deviation), can be expressed in terms of a safety factor and the coefficients of variation of stress and strength. Reliability is defined as the probability that the safety margin is more than 3--assuming that all variables have Gaussian distributions.

REVIEW: The concept of safety margin itself would seem to be of more direct use and benefit than that of safety factor. Except for the arbitrary 3σ limits, the paper adequately fulfills its purpose (although there are numerous typographical errors). If one stays with safety margin there will be little need for most of the formulas in this paper; that course is recommended. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Techniques for predicting reliability, R and D cost and time

AUTHORS: Frank C. Reed and Hiromi M. Dye, Planning Research Corporation, Los Angeles, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 545-554

PURPOSE: To describe statistical techniques for predicting the operational reliability, development cost, and development time for a proposed system.

ABSTRACT: Operational reliability and R and D cost and time are assumed to be random variables. Given the distributions of these random variables, one may predict the intervals within which they may be expected to lie. In this paper three statistical models for reliability, cost, and time are discussed. Two are based on the assumption that these random variables are normally distributed, independently in the first model, and not independently in the second. The third model involves a nonparametric approach; in it no assumptions about the distributions of the random variables are made. The comparative attributes of the three models are discussed.

These techniques are designed to be implemented with relevant empirical data obtained from previous R and D programs. Two studies are referenced in the paper; in these the pertinent data were obtained from contract records, technical documents, historical summaries, and interviews with cognizant project personnel. The models have been programmed for solution on a scientific computer. The statistical procedures include the computation of prediction intervals for the individual estimates.

REVIEW: This paper is a mathematical description of the techniques cited; no details on their application are given. Perhaps those who have a need for further information may get it from the first two references given in the paper (the first one is a confidential document). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Bayesian operating characteristic curves for reliability and quality sampling plans

AUTHOR: R. E. Schafer, Hughes Aircraft Company, Fullerton, California

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 555-559

PURPOSE: To point out a new way of evaluating sampling plans and to suggest that sample sizes can be reduced by including prior knowledge.

ABSTRACT: The operating characteristic (O.C.) curve of a sampling plan indicates only the probability of acceptance of a lot, given that a particular quality is submitted. It tells nothing about the probability of a lot having a certain quality, given that it is accepted. But the latter is, in fact, what many users <u>feel</u> the O.C. curve gives them. A much better approach to the lot acceptance problem is to calculate the probability of a particular lot quality, given that the lot was accepted. This requires some knowledge of the probabilities of having produced a lot of a particular quality. The method for putting together this information is classically known as Bayes Rule. Examples are given.

REVIEW: The subject of this paper is most important and should not have been relegated to standby status at the symposium. The classical sampling plans implicitly assume that the producer does not have the vaguest idea of what quality he is producing--an obvious absurdity for most production lines. If such were really true, the producer would soon go out of business. Some means of taking this previous knowledge about the process into account is important. While this paper is not the final answer, it is a large step in the right direction.

At present, of course, the big customers (U. S. Federal agencies) do not allow such sampling calculations. More papers on this subject, in all sorts of journals and trade magazines, are necessary in order to create an awareness of the problem and to get the right things done about it. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A mechanized aircraft reliability analysis model

AUTHORS: B. F. Shelley and D. O. Hamilton, Lockheed-Georgia Company, Marietta, Georgia

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 560-566

PURPOSE: To show the development of a reliability model useful for calculating system reliability.

ABSTRACT: In the development, manufacture, and operation of equipments, there is, among other things, a need for reliability evaluation of alternate system configurations for selection of an optimum system design and measurement of reliability growth. There is also a need for rapid calculation so that results may be timely applied for design and planning decisions. A computerized technique which may be used to accomplish such evaluation is the subject of this paper. The emphasis is on providing a consistent and realistic reliability evaluation method that measures the achieved reliability and monitors the reliability growth throughout the development and operational life of airborne systems.

Instead of reliability numbers, failure rates are used in the calculations in order to make the arithmetic simpler. The formula for the probability of successful operation of at least n-1 of n parallel branches is derived. Equations for eleven special cases have been calculated, including those for dissimilar branches; four of these are given in the paper. All redundancy calculations are performed by subroutines in the computer; component failure rates can be stored in the memory beforehand. A coding system for "structuring" the model was devised. The computer can perform a complete aircraft analysis in 2.5 minutes. (Authors in part)

REVIEW: The paper is composed largely of a specific analysis of the probability of successful operation of at least n-1 of n parallel branches and of a general description of the computer program and its advantages. The computational procedures seem quite adequate and undoubtedly have advantages over some previous procedures.

A review of a private communication from the first author indicates that a rephrasing of some of the points in the redundancy derivation is in order. These are as follows.

1. It is assumed that after each mission the system is returned to its condition at t = 0. (This can be a rather stringent restriction.)
2. It is assumed that all missions are of the same length, T.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

(The symbol t is used, undefined, in the text and leads to some confusion on this point.)

3. The "exponential" assumption is not made except as is implied in 1. above. Instead of using reliability (or probability of success), a new parameter f is defined by the equation

$R \equiv e^{-fT}$ or $f \equiv [\ln(1/R)]/T$. This can be considered an effective or equivalent failure rate for the mission; since T is not a variable here, the analogy should not be pushed too far.

4. If the reliability for n-1 independent branches out of n is substituted in the equation for R, the resulting expression is $F = \Sigma f_i - [\ln \{1 + \Sigma (e^{f_i T} - 1)\}]/T$ where F is the f for the redundant subsystem and f_i is the f for the i th branch (sums are over i from 1 to n).

5. For a series system of independent subsystems R_{system} = product of ($R_{subsystems}$) or $f_{system} = \Sigma f_{subsystems}$. The arithmetic for the f's is simpler than that for the R's since the R's are all so close to unity.

6. The expression for F is considered by the authors to be "too complicated" for a computer subroutine and so a power series expansion in T is used. The third term is incorrect; it should be, for a Maclaurin series, $[n(n-1)(6n^2-6n+1)/24]\ f^4T^3$. The region of adequate convergence is $nfT \ll 1$. If such is not the case, the series will converge slowly or even not at all. Other subroutines are available on computers for evaluating expressions like F and may be more useful in some regions of nfT.

7. The assumption of statistical independence is sometimes rather severe for identical parallel branches. (See the paper covered by Abstract and Review Serial Number 199 for a more complete discussion of statistical independence.)

In summary, the paper is a worthwhile contribution toward reducing the complexities of making elaborate system reliability calculations. As usual, before using these results, care should be taken to check the assumptions, etc. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A technique for estimating heat shield reliability

AUTHOR: R. M. Sirull, Reliability Analysis Section, Avco Research and Advanced Development Division, Wilmington, Massachusetts

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 567-572

PURPOSE: To show that estimates of reliability can be made for superficially-passive devices.

ABSTRACT: A method is outlined for generating realistic reliability estimates for the heat-shield/substructural composites of re-entry vehicles and for similar critical quasi-passive systems, using a recently developed mathematical model. Some of the factors entering into the determination of the number of tests required to furnish the inputs to this model are discussed briefly, and some of the possible cost trade-offs are identified.

When the reliability-confidence appears to be too low, it will often be of advantage to increase the "implied" sample size. This concept and procedures for evaluating it are given. (Author in part)

REVIEW: This is a rather brief, although good, paper. Some of the extensions of the analysis, called "obvious" by the author, will not necessarily be so to many engineers. Several references are given, however, which should be of help. The discussion of "implied" sample size will be rather new to most people and will need careful study. Again, some references are given. In short, the paper is adequate for those who desire a cursory view of the method; those who require more detail should consult the references cited in the paper. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A rapid reliability estimator for redundant standby configurations

AUTHORS: G. A. Thompson and W. K. Rapp, Minneapolis-Honeywell Regulator Company, Aeronautical Division, Minneapolis, Minnesota

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 573-578

PURPOSE: To present a rapid reliability estimator for configurations containing standby redundant elements with different failure rates.

ABSTRACT: Determining the reliability of a system or subsystem having an exponential density function is laborious and time consuming if a portion of the system or subsystem contains standby redundant elements with different failure rates. The standard methods for determining the reliability of such a redundant configuration require performing a series of multiple integrations or at best evaluating a series of terms. This paper presents a solution to this problem by providing an estimator that is time saving, simple and accurate.

The development of this estimator was suggested by the relationships between the Lagrangian Polynomial, the Taylor Series and the standard reliability equations for such a system. The standard reliability equation for a system of n elements is derived by a classical approximation technique. As an outgrowth of this approach, a definite upper bound on the systems unreliability is thus determined by allowing the number of elements in the system to become arbitrarily large. This estimator, D_n, is shown to be the maximum unreliability that the system can attain. An accurate reliability estimate of the standby redundant system is established by subtracting D_n from unity (i.e., $1 - D_n \simeq R$). The reliability estimate for a system or subsystem with one element in standby has an error of less than one per cent for values of $\lambda t \leq 0.4$ and an error of less than five per cent for values of $\lambda t \leq 0.5$. The errors involved in using this estimator decrease as the number of standby elements increases.

Using this estimator, it is possible to rapidly and accurately determine the effects on the reliability of a standby redundant configuration due to either adding or deleting an element, without having to evaluate the standard equations. Examples showing the use and the amount of error involved are also given in this paper. (Authors in part)

REVIEW: This is a mathematical paper in which the assumptions are clearly stated, the development is outlined, and references are cited in which more details may be found. The examples given have good illustrative value. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The use of entropy in hypothesis testing

AUTHORS: Myron Tribus, Robert Evans, and Gary Crellin, Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 579-590

PURPOSE: To define an entropy, show how it is used in testing hypotheses, and compare it with other methods.

ABSTRACT: A basis for comparing two hypotheses is the use of Bayes' equation in logarithmic form to define the "evidence". The result is that the evidence in favor of an hypothesis over its competitor is the difference between the respective entropies of the competitor and the hypothesis under test. Some brief examples are given. (Authors in part)

REVIEW: While this paper does not deal with reliability per se, it probably has important applications in the reliability field. The paper is quite mathematical in nature (the equations were not checked in detail) and will be difficult, though worthwhile to understand for most engineers. Several references are given for the core of the method, and they are duplicated to a certain extent in the paper.

More work will have to be done by theoreticians in this area before the method can be assimilated readily by engineers--all a worthwhile goal.

The first author, in a private communication, has commented that the paper represents a "Bayesian" response to the chi-squared test and as such is probably of particular interest to those who are concerned with the Bayesian versus classical dispute. ##

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Serial Number 1292 -1
Codes 817;873;883

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A reliability-maintainability trade-off procedure

AUTHORS: Ronald A. Westland, Donald T. Hanifan, Western Division, Dunlap and Associates, Inc., Santa Monica, California and Jacob Sacks, Fleet Electronics Effectiveness Branch, Bureau of Ships, Washington, 25, D. C.

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 600-611

PURPOSE: To describe a procedure for determining reliability and maintainability design approaches which will result in a system design which satisfies a specified availability goal, satisfies design- and mission-related constraints, and results in design optimization with respect to a trade-off criterion such as minimum cost.

ABSTRACT: System effectiveness, or the probability of a system successfully performing the mission for which it is designed, may be determined by the relation between: (1) the probability of operation with respect to engineering standards -- performance; and (2) the probability of operation with respect to time -- availability (or alternative measures such as dependability). Availability, in turn, is determined by the relation between reliability and maintainability, which ultimately are functions of a number of design and support factors. The fact that so many values can be assumed by the variables which contribute at each tier in the hierarchy leading from design and support factors to mission success, provides both the need and the basis for trade-off procedures to establish the optimum relation among them at each tier. A reliability-maintainability procedure is one of the trade-off tools needed, and deals with the trade-offs performed among the variables which affect system availability or dependability.

The reliability-maintainability trade-off procedure described in this paper prescribes a method for determining reliability and maintainability design approaches which will result in a system or equipment design which satisfies a specified availability or dependability goal, satisfies design- and mission-related constraints, and results in design optimization with respect to a criterion such as minimum cost for achieving the specified availability or dependability goal.

The topics discussed include mission requirements, design approaches, and procedure, the latter being given in considerable detail. It is indicated that before the procedure can be applied routinely the areas of MTTR and MTBF prediction must receive more attention. The collection of a body of standard data to simplify use of the procedure and to augment its accuracy is needed. The next steps to be undertaken are application and refinement of the trade-off

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procedure, and development of prediction techniques which are sensitive to the key design and support features which should be subjected to trade-off. (Authors in part)

REVIEW: This is a clearly-presented discussion of a design-oriented approach to the effecting of reliability-maintainability effort trade-offs. Ten pertinent references are cited for those who may desire more details. It should be emphasized that trade-offs are made between the efforts devoted to reliability and maintainability, not to known reliability and maintainability achievements themselves.

This paper and the one covered by Abstract and Review Serial Number 1181 are on basically the same subject. The latter paper is concerned with the theoretical aspects, while this one is more design-oriented. The reader interested in this topic will find it worthwhile to read and compare the two papers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dormant missile system checkout effectiveness

AUTHOR: Robert Willstadter, Lockheed Missiles & Space Company, Palo Alto, California (presently with The Boeing Company, Seattle, Washington)

SOURCE: Proceedings Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964, pp. 612-623

PURPOSE: To present an analytical approach to the problem of activation and checkout of dormant missile systems.

ABSTRACT: This paper presents an analytical approach to the problem of activation and checkout of dormant missile systems. Emphasis is on the establishment of an evaluation model, the delineation of alternate checkout design philosophies and the presentation of fundamental trends and implications associated with each of these philosophies.

The primary measure of effectiveness is taken to be operational readiness per total relative cost expenditure. Operational readiness is defined as the probability that the system will be ready at some time of emergency selected at random within its design operational life. Total relative cost is the ratio of initial and replacement costs to initial cost.

The basic checkout effectiveness factors are taken to be false alarm probability which is the probability that checkout indicates that the system is not ready when in fact it is and failure detection probability, which is the probability that checkout correctly indicates that the system is not ready. False alarm probability is assumed to be negligibly small. Effects of various checkout frequencies are indicated as a function of these effectiveness factors as well as a function of (MTF)/(required life) and (replacement cost)/(initial cost).

The candidate checkout systems are evolved from a statistical decision theory model and consist of scheduled maintenance, no checkout, unconventional maintenance (defined essentially as the opposite of conventional maintenance) and conventional checkout. No checkout is considered with and without subsequent sampling, the former case corresponding in effect to scheduled maintenance. Conventional checkout supplemented by sampling of systems estimated to be operationally ready but which may in fact not be ready due to the failure detection factor is not treated explicitly but lies within the framework of the model developed.

Considering the required operational life to be 5 years, the salient findings with respect to cost effectiveness, based on the range of input parameter values indicated in the paper are

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

as follows:

(1) The potential value of checkout is significantly greater for an MTF of 1 year than for an MTF of 5 (or 10) years.

(2) Independent of MTF, replacement costs must be less than approximately 60% of the initial cost if checkout is to be beneficial.

(3) Significant effectiveness gains may result even if the attained failure detection probability is quite low, although the additional gains associated with high failure detection probability warrant careful attention paid to this parameter.

(4) Based on considering up to 100 checkouts during the operational life, it appears that on the order of approximately 10 checkouts appears most desirable provided the ratio of replacement cost to initial cost is not greater than 60%. Even with a considerably larger number of checkouts, the potential cost effectiveness gain is generally negligible and the "no wear-out" assumption tends to become highly questionable.

Significant trends for the case of scheduled maintenance are as follows:

(1) The optimum number of replacements varies from 0 to 4 depending on (MTF)/(required life) and (replacement cost)/(initial cost); the amount of replacement may be expected to decrease as reliability growth is attained.

(2) Scheduled maintenance desirability decreases with increasing design life. For example, it appears preferable to conventional checkout if failure detection probability is less than approximately 0.5 in the case of [(MTF)/(required life)] = 0.2 and less than approximately 0.2 in the case of [(MTF)/(required life)] = 1.0.

(3) In view of the uncertainty it appears will exist in determining the actual system MTF in a prolonged dormant state, final system selection in any application should be based on sensitivity analysis in which effects of actual MTF significantly different from that anticipated are evaluated. (Author in part)

REVIEW: This is a rather complex paper since it requires the remembering of many definitions. It appears to be quite sound (although not all of the mathematics was checked), and is certainly worthy of study by anyone concerned with this particular area. The concept of unconventional maintenance is apparently introduced for completeness, but no calculations are made concerning it. The term "chance failure" is used and discussed. This concept can be misleading and should be used with caution; for a discussion on this point see Review Serial Number 1216. (Measure of effectiveness is inconsistently defined, but it works out all right in the end. It should be: (operational readiness)/[(total cost)/(initial cost)]). ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability programs for "L" systems

AUTHORS: James R. Barton, Major, USAF and George H. Allen, Electronic Systems Division, Laurence G. Hanscom Field, Bedford, Massachusetts

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 303-309 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss the reliability programs for "L" systems.

ABSTRACT: The AFSC Program Structure assigns numbers and letters to the various programs in order to identify the efforts for management control. The fact that most of the command and control systems have the designator "L" affixed has prompted the reference to them as the "L" systems.

In this paper the mission of "L" systems has been described, the complexity of the equipment indicated, and the importance of these systems to our national defense efforts pointed out.

The efforts by the Electronic Systems Division to comply with the Air Force policy that a comprehensive reliability program be required for each contract to assure delivery of reliable systems and equipment to the Air Force inventory are described in considerable detail. (Authors)

REVIEW: This is a rather long summary, but anyone connected with these systems needs to be familiar with the contents of this paper. Just how effective these programs really are in practice is more difficult to say. Trends toward incentive contracts may help.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing reliability in spacecraft solar power supplies

AUTHORS: I. Doshay and W. F. Emrich, Space-General Corporation, El Monte, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 311-319 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

This paper is essentially the same as the one covered by Abstract and Review Serial Number 651.

TITLE: Achievement of reliability in space systems

AUTHOR: Harvey W. Fritz, Space Systems Division, Air Force Systems Command, Los Angeles 45, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 321-331 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

This paper is essentially the same as the one covered by Abstract and Review Serial Number 303. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: TRANSIT reliability

AUTHOR: Richard W. Cole, Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 333-337 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss the purpose of the TRANSIT satellites and the philosophy behind the associated reliability effort.

ABSTRACT: The TRANSIT navigation system as presently conceived and planned consists of four satellites orbiting at 500 to 600 nautical miles in a polar orbit. Each satellite contains two high frequency transmitters whose frequency is obtained through multiplication from an ultra stable oscillator for doppler data plus a memory from which the satellites present ephemeris data is continuously transmitted in digital form using pairs of doublets with phase modulation on one of the high frequency transmitters. Any ship at sea outfitted with suitable receiving and computing equipment can determine a precision fix on its position by using only the doppler track and ephemeris data from a single satellite pass provided the pass falls within a suitable angle between the horizon and directly overhead. Economic factors make it necessary that the satellites operate satisfactorily in the space environments for periods of time which are long when compared to present day ground equipment where maintenance is used to maintain continued operation. The Applied Physics Laboratory is making every effort to conduct a program which is balanced between research, development, and engineering whose program goal in reliability is to make a long operational lifetime in orbit an inherent "designed in" characteristic of the TRANSIT tactical satellites.

Four of the satellites in this program are still in operation. One is testing the evaporation of 60-40 solder in space--the evaporation is negligible. (Author in part)

REVIEW: This is a rather general summary of the program although the comments on the operating satellites are specific. Most of the paper is taken up with summaries of the goals and their methods of implementation. The comments on lead-tin solder are particularly interesting. ##

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Serial Number 1297
Codes 814;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The economics of a reliable system

AUTHOR: L. N. St. James, Bell Telephone Laboratories, Incorporated, Whippany, New Jersey

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 341-353 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To propose the concept of "an adequate system" in contrast to that of a "reliable system."

ABSTRACT: Reliability of equipment, as usually defined, is not a sufficient concept for its design. The following points are important.

1. Our individual survival, our companies' survival and on up the ladder depends upon the survival of our country which in turn is contingent upon an effective military establishment.

2. An effective military establishment depends upon adequate systems. An adequate system can be defined as the lowest total cost system that will do what the user expects it to do whenever called upon.

3. System performance characteristics, mission reliability and availability are not of themselves adequate goals. The true goal is a system complex that will perform its intended function at the lowest possible total cost.

4. This true goal can be attained by (a) accepting the cost of pushing component failure rates ever lower and (b) accepting the cost of designing systems that will fully realize these lower failure rates. (Author in part)

REVIEW: Obviously one cannot quarrel with the concept of "an adequate system" as defined in the paper. In practice, however, there is more to specifying an adequate system than appears here. While the concept of reliability as formally defined is not sufficient, compared to that of adequate, the two concepts are not incompatible. Further, the term "reliability" as often used connotes low failure rates during useful life. This turns out to be one of the main points of the paper and an important one, indeed--that lower failure rates are needed.

While the main thought is worthwhile, the paper is filled with generalities and the introduction is a highly personal, not universally accepted, philosophy. (The absence of the identifying numbers on the figures in the paper is a source of inconvenience and possible confusion to the reader.)

Much of the content is similar to that in the paper covered by Abstract and Review Serial Number 1199. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System reliability estimation

AUTHOR: L. N. St. James, Bell Telephone Laboratories, Incorporated, Whippany, New Jersey

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 355-361 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss some phases of reliability estimation and the need for the use of low-failure-rate parts.

ABSTRACT: In the usual reliability estimation process the following four assumptions are made.

1. Times between failures are distributed exponentially.
2. Failures are clearly defined.
3. A system consisting of a heterogeneous mixture of parts, some of which have been replaced after failure, approaches a condition of constant failure rate.
4. Inherent failure rates are independent.

It is important that low-failure-rate parts be used in a large system and that the system design be such as not to degrade this failure rate. The amount of money that can profitably be spent in this quest is tremendous if low total cost is used as a measure.

REVIEW: This is a reasonable paper although the main emphasis is not on the subject of the title but on low total cost as in the paper covered by Abstract and Review Serial Number 1297. The discussion on the assumptions involved in estimating failure rates is good but not extensive. The time cost of money is apparently ignored in all the cost calculations. It is stated that "adequacy" is given a full operational definition; however, this does not seem to have been accomplished.

The importance of using (properly) parts with low failure rates cannot be stressed too strongly. However, good system design can increase the tolerance allowed for part drift, and thus effectively increase the part reliability. Those parts with the highest effective failure rates should, of course, be improved first.

(The absence of the identifying numbers on the figures in the paper is a source of inconvenience and possible confusion to the reader.) ##

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Serial Number 1299
Code 831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System reliability evaluation testing

AUTHOR: G. A. Schiehser, Bell Telephone Laboratories, Incorporated, Whippany, New Jersey

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 363-365 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To show the proper purpose of system reliability testing.

ABSTRACT: When tests are performed on systems, their main purpose should be to see that the systems properly fulfill their intended function. Production control tests should check to see whether production methods have degraded this function. Assuming good engineering, everyone is just looking for the occasional error that may creep in. If none has been made, the intended function will be met by production systems and this includes the mean time between failures and the mean time to restore normal operation. Reliability testing should be directed toward the much broader objective of answering the specific questions of the functionally involved organizations, which reduce essentially to error detection rather than to the 90% confidence demonstration of mean times which is becoming currently popular. It is only by such a complete process confirmed by an error detection test, that the user can secure assurance of adequate systems.

Unfortunately, we do not have all the answers to this problem of error detection. To date, we have tried several procedures which have been more or less successful but none have proved ideal. The objective should be to devise test procedures that will yield a high level of assurance of detecting any significant errors in this elaborate and complex process which we have labeled system evolution. (Author in part)

REVIEW: The over-all idea in this paper is useful, but the presentation suffers somewhat from brevity and over-generalization. ##

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Serial Number 1300
Code 783

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Confronting the environment

AUTHOR: T. B. Delchamps, Bell Telephone Laboratories, Incorporated, Whippany, New Jersey

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 367-379 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To discuss environmental definition as an essential ingredient of successful system design and meaningful reliability estimation.

ABSTRACT: Because of the press of schedules (time and cost), too little attention is paid to the adverse effects of the environment on the reliability of parts. Several examples are given to show that the acquisition and use of data on this subject are most important.

Failure is sometimes the price of knowledge. More often, however, the price is paid for information already available or at least accessible at modest cost. Since the environment must ultimately be reckoned with, then its definition is a matter of utmost urgency in any development effort. Continued updating and application of environmental knowledge in design and evaluation are essential factors in minimizing wasted time and effort, two priceless commodities in today's market. Is this not, after all, a common goal of all reliability effort? (Author in part)

REVIEW: The point in this paper is well taken, but it is certainly not new. Perhaps it needs constant emphasis.

(The absence of the identifying numbers on the figures in the paper is a source of inconvenience and possible confusion to the reader.) ##

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Serial Number 1301
Code 831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System reliability evaluation from success and failure data

AUTHOR: R. Hammell, Bell Telephone Laboratories, Incorporated, Whippany, New Jersey

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 381-386 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To point out that proper use of failure information is vital.

ABSTRACT: Naturally, the earlier in the development of a system that reliability troubles can be found and corrected, the better off everyone is. However, careful attention must be paid to finding, reporting and correcting defects all along the line. The conclusions drawn in the paper are the following.

1. Reliability is in transition between art and science. Greater efforts are needed to mix it with other disciplines.
2. To increase understanding by project people, let's not be reticent about our success.
3. We must give balanced attention to success and failure data and use both of them as tools.
4. Failure analysis pays the greatest dividends when done in the earliest equipment design stage.
5. <u>All</u> troubles should be reported from <u>all</u> phases of a system's life, including field use.
6. Analysis of in-use failures is vital to the greater reliability of future systems. If we do not do this, we shall never stop committing the same old errors.
7. If the demonstrated reliability of a system falls far short of predictions, we must look carefully at the tools we used, and the way we used them.
8. Collection of trouble data is not easy.
9. Component failure analysis must go far beyond a mere study of the component.
10. Effort expended in failure analysis should be in proportion to the effect of the trouble on the system's main mission.

(Author in part)

REVIEW: This is a general paper with a good, but not new, message. It conveys worthwhile impressions rather than specific technical information. ##

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Serial Number 1302
Codes 802;821;831;
840

782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A survey of techniques for analysis and prediction of equipment reliability

AUTHORS: H. Elmore Blanton, Raytheon Company, Lexington, Massachusetts and R. M. Jacobs, Sylvania Electric Products, Incorporated, Waltham, Massachusetts

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 387-400 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

This paper was covered by Abstract and Review Serial Number 191.

TITLE: Hydraulic control reliability in space vehicles

AUTHOR: A. B. Billet, Vickers Incorporated, Detroit, Michigan

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 401-422 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

This paper is essentially the same as the one covered by Abstract and Review Serial Number 747. A similar paper by the same author was covered by Abstract and Review Serial Number 1183. ##

Serial Number 1303
Codes 813;814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability in procurement -- F-105 aircraft electronic systems

AUTHORS: Arthur P. Coletta, Joseph A. Cravero, and Charles W. Russell, Republic Aviation Corporation, Farmingdale, New York

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 423-439 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present in some detail the calculation of cost savings due to reliability improvement for the F-105 aircraft electronic system.

ABSTRACT: Design of new weapon systems now includes reliability orientation, but the initial design of many existing weapon systems did not include reliability orientation as we think of it today. The requirement for a specific, proven reliability under a specific environment was not generally included in the procurement contracts for high volume production.

This paper describes a technique, applied to an existing production program, which justifies the cost of reliability improvement by expressing the resulting benefits in terms of dollars and cents and also studies the sensitivity of the estimated savings to variations in the basic assumptions. This makes it possible to evaluate the program in terms of an investment having specified risks and a significant return, bringing it closer to a strict management-accounting type of decision.

The point is made that maximum benefit is obtained from early investment in reliability, which will increase first cost, but which must be considered as an investment with a virtually guaranteed return. (Authors in part)

REVIEW: It is interesting to compare this paper with the one covered by Abstract and Review Serial Number 1297, which is on a similar topic. The philosophies expressed in the two seem to be rather different.

The amount of detail presented here is suitable for someone interested in pursuing these particular calculations (and assumptions) in detail. It is more than the casual reader will care to study. ##

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Serial Number 1304
Codes 224;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability monitoring by optional stopping sampling

AUTHOR: Norman R. Garner, Aerojet-General Corporation, Azusa, California

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 441-446 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present the derivation and to discuss the value of a sequential sampling plan for reliability monitoring.

ABSTRACT: An optional stopping sampling procedure is recommended for reliability monitoring. This procedure allows testing to continue until k defects are observed. At this time one of three decisions is made. If the number of trials is too small, testing is stopped and an engineering change is required. If the number of trials is too large, then a new reliability plateau has been achieved. If the number of runs is neither too small nor too large a new sequence of testing begins. Thus, only a minimum amount of testing would be performed on unreliable systems - a very desirable characteristic for the proper monitoring of reliability. On the other hand, if an engineering design change was made which improved reliability appreciably, the length of trials would become longer and, so, a more efficient estimate of reliability would be made for the improved system. This is precisely what is desired by a monitoring system. The mathematical model is discussed, cumulative probabilities are given so that control charts can be established, and an example is presented. (Author)

REVIEW: The material in this paper is clearly and concisely presented. The plan should prove to be quite useful in certain development programs in which surveillance by attributes (success or failure) is appropriate; its specific advantages have been explained in the paper. Those who are responsible for reliability monitoring should find this to be a useful paper. ##

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Serial Number 1305
Codes 833;837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical circuit analysis in practice

AUTHORS: F. A. Applegate and N. A. Scianna, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: Seventh Military-Industry Missile and Space Reliability Symposium, San Diego, California, June, 1962, pp. 447-462 (U. S. Government Printing Office, Washington, D. C., 20402, Catalog No. D4.2: M69/962, Price $2.75)

PURPOSE: To present a plan of component testing that fits in well with circuit analysis.

ABSTRACT: In recent years several methods of relating component-part behavior to circuit behavior have been described; however, the authors know of no papers relating the so-called statistical circuit analysis to a component-part test program. Assuming a correct model, circuit synthesis is only as good as the component-part data used. Because of this dependence, considerable effort must be expended in designing an accurate and efficient component-part testing program. The results of the program can then be used in the statistical worst-case analysis of the circuit in which the parts are to be used.

This paper describes a program for the collection and use of component-part test data for reliability in general and for statistical circuit analysis in particular. The worst-case analysis is applied to the steady-state operation of a NOR circuit and appropriate failure equations are derived. Examples of good life testing procedures are given. (Authors in part)

REVIEW: The plans presented here are not necessarily new, but they are useful, and the author gives a good perspective on them. The use of empirical models for circuit performance is not emphasized.

The absence of the identifying numbers on the figures in the paper is a source of inconvenience and possible confusion to the reader. However, the first author, in a private communication, has called attention to the paper cited below [1], which is based upon the present paper. The reader will find [1] to be a somewhat clearer presentation of essentially the same material.

REFERENCE: [1] F. A. Applegate, "Statistical circuit analysis based on part test data," Electro-Technology, vol. 71, May, 1963, pp. 140-145 ##

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