RELIABILITY ABSTRACTS and TECHNICAL REVIEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Office of Reliability and Quality Assurance
Washington, D. C. 20546

1962-1963
SECOND ANNUAL VOLUME
Abstracts 276-775

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. This, the second annual volume contains Serial Numbers 276-775, produced during the period between June, 1962 and May, 1963.

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, and seven. 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.

ERRATUM

In Serial Number 424 the fourth line in the ABSTRACT should read as follows: similar to tensile strength. The endurance limit (S_e) of the

000 GENERAL
- 010 QUALITY CONTROL DEFINITIONS / SYMBOLS
- 090 BIBLIOGRAPHIES

100 STATISTICAL PROCESS CONTROL
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  - 511 SIGNIFICANCE TESTS
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- 540 CURVE FITTING
  - 541 LINEAR REGRESSION
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  - 543 MULTIPLE REGRESSION
  - 544 ORTHOGONAL POLYNOMIALS
  - 545 TIME SERIES
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(AS REVISED JANUARY, 1963)

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Serial Number 276
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Limit testing electronic circuitry

AUTHOR: Harvey L. Morgan, Consulting Engineer, Phoenix, Arizona

SOURCE: Electronic Equipment Engineering, vol. 10, March, 1962, pp. 45-50

PURPOSE: To describe methods which were developed in a reliability laboratory for use in evaluating circuitry going into a data processing computer.

ABSTRACT: An electronic circuit should be designed and tested so that if put into production, any combination of parts which can occur from the normal distribution of component values should produce, in a very large percentage of cases, an acceptable result. Further, the possible combinations of environmental effects should not produce out-of-tolerance results on circuits with marginal value components.

Load and input conditions to a circuit may vary, as well as the power supply. A circuit which does not have the stability and tolerance to component variations due to manufacturing, environmental, circuit conditions, and supply voltage variations, to stay with limits of performance under these conditions cannot be said to be reliable.

As a first approximation to assuring circuit reliability, limit testing is used. Each component is substituted with end-of-life extreme values and circuit performance is determined at the limits of supply voltage variation. If satisfactory performance is not obtained, circuit modification to obtain satisfactory performance is necessary. The appropriate tests are those concerned with parameter variations of importance in a given circuit. Quite often, necessary tests cannot be determined by inspection.

Limit testing considerations and techniques are described for transistors, diodes, resistors, capacitors, inductances, and for circuits as entities. (Author in part)

REVIEW: This is a fairly detailed discussion of techniques developed for the limit testing of the circuitry of an electronic computer. As such, it will be of interest to design engineers. The material in the two appendices should also prove helpful. Appendix 1 describes a circuit which can be used as a variable-beta transistor, while Appendix 2 gives circuits which can be used as variable zener diodes for testing purposes or circuit applications. Appendix 3 is a table giving initial and end-of-life tolerances, temperature coefficients, and derating data on certain types of resistors, capacitors, inductors, transistors, and diodes. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: When is reliability improved by quad redundancy?

AUTHOR: Alan Plait, Senior Reliability Engineer, The Magnavox Company, 2131 Bueter Road, Fort Wayne, Indiana

SOURCE: Space/Aeronautics, vol. 37, March, 1962, pp. 77-82

PURPOSE: To analyze the advantages of simple and bar quads for resistors and diodes and review the effects of variations in quad parameters.

ABSTRACT: A "quad" circuit can be defined as a combination of four elements --either electronic components or complete circuits--in a series-parallel (simple quad) or parallel-series (bar quad) arrangement. Such arrangements can effect very considerable increases in reliability over that of single components. This fact is illustrated for resistors and diodes by comparing the single-component circuit with two, three, and four units in parallel, four units in a simple quad, and four units in a bar quad. Only catastrophic failures are considered. For each of the above circuit configurations the various possibilities are tabulated, and their associated probabilities are worked out. Numerical illustrations of the effects of varying the quad parameters are given.

REVIEW: This paper is useful in illustrating the advantages of quad redundancy. It also serves as a tutorial work for those not familiar with the methods of analyzing the reliability of such circuit configurations.

In the first paragraph the author states that "quadding can increase reliability by nearly three orders of magnitude." Since the reliability of a component is a probability (certainly between 0.9 and 1.0 in most practical cases), it is evident that the quoted statement cannot be literally true. For components of high reliability a statement that "quadding can decrease unreliability by nearly three orders of magnitude" would appear to be correct. This is, no doubt, what the author means.

The use of quadding to increase reliability requires that the circuit be able to function adequately with wide variations in its parameters. Thus in any application the circuit should be carefully analyzed to determine whether the quad concept is in fact applicable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable welding

AUTHOR: Charles J. Heslin, Industrial Components Division, Raytheon Company, Newton, Massachusetts

SOURCE: Electronic/Electromechanical Production, vol. 2, April, 1962, pp. 6-9

PURPOSE: To indicate the results of an investigation of the reliability of resistance welding as a joining technique.

ABSTRACT: Many production engineers have shown great concern over the reliability of the resistance welding process. Insufficient experience and limited data have made it difficult to give quantitative reliability figures on welding or make direct comparisons with soldered connections. However, the potential reliability of the welding process can be appreciated by examining the data accumulated on vacuum tube welds and design models of welded computers. Test data from vacuum tube life tests conducted at Raytheon indicate a very high reliability for welded joints--some details are given.

To further improve the reliability of welded modules Raytheon established a program for the further investigation of the welding process. After considering many methods of distinguishing between marginal and satisfactory welds, it was decided to employ a simple destructive test using a tensile tester to expose the weld to every stress to which a weld might be subjected. Metallographic examinations and visual inspection were used to aid in analyzing the results of the tests.

Factors affecting consistent operation of welding equipment are discussed and illustrated. The results of tests conducted to determine the most effective combinations of welding equipment, electrode size, shape and material, and applied energy and pressure to optimize weld strengths for particular material combinations are indicated. Suggestions are made for the establishment of adequate controls to assure high reliability in the welding process.

REVIEW: This paper should be of considerable value to production engineers concerned with the reliability of resistance welding. The points made are clearly illustrated with tables, graphs, and figures. Positive suggestions for the implementation of a reliable welding process are presented. ##

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Serial Number 279
Codes 813;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fundamental principles in reliable soldering

AUTHOR: Raymond G. Hampson, Chemical and Physical Engineering, Westinghouse Electric Corporation, Electronic Tube Division, Bath, New York

SOURCE: Electronic/Electromechanical Production, vol. 2, May, 1962, pp. 6-8

PURPOSE: To indicate how, through the careful selection of materials and the proper design and control of methods, soldered connections can be made to meet the reliability required for critical applications.

ABSTRACT: Problems that are encountered in the soldering of bases to GT type electron tubes are not necessarily unique. They involve a number of diverse factors which require an optimum method design and maximum control procedures that apply generally to many soldering situations. Various elements and phases of the soldering process are all interrelated and poor design or lack of control of any one can seriously impair the effectiveness of others.

Problems may appear in the obvious form of failure to accomplish a solid joining of base pin to tube lead, or they may occur, even with a satisfactory solder bond, as corrosion, conductivity (a conductive path across the stem surface between leads caused by deposition of flux residue on the stem), or external excess solder. Although poor bond or excess solder may be detected immediately through inspection and gauging, corrosion and conductivity are more insidious in nature and may not appear until after parts have reached the field. It is therefore imperative that maximum quality assurance be obtained through the selection of appropriate materials and proper process design and regulation. (Author)

The discussion in the paper is organized under the headings: selecting the flux and solder alloy, pre-cleaning and tinning, application of the flux, soldering the assembly, removal of external flux residue, and gauging and inspection.

REVIEW: Soldered joints are often cited as a major cause of failure in electronic equipment. This paper should therefore be of considerable value to production engineers concerned with reliable soldering. It contains positive suggestions for the implementation of a reliable soldering process. Several diagrams are helpful in illustrating the points made. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thermal design for reliability

AUTHOR: Robert E. Henry, Heat-Transfer Specialist, Hazeltine Electronics Division, Hazeltine Corporation, Little Neck, New York

SOURCE: Electro-Technology, vol. 69, May, 1962, pp. 87-89

PURPOSE: To show how ambient temperature data and other information on components may be used to develop curves to depict failure characteristics at various component temperatures.

ABSTRACT: The temperatures of individual components are highly significant when equipment reliability is to be determined. Present failure-rate data are inadequate for thermal design since they are based on ambient temperature and ignore the fact that, for a given ambient temperature, the temperature of any component can vary widely. Irreversible changes in the materials of a component cause failure, and such changes are a function of the temperature of the materials; there is no simple relationship between component temperature and surrounding, or ambient, temperature. The departure from a simple relationship may be extreme under cyclic or random transient conditions.

Present failure-rate data are especially unsatisfactory in the design of forced-air-cooled equipment. Increased cooling rate lowers the operating temperature of the components and should give an increase in reliability; yet available failure-rate data cannot be used to evaluate the effects of reducing component temperatures.

In system thermal design it is impractical to obtain failure-rate characteristics as a function of component temperature for each component used. However, the reliability of a piece of equipment is determined primarily by the reliability of the components with the shortest lives. If these critical components are identified and it is assumed that their combined reliability is that of the system, a more readily handled thermal design problem is obtained. The failure characteristics of the critical components at various temperatures may sometimes be found in curves expressing failure rate as a function of ambient temperature, forming part of the specifications for the components. In other cases the component manufacturer can usually supply pertinent data on the failure rate at various points in the region near his rating. An illustration of the application of the method is given. (Author in part)

REVIEW: This paper provides some useful ideas to assist in achieving reliability in the design of electronic equipment. The ideas are adequately presented and illustrated with a typical example, graphs, and diagrams. In practice, in developing curves such as those for failure rate versus ambient temperature for given components, it

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AND TECHNICAL REVIEWS

would be well for the user to keep in mind the need for having enough adequate data on which to base a truly representative curve. In cases where such data are not readily available from the sources mentioned by the author, some laboratory testing of critical components may prove to be very worthwhile. ##

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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: Improving contact reliability in low-level circuits

AUTHOR: J. J. McManus, Project Engineer, Research and Engineering Department, Western Union Telegraph Company, New York City

SOURCE: Electro-Technology, vol. 69, May, 1962, pp. 98-101

PURPOSE: To report on methods used in telephone and telegraph circuits to prevent electrical contact failure.

ABSTRACT: The use of transistors in communication switching systems and elsewhere has resulted in frequent use of electrical contacts working into low-voltage and low-current circuits, and has created a problem in reliable contact closure. To meet this dry-circuit problem, a study was made at Western Union of the history, literature, and industry opinions concerning electrical contact performance in low-level circuits. Out of the study came recommended methods to prevent electrical contact failure in these circuits.

Surface contamination of telephone relay contacts, in the form of very thin films caused by tarnish, grease, water or gases, can effectively insulate against very small speech voltages. This is overcome by passing a small d.c. current through the voice-signal contacts. The process is known as the "wetting" of speech contacts. Some details are given and two typical wetting circuits are shown. Some of the most prevalent factors which cause contact failure are cited. Information is summarized from a number of sources on the range of threshold voltages required to break down surface films. Recommendations which have been made to cover electromechanical and other contacts working into transistor and other low-level circuits used by Western Union are listed.

REVIEW: The methods described in this paper apply directly to telephone and telegraph circuits. However, they may well have applicability, either directly or indirectly, to many other types of circuits in which contact reliability is a problem. For those who wish to go into the subject in more detail, nine references are cited in addition to a bibliography of some ten items. ##

Serial Number 282
Codes 775;762

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nondestructive testing in the automotive industry

AUTHOR: Robert B. Allured, General Motors Corporation, Warren, Michigan

SOURCE: Nondestructive Testing, vol. 20, pp. 180-181, May-June, 1962

PURPOSE: To describe the solutions to several problems in nondestructive inspection at high production rates.

ABSTRACT: The high production rate in the automotive industry presents a real challenge to the nondestructive inspection engineer. Nondestructive inspection methods are, in general, slow, and in many cases sampling inspection is used. Recent increased emphasis on reliability has sparked a greater demand for 100 per cent inspection. These conditions have led to problems requiring unique solutions, several of which are described in this paper.

The magnetizing and part-handling functions in magnetic particle and dye penetrant inspection have been mechanized to permit operators to inspect castings at 900 parts per hour. The basic elements of sonic testing, which has also become highly mechanized, are described. Castings of certain parts have been successfully sonic tested at rates up to 1200 parts per hour. An automated magnetic comparator sorts parts for metallurgical properties at the rate of 900 parts per hour. Eddy current inspection is being used extensively for the inspection of welded seam tubing, as well as for the detection of cracks in other types of parts. Some applications are described. Many of the capabilities of ultrasonic inspection are being applied both in sampling inspection and production line checking. Applications in the measurement of the hidden thickness of cylinder walls, and inspection of the bonding of babbitt bearing liners are described.

REVIEW: This is a brief description of some of the uses of nondestructive testing in the automotive industry. It illustrates the solutions found for several problems brought on by high production rates. Some of the principles may well be applicable in other types of industry. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Basic guide to component reliability

AUTHOR: Bernard Kovit, Associate Editor

SOURCE: Space/Aeronautics, vol. 37, May, 1962, pp. 113-117

PURPOSE: To outline the basic statistical procedures used in calculating the reliability of electronic systems.

ABSTRACT: The reliability of an electronic system can be evaluated by simply finding the sum of the failure rates of all the parts making up the system, this sum then being the over-all failure rate. Failure rate data can be budgeted as design targets for development programs. Data from the literature and company compilations should, insofar as possible, be modified on the basis of the practical experience that corresponds most closely to the operating conditions of the circuit under consideration.

An early first evaluation of the reliability of a circuit should be made when the feasibility of the design is being worked out. The component failure rates and the K-factors for conversion from standard laboratory conditions to operating conditions (listed in a table in the paper) can be of help in this. The customary exponential equation for the determination of the probability of part survival is cited. Some numerical examples are given. A table of reliability values for preliminary evaluations is given. As modified by factors allowing for the effects of the operating environment, these data can be used in the selection of components. For the chosen components, another reliability evaluation is then made, whose results are recorded in prediction charts that can be used as yardsticks for component acceptability. (Author in part)

REVIEW: This paper outlines some very elementary points in the calculation of system reliability from component reliability. The title is therefore not very descriptive of the actual content of the paper. Some of the basic assumptions underlying the outlined procedure are not mentioned. For example, the technique of adding failure rates of components to get an over-all system failure rate is based on the assumption that components fail independently of one another. No indication is given as to the source of the reliability and K-factor values which are cited. The paper has value as a tutorial work, provided these limitations are kept in mind.
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Serial Number 284
Code 802

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--Fundamental Concepts Part I

AUTHOR: --

SOURCE: A brochure of the material presented in Film MN 8770a, 24 pp., The Bureau of Naval Weapons, Department of the Navy, Washington 25, D. C., for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C., price 20 cents

PURPOSE: To supplement the instruction contained in Film MN 8770a in providing basic information on reliability to professional-level persons concerned with the design, production, use, or maintenance of equipment in which reliability is a critical factor.

ABSTRACT: This brochure, and the film which it supplements, introduces some of the basic reliability theoretical concepts as a background for more specific and practical material covered by later films in the series. It is designed to aid in self-study or group-study procedures by including exercises which may be completed by the student.

Topics covered are as follows: a definition of reliability, probability, the reliability function, the failure rate, the mean-time-between-failures, estimation of reliability from field data, and some characteristics of the exponential reliability function.

REVIEW: For those who wish to acquire a knowledge of the most fundamental concepts in reliability theory, this brochure will be helpful as a beginning work. It should be recognized, however, that the serious student will need to delve much more deeply into the subject than this introductory work will carry him. In addition to the later films and brochures in the series, the references cited in this brochure should prove to be helpful. ##

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Code 802

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability Engineering--Fundamental Concepts Part II

AUTHOR: --

SOURCE: A brochure of the material presented in Film MN 8770b, 29 pp., The Bureau of Naval Weapons, Department of the Navy, Washington 25, D. C., for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C., price 25 cents

PURPOSE: To supplement the instruction contained in Film MN 8770b, in developing the basic reliability concepts necessary as a background to the practical application of techniques to increase and assure the reliability of Naval weapon systems.

ABSTRACT: A system is generally composed of a number of subordinate elements designated as subsystems, equipments, components, or parts. The relationships between the reliabilities of these elements and the reliability of the system which they constitute is a matter of primary interest in measuring, analyzing, and improving system reliability. As an introduction to this topic, some of the laws of probability are first reviewed. These include: compound events with mutually independent constituents, and mutually exclusive events.

System reliability as a function of the element reliabilities is considered in the case in which element failures are mutually independent. The reliability of a series combination of elements with simple exponential reliability functions is discussed. Other topics considered include elements with reliability functionally related to operating cycles, the reliability of redundant elements, and system elements with non-exponential reliability functions. Under the latter heading the "early failure" period and the "wear-out" period are discussed. No mathematical formula is used to describe the early failure period; the normal or Gaussian function is suggested as a reasonably accurate description of reliability in the wear-out period. Numerical illustrations of the use of the formulas developed are given.

REVIEW: This is the second in the series of brochures, of which the first was covered by Abstract and Review Serial Number 284. It continues the development of basic reliability concepts, and should be very helpful to those who wish to make a study of these fundamentals.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure Therbligs

AUTHORS: D. R. Earles, Chief, Reliability Analysis Section and R. H. Mohler, Senior Scientist, Research and Advanced Development Division, Avco Corporation, Wilmington, Massachusetts

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 56-60, April, 1962

PURPOSE: To present a technique for the derivation of design feature function failure rates.

ABSTRACT: The concept of a "Failure Therblig," which is 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 the design feature. The feasibility of predicting the reliability of a specific component or piece-part by functional operations is discussed. It is shown that a failure rate can be determined for a component functional element, and possible applications of this rate in reliability prediction for design analysis are illustrated.

A technique is given for determining this rate from gross overall component and component part failure rate data. This determination is presented as a solution of simultaneous equations and/or multiple regressions. The technique presented makes optimum utilization of available data and permits refinement of the failure rates as more data are available. (Authors)

REVIEW: This is an introductory paper on a concept to serve in the development of failure rates for nonelectronic equipment. The ideas are presented clearly, and the term "therblig," which will be new to many readers, is adequately explained. As the authors say, the concept, while still untried, seems logically feasible and mathematically sound. The authors are to be encouraged to proceed further with its development. ##

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Serial Number 287
Code 811

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Organizing for reliability

AUTHOR: G. W. Lindsay, Staff Engineer for Reliability, Deputy Chief of Staff/Materiel, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio

SOURCE: Electronic Systems Reliability--A Symposium, sponsored by Kansas City Section, Institute of Radio Engineers, Kansas City, Missouri, pp. 9-27, November, 1961

PURPOSE: To discuss company organization for reliability.

ABSTRACT: To meet true reliability requirements, an organization must exist to exercise detailed control over all aspects of the operation. The nature of the reliability organization will vary with the size of the company as well as with other factors such as the exact product. It appears that, other things being equal, the percentage of engineering effort in the over-all reliability effort decreases with increasing size. No magic formula exists to determine optimum reliability organization. The solution for each company must be based on recognition of the problem and the use of techniques in solving it which may be regarded as facets of industrial engineering. It is indicated that the reliability control function can usually be best implemented in small organizations by the Engineering Department, but large organizations require a different approach. (Author)

REVIEW: This paper will be of interest to those concerned with industrial management for reliability. Included at the end of the paper is the text of the author's oral presentation and also of several questions and answers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of electronic parts and systems

AUTHOR: H. T. Gruber, Project Leader, Reliability Engineering Division, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Electronic Systems Reliability--A Symposium, sponsored by Kansas City Section, Institute of Radio Engineers, Kansas City, Missouri, pp. 29-51, November, 1961

PURPOSE: To point out generally how a reliability group can function and how it can aid in obtaining higher reliability.

ABSTRACT: The achievement of reliability in the field requires a carefully organized and all-encompassing approach, extending from conceptual design to field-use and maintenance. A reliability goal should be established early in the preliminary or conceptual design stage. Some attributes of the steps through which the product goes after preliminary design to assure reliability are: (1) careful product design including conservative application of component parts, (2) a continual questioning attitude toward any changes made in the basic design to improve manufacturability, (3) controlled production, (4) educated users, and (5) disciplined maintenance personnel providing feedback for product improvement.

Management is concerned with the cost of reliability and the question of whether the results are worth the expenditure. The implications of this for military equipment and consumer goods are considered. The real economic problem is the finding of the optimum relationship between the cost of achieving a long-lived product and the cost of demonstrating that life. It is contended that the best allocation of funds occurs when the reliability achieved is equal to the demonstrated reliability. The reaching of an approximate balance in this respect can be done only through careful reliability planning.

The relationship between the reliability group and other groups within a company is very important, and the operation of the reliability engineering group must be tailored to the operation and needs of the particular company. Some ways in which companies are organized for reliability are discussed.

At the initiation of a reliability program it is essential that alternative courses of decision or action be made prior to the accumulation of data. The principles of good experimental design should be followed. A well planned and implemented information-handling procedure should provide enough information either to enable necessary decisions to be made or to make it possible to recognize when there is not sufficient information to make the decision.

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Perhaps the biggest job in achieving reliability is that of writing adequate specifications. These logically fall into two categories: design objective specifications and procurement specifications. Some points to be kept in mind in writing specifications are given.

REVIEW: This paper covers, in a general way, a lot of matters related to reliability management. The reader concerned with such matters will no doubt find in the paper ideas which he can adapt to his own situation. Included at the end of the paper is the text of the author's oral presentation and also of several questions and answers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Meeting AGREE reliability requirements for airborne TACAN equipment--history and results

AUTHOR: A. L. Floyd, Director of Plans and Programs, Military Products Division, Hoffman Electronics Corporation, 3761 S. Hill Street, Los Angeles 7, California

SOURCE: Electronic Systems Reliability-- A Symposium, sponsored by Kansas City Section, Institute of Radio Engineers, Kansas City, Missouri, pp. 53-80, November, 1961

PURPOSE: To present the background experience at Hoffman Electronics covering the design, development, production, and delivery of airborne TACAN equipment.

ABSTRACT: The requirements covering reliability in the specification of TACAN Airborne Navigation Equipments, Model C are listed. This was the first major production procurement contract for airborne electronic equipment containing a specified reliability index to be statistically tested under the procedures outlined by Task Group 3 in the AGREE Report. The steps taken at Hoffman Electronics toward meeting the reliability requirements are described. The description includes the proposal phase, design requirements, testing program, component selection procedure, component procurement, and test results.

Several general conclusions resulting from this experience are listed by the author as follows:

1. Designing equipment according to reliability design data available at start of this project did not in itself result in meeting the reliability requirements, although it was necessary in the chain of reliability activities.

2. Testing and removing design causes of failure--i.e., such as transients during switching, misapplication of tubes, etc.--did not alone result in meeting the reliability requirement.

3. Quality Control procedures are not capable of determining that component parts used in building an equipment are satisfactory for reliability requirements if any reasonable economic limits are considered. However, this reliability goal did not require such controls.

4. Reliability testing and failure analysis with corrective action in all phases of company activities associated with the TACAN, RT-220C, (design, production engineering, material procurement, production testing, etc.) resulted in an equipment meeting the reliability requirement.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

5. The final reliability achieved was limited by the degree of testing performed on completed equipments for reliability control and corrective action applied as a result of testing rather than design, state-of-the-art, quality control, etc.
6. Testing according to the AGREE statistical requirements for 150 hours MTBF on an equipment having approximately 1,000 electrical components provided sufficient data for reliability control and corrective action to achieve the reliability goal after six tests or a total of approximately 25,500 operating hours. This is 170 multiples of the MTBF specified.

REVIEW: This is a fairly detailed account of the experience gained in the production of one type of electronic equipment. The text material is supported by a table of component failure rates for accepted tests, and several relevant figures and charts. Included at the end of the paper is the text of the author's oral presentation and also of several questions and answers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The second reliability problem

AUTHOR: Anthony J. Finocchi, Director of Reliability Engineering, ITT Federal Laboratories, Nutley, New Jersey

SOURCE: Electronic Systems Reliability--A Symposium, sponsored by Kansas City Section, Institute of Radio Engineers, Kansas City, Missouri, pp. 81-101, November, 1961

PURPOSE: To discuss the problem of building reliability into the equipment after R & D engineering has designed it into the item.

ABSTRACT: After an item has been designed, there arises the problem of building it within the applicable constraints consisting mainly of cost and time. The problems involved may be segregated into the four categories: (1) organization, (2) manpower, (3) cost reduction, and (4) time study. The hazards to the maintenance of reliability in each category are described.

In order to insure continuous reliability effort, it is suggested that the reliability function be centralized for the R & D and Manufacturing complex. The same reliability group should follow the product from the beginning to the end of the production schedule. Any changes in the product must be carefully evaluated. Management must provide mature, skilled personnel, and support their conclusions. The desired level of inherent reliability must be achieved during design, and reliable design must be followed by homogeneous manufacture, compatible installation, and prescribed operation and maintenance.

REVIEW: This is a worthwhile discussion of the problems involved in actually producing reliable equipment. Examples serve to give additional clarity to many of the points which are made. Included at the end of the paper is the text of the author's oral presentation and also of several questions and answers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: What have you proved?

AUTHOR: W. E. Boyes, Manager, Reliability Department, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Electronic Systems Reliability--A Symposium, sponsored by Kansas City Section, Institute of Radio Engineers, Kansas City, Missouri, pp. 103-127, November, 1961

PURPOSE: To discuss the problems involved in the proving of reliability.

ABSTRACT: From the commonly accepted definition of reliability it is reasoned that the only true reliability numbers on weapons must come from the results of their actual use. Anything short of this is a test from which is derived a quality number which is a predictor of reliability. A test's efficiency as a predictor of reliability depends on how closely it simulates the service conditions. This paper is concerned with the degree of simulation and the importance of its interpretation.

The testing program at Sandia Corporation is described. The following twelve steps in the proof of reliability of nuclear weapons are listed:

PROOF OF RELIABILITY

1. NUCLEAR - WAR (drops or shoots)
2. NUCLEAR - TEST " " "
3. H. E. (High Explosive)" "
4. INERT (No Explosive) " "
5. QEST (Quality Evaluation System Test)
6. MULTIPLE LABORATORY ENVIRONMENT - WEAPON
7. MULTIPLE LABORATORY ENVIRONMENT - COMPONENT
8. UNIT LABORATORY ENVIRONMENT - WEAPON
9. UNIT LABORATORY ENVIRONMENT - COMPONENT
10. AMBIENT LABORATORY ENVIRONMENT - WEAPON
11. AMBIENT LABORATORY ENVIRONMENT - COMPONENT
12. ENGINEERING JUDGMENT

The steps are listed in order of decreasing reality and are generally in order of decreasing cost. The discussion centers

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AND TECHNICAL REVIEWS

about the potential difficulties to be encountered in the various steps.

REVIEW: This paper emphasizes an important point which may often be overlooked, namely that the value of reliability predictions based on tests depends on how realistically the tests simulate actual use conditions. This is difficult to allow for in stipulating amounts of risk of error. It is equally a problem to know just what actual use conditions are in a field test. Difficulties will be numerous in trying to get conditions the same each time. In view of this, the choice of use vs. laboratory tests is not an easy one to make. Included at the end of the paper is the text of the author's oral presentation and also of several questions and answers. ##

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Serial Number 292
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Space payload failure data analyzed

AUTHOR: Philip J. Klass, Avionics Editor

SOURCE: Aviation Week and Space Technology, vol. 76, May 28, 1962, pp. 55-56

PURPOSE: To summarize the highlights of data on the reliability of space vehicle avionics reported at the National Electronic Components Conference in Washington, D. C. in May, 1962.

ABSTRACT: Reliability data based on analyses of the in-orbit performance of 16 different satallites was presented at the National Electronic Components Conference. This paper summarizes the principal results reported by Arinc Research Corporation.

Satellite failure data based on an analysis made for the Advanced Research Projects Agency by Arinc Research Corporation points to the need for at least an order of magnitude improvement in avionic reliability for most applications. The analysis indicates that any one of many "operational functions" in a satellite payload has a 95% probability of operating without failure for only 25 hours in orbit if it is the cyclic on-off type (commanded) function. An operational function which is on continuously in orbit has a 95% probability of operating for about 2000 hours before failure. This difference in times-to-failure between commanded and continuously operating functions does not represent a corresponding difference in their reliabilities since the commanded type functions operate for only a fraction of the time in orbit. Working on the basis of times-to-failure for "active element groups," Arinc Research came up with the following failure rate data: commanded function: 2.16 failures per million hours, and continuous function: 34.6 failures per million hours.

REVIEW: This is a useful summary of the highlights of the papers mentioned. The reader interested in the details will, of course, wish to refer to the original papers. A minor point should be clarified regarding the reference to "an order of magnitude improvement" in reliability (see ABSTRACT). Clearly a reliability of, say, 0.95 cannot be improved by an order of magnitude since no probability can exceed 1 in value. The author, in a private communication, has indicated that the "order of magnitude improvement" refers to reliable operating time (say 20 to 30 months instead of 2 to 3 months). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Saturn G & C parts get quick check-out

AUTHOR: (Editorial Matter)

SOURCE: missiles and rockets, vol. 10, June 4, 1962, p. 32

PURPOSE: To describe a ten-week program aimed at giving NASA a quick clue to the reliability of semiconductors.

ABSTRACT: A fast-moving component test program is being conducted by Associated Testing Laboratories, Inc., Wayne, New Jersey, to check out random samples of 33 different diodes and transistors used in the guidance and control system of the Saturn booster. The program is aimed at providing meaningful reliability data on the components about ten weeks after the start of testing.

The program is divided between measurement of basic performance parameters and a series of operating and storage environmental checks. The performance parameters checked include leakage currents, saturation voltages, gain at dc levels and also in the VHF (200 megacycles) range, output capacities, switching time characteristics at speeds to 1 nanosecond, noise figures, and some small signal parameter tests at 1 kc. The thermal portion of the environmental series includes temperature cycling between -65°C and +200°C, moisture-resistance tests at humidity levels approaching 100%, thermal shock tests to check glass-to-metal seals, and case leakage checks using both hydrostatic (gross) and helium (fine) techniques.

REVIEW: This paper describes a testing program aimed at limiting the chances of a relatively inexpensive component causing an abort in a multimillion-dollar vehicle. The types of tests and some of the details regarding them are indicated. ##

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Serial Number 294
Codes 814;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating design factors affecting costs and reliability of systems and assemblies

AUTHOR: L. D. Miles, Manager, Value Service Staff, General Electric Company, Schenectady, New York

SOURCE: 4 pp., presented at ASME Design Engineering Conference, Chicago, Illinois, May, 1962, Paper No. 62-MD-24

PURPOSE: To provide some aids to the task of getting better results sooner in the design process, in system and assembly selection.

ABSTRACT: Today's systems and assembly designer faces, on the one hand, a growing mass of knowledge of functional capabilities to be utilized, and, on the other, a growing requirement to make selections which will shorten development time, increase reliability, and lower cost. He requires both greatly improved search techniques and effective quick rejection techniques.

This paper is concerned with the contribution which the technology of value engineering can make in this area. The mechanism of evaluating functions and using this evaluation with the design logic is described and illustrated. The procedure is summarized by the author as follows:

1. Secure clearly defined performance needs.
2. Secure definite cost needs.
3. Intensely study all functions and sub-functions both as to the results to be accomplished and the conditions under which they must be accomplished.
4. Create design logic complete with ...
   (a) systems design approaches
   (b) principal assembly and product selection approaches
   (c) manufacturing or equivalent approaches
5. Evaluate functions and subfunctions in dollars. Bring enough effectiveness into this task to achieve an evaluation equal to or below the cost objective.
6. Apply the function evaluation to the design logic eliminating concepts, approaches, assemblies, etc., which cannot be used. Commit resources to the remaining alternatives.
7. Identify the areas in the remaining system where lack of knowledge or lack of suitable ideas produce what we have called a "performance gap."
8. Pinpoint sufficient resources on these gaps to bring forth effective solutions. (Author in part)

REVIEW: This paper describes a useful tool for the design engineer. Its applicability should be considered at the inception of any involved system or assembly design project. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating design factors affecting costs and reliability of components and parts

AUTHOR: S. M. Frey, Manager, Falcon-Comet Design Department, Ford Division Product Engineering Office, Ford Division, Ford Motor Company, Dearborn, Michigan

SOURCE: 13 pp., presented at ASME Design Engineering Conference, Chicago, Illinois, May, 1962

PURPOSE: To outline criteria used in the automotive industry for determining whether the cost of a component can be reduced or the reliability improved.

ABSTRACT: This paper discusses criteria used by the automotive designer in evaluating components for cost reduction factors and improvements in reliability and durability. The principal criterion in a study of design cost reduction is that the new or redesigned part must function as well as or better than the existing component. If the function is equal the next criterion is: "will it last as long and be just as reliable?" The third fundamental criterion is that a design change to reduce cost must not impair the serviceability of the part. Laboratory and road tests to evaluate new versus existing designs can usually be devised readily. The study of whether or not the cost of an existing part can be reduced is a much more difficult and challenging task.

Cost reduction ideas originate primarily with the design engineer. Another potential source of such ideas is comparison of the current design with that of one's competition. This is a fairly common approach, especially in the automotive industry. The extensive detail by detail review of competitors' products is discussed. The course of events in carrying the cost reduction projects through to production is outlined.

Factors affecting the reliability and durability of a vehicle component are reviewed. A close look at fundamentals is prescribed especially where the aspect of safety is involved. Operating environment is mentioned as an area where strange effects can often elude initial analysis. Following redesign, the engineer is advised to use statistical analysis to obtain more definite decisions from the results of his laboratory or vehicle tests. It is pointed out that in many cases the question of "can the reliability be improved" is often pre-empted by the statement that the reliability must be improved. This judgment is made based on the results of established laboratory tests, vehicle tests, and especially on customer experience as evidenced by field service. (Author in part)

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REVIEW: This is a clearly-presented outline of cost reduction and reliability improvement criteria and practices for components in the automotive industry. The paper does not mention the possibility that a part might be too good and that costs would be decreased by redesign of this part to have less strength or a shorter life. Many of the ideas may well be applicable to other types of industry as well. ##

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Code 830

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: Effective application of materials engineering in design

AUTHOR: James W. Cantwell, Engineering Materials Supervisor, Technical Services Division, Engineering Department, Caterpillar Tractor Company, Peoria, Illinois

SOURCE: 5 pp., presented at ASME Design Engineering Conference, Chicago, Illinois, May, 1962, Paper No. 62-MD-26

PURPOSE: To discuss the role of materials engineering in the design of equipment.

ABSTRACT: With the advance in metals technology since World War II, the materials and materials-processing field has provided a fertile area for cost reduction. With capable staffs operating in this field, many gains are being made which must be incorporated into design if competition is to be met with regard to cost and reliability. The problems encountered in incorporating the developments from the materials field into the already established field of design, prompts a look at some of the principles of design and the role of the materials engineer in the design function. (Author)

REVIEW: The discussion in this paper centers about materials engineering in the design of heavy construction equipment (earthmoving equipment). The principles involved may, however, well find applicability in other areas. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Testing to establish a high degree of safety or reliability

AUTHOR: F. J. Anscombe, Princeton University and Bell Telephone Laboratories

SOURCE: Bulletin de l'Institut International de Statistique, 33[e] Session, Paris, 1961, 6, 17 pp.

PURPOSE: To propose a particular type of assurance of safety or reliability, and to derive an appropriate sequential test procedure for establishing it.

ABSTRACT: This paper is concerned with the possibility of establishing the safety of a weapon or the reliability of a component or device by testing a large number of specimens under some standard operating conditions and demonstrating that the proportion of failures, p, is very small. The most satisfactory approach to this problem is an economic one, taking into account the cost of testing and the revenue or loss resulting from alternative decisions. However, sometimes the wholly economic approach cannot be followed, for reasons such as the incomparability of testing costs with decision losses, and the division of responsibility. In such cases one might consider a requirement such as

(A) The device will be accepted for service only if the test results give 99% confidence that $p < 1/2000$.

By analogy with the definition of a confidence coefficient, most statisticians will be likely to interpret A to mean the following:

(B) The acceptance rule must be such that, for all values of p above 1/2000, the least upper bound to the chance of acceptance = 1%.

As a reasonable compromise to (A) and (B) it is suggested that one might use

(C) The device will be accepted only if the test results justify fair betting odds of 99 to 1 that $p < 1/2000$.

A probability distribution f(p) is selected to represent the initial judgment of an open-minded unprejudiced observer. Acceptance conditions for a requirement of type (C) are derived. Economic provisions for truncating the trial are discussed. (Author in part)

REVIEW: This paper is a contribution to the mathematical theory of life testing, in particular to that of sequential life testing procedures. As such it is likely to be of most interest to the theoretician. The simplifying assumptions on which the results are based are clearly stated, so that conditions of applicability are readily identifiable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Sequential life testing

AUTHOR: Gideon Schwarz, Acting Assistant Professor of Statistics, Stanford University

SOURCE: Bulletin de l'Institut International de Statistique, 33e Session, Paris, 1961, 90, 9 pp.

PURPOSE: To apply two asymptotic results to two sequential life testing problems in the exponential case.

ABSTRACT: For many sequential decision problems, the optimal solutions have been fully characterized; but the characterization is far from being explicit and often cannot be utilized in practical applications even with the aid of high speed computers. On the other hand, heuristic approaches and simplifying assumptions have led to procedures that are easy to apply and sometimes easy to evaluate, but there is no reason to believe that those procedures are optimal in any sense of the word.

It is possible to bridge the gap between the extremes by developing an asymptotic theory. Work in this area has been done by Wald and also by Chernoff. Chernoff defined large sample theory in sequential analysis as the study of sequential problems when the cost of an observation approaches zero. Chernoff's procedure specifies not only a stopping rule, but also a principle of choice between different experiments that may be available at any stage of experimentation. The proof of asymptotic optimality was given originally only for problems in which the number of possible states of nature and the number of available experiments are both finite. After the removal of these restrictions, there remained one essential restriction, viz., that the hypotheses to be tested have to specify two sets in parameter space, not only disjoint, but at a finite distance from each other. Furthermore, the true state of nature must be known to lie in one of those sets. The author has done work on the case when the last restriction is violated, leading to the method of "Asymptotic Shapes," which describes asymptotically the exact optimal procedures. The method of asymptotic shapes cannot be used to choose among different experiments; it only provides a stopping rule.

In this paper Chernoff's procedure and the method of asymptotic shapes are applied to two problems. The first is applied to the problem of accelerated life testing; the second is applied to sequential life testing when no acceleration is permitted. (Author in part)

REVIEW: This paper is a contribution to the theory of sequential life testing. As such, it will be of principal interest to the theoretician working in this area. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The design of digital circuits to eliminate catastrophic failures

AUTHORS: James H. Griesmer, Raymond E. Miller, and J. Paul Roth, International Business Machines Corporation, Thomas J. Watson Research Center, Yorktown Heights, New York

SOURCE: Research Paper RC-604, 22 pp., International Business Machines Corporation, Yorktown Heights, New York, January, 1962

PURPOSE: To summarize an approach to the design of reliable computers applicable to a micro-miniature technology in which large numbers of components are batch-fabricated and encapsulated in large units.

ABSTRACT: In classical redundancy techniques for improving the reliability of digital systems failures are assumed to occur only in the logical elements and not in the interconnecting circuitry. In a batch-fabricated micro-miniature technology, however, failures can also occur in the interconnecting circuitry; and indeed these failures might be catastrophic. For example, a short circuit, which would seem to be the failure most common in a cryogenic technology, might turn off large portions of the machine or it might connect portions of the machine not normally connected. Such catastrophic failures would have to be detected and corrected for the machine to operate correctly.

This paper proposes a method of design which provides for the correction of catastrophic failures. In this method of design, which we call the replacement system, spare units are incorporated into the design, along with suitable control circuitry capable of switching out defective units and switching in their replacements. In a mathematical model of this system, it is shown that, for suitable ranges of the parameters, the reliability of the system is increased. A detailed description of this scheme is given for a thin film cryogenic technology. (Authors)

REVIEW: This paper is a contribution to the theory of design of reliable digital computers. The need for and the role of the suggested replacement system, as well as the system itself, are adequately explained. ##

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Serial Number 300
Codes 820;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Specification and measurement of the reliability of parts of guided missiles and space vehicles

AUTHOR: Erich Pieruschka, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: Technical Report LMSC-800920, 47 pp., Lockheed Aircraft Corporation, Missiles and Space Division, Sunnyvale, California, September, 1961

PURPOSE: To clarify some of the problems encountered in measuring high reliabilities and in specifying test requirements for such determinations.

ABSTRACT: The attainment of an acceptable overall reliability demands that the reliability of each part of such a complex equipment as a guided missile or space vehicle be extremely high. For this reason it has been standard practice to specify extraordinarily high reliabilities for such parts. However, it is obviously meaningless to specify something unless we are able to prove that we have actually met the specification.

This study discusses the statistical techniques of measuring high reliabilities, it introduces the quotient of inaccuracy of the measurement of reliability; it investigates the economic and experimental consequences of measuring high reliabilities with an acceptable accuracy; and it discusses the possibilities of meaningful specification for parts of guided missiles and space vehicles. Finally, an upper limit of space vehicle reliability is estimated on the basis of the achieved reliability of intercontinental ballistic missile types. (Author)

REVIEW: Approximately the first half of this paper is concerned with the mathematical theory of measuring a small portion of a population. The remainder considers the implications and application of the theory. The conclusions are conveniently summarized at the end of the paper. The difficulties encountered in attempting to obtain the necessary reliability in space vehicles are frankly presented. Those concerned with the specification and measurement of such reliability should find the paper to be worthwhile reading. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A combined environmental testing program for increasing Atlas missile reliability

AUTHOR: C. C. Campbell, Convair (Astronautics) Division, General Dynamics Corporation

SOURCE: 6 pp., presented at National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, California, October, 1961, Society of Automotive Engineers paper 418A

The text of this paper is very similar to that of the one covered by Abstract and Review Serial Number 53. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Today's actions for tomorrow's reliability

AUTHOR: G. W. Weber, General Electric Company

SOURCE: 6 pp., presented at National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, California, October, 1961, Society of Automotive Engineers paper 418B (summarized in SAE Journal, vol. 69, December, 1961, p. 117 under the title "Inexpensive ways to improve reliability")

PURPOSE: To show what can be done, beginning now, to improve the reliability of jet engines.

ABSTRACT: Little can be done to improve the reliability of today's mass produced products, but we can start now to plan for tomorrow. The first thing is to measure the reliability of present products. Two problems arise: (1) accurate field reports are difficult to get and (2) reports and failure analysis are expensive. If the customer and producer both have a real need for reliability analysis, these two problems can be overcome to some extent. Failures must then be defined and sorted into classes of seriousness and responsible parties. These data must be stored and analyzed if they are to mean anything. The biggest problem is finding the incident cause of failure.

If reliability goals are set and the reliability needs of the market are determined, it will educate producers and consumers and will guide product improvement effort. If these goals are set with realistic costs in mind, they will contribute to the improvement of reliability.

In future products, reliability must be designed in. Explicit listing of failure modes, and their probability of occurrence are most important. To do this will require a good knowledge of the general environment and stresses, of the capabilities of manufacturing, of maintenance and of failure definition. The design engineers will need the assistance of a group of reliability specialists. If reliability must be demonstrated, then additional funding must be allowed. But demonstration tests are not the most effective way of finding failures. The stresses must be increased to as high a point as possible without changing the ways in which parts fail. This is the way to find weaknesses as cheaply as possible.

REVIEW: This is a very general introductory article with little mathematical detail. Some of the practical problems in obtaining adequate failure data on jet engines are discussed. Those who are just considering a reliability program may wish to read this paper. ##

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Serial Number 303
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Achievement of reliability in highly complex missile and space systems

AUTHOR: Harvey W. Fritz, Air Force Systems Command, Space Systems Division

SOURCE: 15 pp., presented at National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, California, October, 1961, Society of Automotive Engineers paper 418C (summarized in SAE Journal, vol. 70, p. 130 under the title "Reliability difficult in complex space systems")

PURPOSE: To show the need for large safety margins in component application.

ABSTRACT: Jet aircraft are very complex and quite reliable, but this is accomplished by having many types of failures be non-critical (not producing complete failure of the aircraft). The reliability of the components is such that if most all were critical, the plane would be unreliable. In a space vehicle or missile, most of the components are critical, therefore they must be much more reliable than ordinary components. (Examples are shown.) There are many areas where reliability is affected--this paper deals with only one, the design area. Engineers use safety factors in commercial structures. The safety factor is the ratio of nominal strength to nominal stress. The safety margin is a better concept because it takes into account the variability in the strength of components. It is defined as the number of standard deviations by which the design strength exceeds the design stress. An initial safety margin can be improved by the conventional ways of increasing mean strength or decreasing the stress; it can also be improved by decreasing the variability. The safety margin should be at least 5. The number of units tested must be large; 10 or 12 is much too small. (An example is given of some design tests.) The designer establishes the maximum potential reliability of the system; he should use the best tools at his command, and the safety margin is one of them.

REVIEW: This is a good introductory exposition of the need for the safety margin concept. No discussion is given of the problems involved in knowing the chance of failure (when it is small) from the measurements on "reasonable" size samples. They can be extremely difficult because knowledge of the distribution of strengths at 4 or more standard deviations is impossible to get without extremely large samples. Nevertheless, the concept is a good one and engineers should use it as best they can. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to select an adequate cooling system. Ten basic ways to maintain the proper thermal environment to ensure maximum system reliability.

AUTHOR: Alfred L. Johnson, AiResearch Division, Garrett Corporation, Los Angeles, California

SOURCE: Electronics, vol. 34, October 20, 1961, pp. 54-57

PURPOSE: To explain the various methods and applications of heat transfer.

ABSTRACT: The reliability of a piece of equipment is almost entirely a function of its temperature, other things being fixed. In general, the cooler, the better. Heat is transferred by conduction, convection and radiation. The equations for each kind are given. A figure shows, in tabular form, some examples of conductive and convective heat transfer--both inside the system and outside it. If the sink is at a higher temperature than will allow the proper dissipation, a heat pump must be used. A gas cycle, vapor cycle, and a thermoelectric method for pumping heat are shown in a figure. Some calculations can be made of approximate sizes of the heat-transfer hardware.

REVIEW: This is an introductory engineering article on heat transfer. Some of the equations are more specialized than is indicated (limited to large plane parallel surfaces, for example). The figure for the size of the hardware seems to have been omitted. No details are given for radiative transfer. Those who need a review of the subject may find this paper helpful. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing equipment for nuclear environments

AUTHOR: P. Barrat, Pye Ltd., Cambridge, England

SOURCE: Electronics, vol. 35, March 16, 1962, pp. 51-57

PURPOSE: To describe the effects of nuclear radiation on materials and on the life of electronic equipment.

ABSTRACT: This article deals with low dose rates and high total doses. Experimental data are limited and the approach is qualitative. Tables are given of doses and dose rates for various environments. The response of most materials is determined by their structure. Four classes are distinguished: metals, inorganics, organics and semiconductors. Metals act as ions with lots of free electrons; ionizing radiations do not appreciably affect them. The structure of alloys can be modified by lattice changes. Inorganics are more sensitive to ionization. Organic compounds have chemical bonds which are easily broken by ions; higher melting points usually mean better resistance. Semiconductors as used in electronics are sensitive to structure and impurities and are thus very easily affected by radiation. Tables and figures are shown of types of bonds, types of radiation damage, kinds of radiation and their properties and radiation damage as a function of total dose. Slow neutrons may induce radioactivity (this is discussed at length). Fast neutrons and gammas may heat the substance. Practical suggestions are made for choice of materials.

REVIEW: This is a rather comprehensive review of the subject. Beginners may have a hard time with it, but will find it of help. Fifteen references are given for further study. While this article will help an engineer understand the situation, he should probably get expert help if an actual problem arises. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: AE describes approach to high reliability relay

AUTHOR: (Editorial Matter)

SOURCE: Industrial Electronic Distribution, vol. 2, April, 1962, p. 9

PURPOSE: To show the care taken in the manufacture of high reliability relays.

ABSTRACT: A 2-pole crystal-can relay is the first to be built. Parts are carefully selected to minimize corrosion and to assist in cleaning and plating. Most parts are gold-plated. Special care is taken in handling the parts. They are cleaned in a Clean Room: first an ultrasonic bath, then solvent, detergent, and a five-stage rinse in de-ionized water. The air is filtered to 0.3 microns. The same air is heated for drying the parts. After assembly the relays are cleaned again in the same way. The atmosphere is changed to dry pure nitrogen and the parts are transferred to the vacuum bake station. Moisture content is monitored the rest of the way. The automatic sealing is done in pure nitrogen; the can is finally evacuated, then back-filled with filtered nitrogen and 10% helium leak tracer. No fluxes are used and atmospheric contamination is eliminated. The units are functionally tested and also leak tested (less than 2×10^{-9} cc/sec.).

REVIEW: This is a typical article describing a process which the manufacturer hopes will make a very reliable product. No data are given on the actual reliability of the relay. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How IRC achieved high reliability

AUTHOR: Jack R. Isken, Documented Reliability Division, International Resistance Company

SOURCE: Industrial Electronic Distribution, vol. 2, April, 1962, pp. 22-24

PURPOSE: To describe the approach IRC has taken in producing a high reliability resistor.

ABSTRACT: By selecting the vendor and culling through his product, life can be improved by a decade or two. Anything beyond this requires a drastic change in design and manufacture. In the new approach, reliability was considered above all else (even cost). The process design and product design went hand-in-hand. Marginal solutions were rejected; for example, alkaline earth ceramic substrates were rejected and high purity ceramics chosen, and inorganic materials were used exclusively--no organics were allowed. The tradeoffs that were necessary cut across conventional boundaries and new approaches were created. For example, the thermal strains due to different materials could have been matched (with all sorts of attendant problems); instead, a flexible member was introduced to eliminate any thermal stresses. Jigs and fixtures were designed to not accept bad parts from a previous process; for example, one end is sealed, then a vacuum is pulled on it during the sealing step for the next end--leaky parts are discarded. An important consideration is that the processes must be done exactly as instructed--even if defectives are produced. Each part must behave like others in the group; if not, it is rejected. Careful working documentation is kept all along the way; each unit has its own serial number. Tables show some of the resistor characteristics.

REVIEW: This is a fairly complete article on the philosophy of producing this reliable resistor. One of the most important aspects and probably one of the more difficult is to not allow anyone to make changes in any process until revised documents are properly issued. Reliability data are given. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Q. A., etc., so much bushwah?

AUTHOR: James A. Lippke, Editorial Director

SOURCE: Industrial Electronic Distribution, vol. 2, April, 1962, p. 26

PURPOSE: To question the use of the words quality and reliability as used in advertising.

ABSTRACT: The words "reliability," "quality," and "quality assurance" have been overworked and misused to the point where they are meaningless unless quantified. Advertising and sales have tried to do, with words, what engineers have not done. At the IRE show, almost all displays used these words, yet finding a reliable component is the biggest problem a buyer has. There is not enough talk about MTBF, failure modes and other explicit failure concepts. There is a body of quantitative information building up, but it is slow, expensive and difficult. One solution might be to actually publish the test data. Until something is done, reliability, as a word, is so much bushwah.

REVIEW: This has needed saying for some time. The only adverse criticism possible is that it hasn't been said strongly enough or often enough. The advertising matter is largely at fault, and few, if any, magazines attempt to screen out the offending material. Obviously much good and important work is being done in the area of reliability, both in mathematical theory and in hardware. One wishes that some of this excellence would seep into the advertising matter more often. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: More facts at hand on reliability (from Microelectronics in review)

AUTHORS: Donald Christiansen and Robert Haavind, Editors

SOURCE: Electronic Design, vol. 10, February 15, 1962, pp. 69-71

PURPOSE: To present up to date facts on microelectronic reliability.

ABSTRACT: Reliability data are hard to get on long-lived, rapidly improving parts. A priori knowledge of similar devices is being used wherever possible. Micromodules have exhibited a MTTF of 99,421 hours; the goal was 75,000 hours at 10% confidence. Parts made on the same substrate tend to be similar in performance. This makes the use of redundancy more difficult. Thin film tantalum resistors, hotspot 175°C, were tested for 1000 hours with less than 1% change. Thin film flip-flops had an extrapolated MTTF of over 2000 hours. Where large quantities of data are not available, sound reasoning can be used. Thus these techniques would be expected to improve reliability: fewer materials or processes, reduced interconnections, surface passivation, and hermetic sealing. Microelectronic parts, whose exact use is known, need not have the versatility of usual components. Failure modes and mechanisms are important. Companies are reporting failures and the corrective measures taken. Micromodule tantalum capacitors have a failure rate of 0.45%/1000 hours (90% confidence). DOFL corrected a high infant mortality on binary dividers by replacing conductive adhesive by tiny soldered wires. (Other typical data are presented.)

REVIEW: This paper shows how little is actually known about reliability in microelectronics. The use of sound reasoning may be useful where engineering decisions (<u>un</u>calculated risks) must be made, but it is not an adequate substitute for tests in the life estimation process. Too much glib use is made of "sound reasoning" already in promotional literature. The 10% confidence in the micromodule program is undoubtedly an error. The use of 5 significant figures in the MTTF (99,421) is most likely not justified and tends to lend an undue air of precision to the results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Point-Availability nomograph

AUTHOR: R. R. Trachtenberg, Lockheed Electronics Company, Plainfield, New Jersey

SOURCE: Electronics, vol. 35, January 12, 1962, p. 68

PURPOSE: To display a nomograph which relates availability (A), mean time between failures (MTBF) and mean time to repair (MTTR).

ABSTRACT: An availability specification (now used by many military contracting agencies) can work for or against an engineer. In some cases he can trade off MTBF against MTTR. If the MTBF is very low however, the MTTR might be short indeed. The equation is $A = MTBF/(MTBF + MTTR)$. The nomograph is presented.

REVIEW: A nomograph such as this may be useful for those who must make many of these calculations or who wish an "analog" presentation of the formula. For occasional use, a slide rule would probably be used since the equation is essentially a very simple one. In fact, for reasonably high availability, the approximation $1 - A \doteq MTTR/MTBF$ is rather good. ##

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Codes 830;711

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fatigue: a design consideration for hydrofoil craft

AUTHOR: Richard G. Merritt, Advanced Marine Systems, The Boeing Company, Seattle, Washington

SOURCE: Undersea Technology, vol. 3, March/April, 1962, pp. 29-32

PURPOSE: To show how fatigue must be considered in mechanical design.

ABSTRACT: The fatal fatigue failures of aircraft in the last 15 years have made engineers more aware of the need for fatigue analysis. The navy has a program in fatigue of ferrous metals for submarines and other craft. The Bureau of Ships is conducting tests at Boeing on hydrofoils. Fatigue is important because waves, take-offs and landings, and other maneuvers all produce cyclic or fatigue loading. In order to estimate the fatigue characteristics of a part one must (1) define a representative load spectrum, (2) find stress-life data for the materials, (3) use a cumulative fatigue method to combine 1 and 2, (4) define the life requirements for the structure. Each major structural element may have a different load spectrum. The maneuvers and the environment must be considered in detail. Tests can be run on fatigue specimens, usually notched, to find the S-N curve. Axial loading is better than rotating beam methods. Miner's method for cumulative fatigue effects is known to be not accurate, but no other method is either. Scatter factors of 2.0 are used in current airplane design and higher ones may be required at times. The load factor ordinarily used (referred to tensile properties) is not adequate; the fatigue strength must be considered. The last step can be done by calculating the life of particular parts. In some cases, minor changes in parts or materials can appreciably improve life.

REVIEW: This is a good paper on fatigue problems in design. It shows an appreciation of the field of fatigue that is lacking in some engineering papers. More information on fatigue can be obtained in a book such as Sines & Waisman--Metal Fatigue. ##

Serial Number 312 -1
Code 831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Methodology for system reliability analysis

AUTHORS: Bernard Tiger, Radio Corporation of America, Camden, New Jersey and Morton J. Smith, Norden Laboratories, Division of United Aircraft Corporation, Norwalk, Connecticut

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 135-141, January, 1962

PURPOSE: To present a methodology for deriving and evaluating reliability models of a system.

ABSTRACT: Methodology is described for measuring various reliability parameters of complex systems containing redundancies and alternative modes of operation. In this procedure a system block diagram is transformed into a logic diagram having the form of a switching network. Measures of the required reliability parameters are then determined through the application of probability analysis.

This methodology combines system engineering, component reliability and mathematical statistics to derive a system reliability model highly representative of the modes of system operation, their relative importance and their intended use in the system.

Two examples are presented: an application to a satellite system and another to a ground communication system. Practical and theoretical advantages are discussed. (Authors)

REVIEW: This paper tries to be rather rigorous in that the assumptions and definitions are explicitly listed. Two of the assumptions are rather restrictive. Number 4 states that "... Whenever a system failure occurs, every device in the system receives the necessary maintenance to restore it to its t = 0 condition." If interpreted strictly, this requires for catastrophic failures either complete replacement or components with constant failure rate and/or for parts with no catastrophic failures, the complete removal of drift and its effects. In a private communication (p.c.) the author indicates that this is intended to mean only that any obvious defects such as worn parts and misalignment are fixed. Assumption 6 states that "the reliability function of each device is independent on the reliability function of other devices." This will eliminate from consideration any systems where some stresses such as shock or temperature are related for many of the devices.

In the section on definitions, there is some difficulty. The author states that "... The common definitions of some of these measures imply a Poisson distribution." Very few of the actual definitions of measures of reliability imply a Poisson distribution, although many of the illustrations employ it. The author

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(p.c.) feels, however, that the intent of his statement is clear.

Definitions Numbers 3 and 4 for Hazard and Mean Time Between Failures (MTBF) cause the main difficulty in the paper. Number 3 is "Hazard (F) is the expected number of failures per unit of time. $F = -(\ln R)/t$." The two expressions are mutually exclusive except for a particular set of functions. The definition in words is ambiguous but is equivalent to saying that F is equal to one of the following: $-N_o dR/dt$, $-dR/dt$, or $-d(\ln R)/dt$, and obviously none of these are identical to $-(\ln R)/t$. (N_o, t, R, and ln are respectively the initial number, time, reliability, and natural logarithm.) Although it is an author's prerogative to define as he chooses, those definitions which are contrary to custom should be pointed out. In definition Number 4 MTBF is defined as "... the average time between failures and is the reciprocal of F. $MTBF = 1/F = -t/(\ln R)$." Obviously, more explanation is necessary on how these definitions (written and formula) are mutually consistent.

In definition Number 5, the average time to locate a failed area is somewhat ambiguous. If the average is weighted by the relative occurrence of each failure type, it would have been more appropriate to break it down as was done with other down times; if not, it may not fit reality very well.

Little of the valid material in this paper will be new to the experienced reliability statistician or engineer. See, for example, papers covered by Abstracts and Reviews Serial Numbers 28 and 124. The beginner is cautioned that while some of the ideas may be worthwhile, the mathematical rigor is poor.

The author (p.c.) feels that this is an advancement over current techniques in describing reality, that engineers and reliability analysts can be trained in the methodology, that the methodology will assist in making design decisions, and that the paper contains originality and is in the direction of furthering the state of the art. He has done further work on the subject (p.c.) which helps to clarify some of the problems mentioned above. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Basic effects of nuclear radiation

AUTHOR: J. R. Crittenden, Consultant, Radiation Effects, General Electric Company, Owensboro, Kentucky

SOURCE: Electronic Industries, vol. 21, January, 1962, pp. 102-106

PURPOSE: To describe nuclear radiation, its effects and measurement.

ABSTRACT: In addition to conventional environments, the designer must consider nuclear radiation. Nuclear radiation may be charged or uncharged particles or electromagnetic waves. Protons, alphas, betas (electrons) and fission products are examples of charged particles. The neutron is the only uncharged particle of interest here. The electromagnetic waves are gamma rays--similar to X rays. The charged particles interact strongly with matter and penetrate a short distance. The neutrons and gammas are difficult to stop. The range of energies which might be encountered range from fractions of an electron-volt for thermal neutrons to many million or billion electron volts. The type of interaction with matter depends on the energy. It is important in specifying an environment to give the types of particles and the energy range of each. The radiation effects will be ionization, displacement of atoms (ions) in a crystal lattice and transmutation; ionization is the most important, transmutation the least. The effects may also be transient, permanent or some of each. Nuclear radiation is detected and measured by three processes: ionization (and consequent changes in conductivity), displacement (by transferring energy to other particles), and transmutation (by observing the particles and energy released).

Throughout the paper examples and extended discussion are given.

REVIEW: This is a paper for those not familiar with the effects of nuclear radiation on electronic materials, components, and circuits. It serves as a good introduction to the subject. By and large, the novice will want to consult an expert if he has any problems in this field. Articles such as this allow him to converse intelligently with the experts. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Precision spot welding vs printed wire soldering in high density packaging--a panel debate

PANEL: Robert Swiggett, Robert Curran, Samuel Francis, Edward Duggan, and Jack Staller (at the New England section of the Professional Group on Product Engineering and Production of IRE)

SOURCE: Electronic/Electromechanical Production, vol. 2, January, 1962 pp. 9-14

PURPOSE: To discuss the good and bad points of each of two joining processes.

ABSTRACT: Printed wire soldering can be done which is very reliable and does not require extremely large capital outlays or operator training. The industry made many mistakes as it grew and some misapplications have given it a bad name. There is a great deal of experience from which actual reliability figures can be obtained. The method has a few problems with regard to overheating of components and vibrations in the printed board. In some cases, joints are all soldered by hand or retouched by hand.

Welding can be very good, under ideal conditions, as shown by its use in vacuum tubes where manufacturers can select many of their materials. There are problems in welding components because of various lead materials, lack of automation, a high degree of required operator skill, and close control needed for the process. If production quantities become the same as those for printed circuit soldering, many of the problems will be eliminated. Materials can be specified more easily and automation will reduce training and speed problems. The welded joint seems as if it should be capable of a higher reliability than the soldered joint. This will require a maturing in the industry.

Other processes are competing and will compete with these two. It is expected that excellent joining techniques will come out of the situation.

REVIEW: This is an interesting article for those who are somewhat familiar with the situation and would like to see how the "experts" answer each other's questions. Informal discussions of this sort are valuable and their publishing should be encouraged. ##

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Serial Number 315
Codes 813;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Resistance-welding of electronic components

AUTHORS: Joseph C. Heindl, Joseph N. Alberts, and Bert D. Brock, Product Engineering Department, Electronics Division, Space Technology Laboratories, Inc., Redondo Beach, California

SOURCE: Metal Progress, vol. 81, June, 1962, pp. 97-101

PURPOSE: To discuss factors affecting the welding of component leads.

ABSTRACT: Some advantages of resistance (spot) welding vs. soldering are high packing density, minimum degradation of components due to heat, elimination of some metal interfaces, process automation and simpler joining procedures, higher temperature operation, and greater resistance to mechanical failure. The properties of the metals which are welded govern the metallurgy of the weld. Some metals, e.g., aluminum, steel, and nickel, form fusion joints. Brass and copper are difficult to weld and have a "forged" joint. The fusion welds are more consistent and reliable since welding conditions are not as critical. One problem is the many different alloys and coatings used for leads. The welding electrodes must be properly selected for the materials that are being welded. A table lists the various lead materials and another gives suggested electrodes. The welding pressure and energy input must be determined once the leads and electrodes are selected. A good method for determining these is the isostrength diagram. The energy and pressure are the coordinates and the points are marked with a measure of their mechanical strength. Contours (isostrength lines) are drawn for given strengths. The allowable variations of pressure and energy are then easily determined. The chart can be made for different electrodes or other conditions and by superposition, the optimum parameters can be selected. The metallurgy of the joints are discussed and several photomicrographs are shown. The effect of lead coating is small, in general; the coating seems to be forced out of the weld zone. A table of weld strengths is included.

REVIEW: This paper has more of a metallurgical point of view than do the usual electronics papers on welding. There are no reliability data per se, but the discussion on weld strengths will be informative. No mention is made of fatigue as a mode of failure and one might suspect that it would be significant if movement is permitted. ##

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Serial Number 316
Codes 412;422;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Truncated life test procedures

AUTHORS: L. Frank Caskey and John L. Colley, Western Electric Company

SOURCE: The Western Electric Engineer, vol. 6, April, 1962, pp. 30-37

PURPOSE: To discuss several methods of determining confidence limits for the mean time between failures.

ABSTRACT: A numerical value for equipment reliability, in terms of probability of satisfactory operation, may be derived from failure data observed over a known period of time. An estimated mean time between failures, MTBF, is obtained from the failure data. This is used in the Poisson Formula to find the probability of satisfactory operation during the next specified period of time. The validity of the calculated probability is dependent on the estimation of the MTBF and the assumption of exponentiality for the occurrence of failures.

From a practical standpoint it may be advantageous to use the data in its MTBF form. It is the purpose of this paper to discuss several methods of determining confidence limits for the actual but unknown mean time between failures. These intervals may be used to determine the adequacy of the estimated MTBF obtained from the failure data. In addition to confidence intervals for MTBF estimates, the paper discusses the planning of equipment life tests. (Authors)

REVIEW: This paper provides a useful outline of life testing procedures with emphasis on their applicability in product evaluation. The description of the methodology should be helpful to those who are concerned with the life testing of components or systems. For those who are interested in the underlying theory, some nine pertinent references are cited. ##

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Code 711

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A note on fatigue damage

AUTHOR: Joseph I. Bluhm

SOURCE: Materials Research & Standards, vol. 2, pp. 122-123, February, 1962

PURPOSE: To introduce a new mathematical model for fatigue damage.

ABSTRACT: Some of the current cumulative damage criteria are briefly reviewed. The concept of allowable strain is introduced. Allowable strain is the maximum strain which can be repeated indefinitely without causing failure. This changes with the amount of damage already incurred. The damage done in any load application is the amount of strain in excess of the allowable strain. The theory is developed from these assumptions and some graphical methods of solution are illustrated. A critical value of damage for crack formation is hypothesized. No experimental work has been carried out; this is a theoretical paper only.

REVIEW: In a new theoretical paper which makes no claim to fit reality, about all that can be judged is the rigor of the development and the ease with which the theory can be tested. The rigor seems adequate, although the concept of endurance limit is not explained too clearly, especially with regard to the differences between unidirectional loading and completely reversed loading. A more detailed treatment of this would help the rigor of the paper. The testing may present a problem since the strains may be difficult to measure and more especially since virtually all existing data are in terms of stresses. Experimental testing is the next step (after the clarifications suggested above), and it would seem worthwhile to do some. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fatigue gages of aluminum foil

AUTHOR: W. G. Fricke, Jr., Research Metallurgist, Alcoa Research Laboratories, New Kensington, Pennsylvania

SOURCE: Materials Research & Standards, vol. 2, pp. 268-269, April, 1962

PURPOSE: To propose a method for anticipating a fatigue failure.

ABSTRACT: Small pieces of aluminum foil can be bonded to structural parts by using non-evaporating adhesives. The foil and the part receive the same strain. The strength of the foil can be made less then the part by using softer foils. The foil will begin to fail before the part does. The examination can be made by the unaided eye or by a low power microscope. On steel parts, the foils will generally fail much too soon to be very useful except on short life parts. Some experimental work has been done and appears promising.

REVIEW: If this idea proves successful in application, it may very well be of great assistance in a maintenance/reliability program. The concept of a strain gage--usually a wire--which would fail before the part does is not new. They have not been too successful so far. It would be interesting to see if one could find a failure anticipator in a similar fashion for electronic parts. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A simple direct stress fatigue machine for cumulative damage studies

AUTHORS: G. W. Brock, Staff Engineer, International Business Machines Corporation, General Product Development Laboratory, San Jose, California and R. Braune, Technical Assistant, International Business Machines Corporation, Thomas J. Watson Research Laboratory, Yorktown Heights, New York

SOURCE: Materials Research & Standards, vol. 2, pp. 401-402, May, 1962

PURPOSE: To describe a machine for stressing small specimens with a complex stress wave shape.

ABSTRACT: The specimen is a metal tape held in Lucite grips. The movable grip is constrained for axial movement only. The load is applied by pushing (transversely) on a steel loading tape in much the same manner that a clothesline can be stressed by pulling on the middle. Rollers, fastened to a wheel, do the pushing. The rollers can be adjusted to give the proper force, as measured on a transducer attached to the specimen. An oscilloscope trace shows a typical wave shape that can be applied. The mean stress can be adjusted by a pretensioning of the loading tape. In a system of this type, compression loads are not possible.

REVIEW: This fatigue machine may be very useful for studies in a limited area. There is no claim that any desired wave shape can be obtained. No mention is made of how close to zero load a cycle can come without causing shock loads. Apparently a machine has been built and has been demonstrated successfully. Cumulative damage is certainly an area where much work needs to be done. ##

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Serial Number 320
Codes 822;711

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The Weibull distribution function for fatigue life

AUTHORS: Task Group in Subcommittee VI of ASTM Committee on Fatigue, E-9, C. A. Moyer et al.

SOURCE: Materials Research & Standards, vol. 2, pp. 405-411, May, 1962

PURPOSE: To present a discussion of the Weibull distribution and tables for its use in analyzing fatigue data.

ABSTRACT: A method is given for using straight line plots of the Weibull distribution to estimate the distribution parameters from a set of data. Other charts are given for estimating confidence limits and for making significance tests. Fourteen references are given for further study. Comments are requested concerning the adequacy of the treatment.

REVIEW: This paper presents a graphical approach to estimation and testing problems involving the Weibull distribution. The applicability of the methods to data from specific sources depends heavily on the degree to which the Weibull is a good representation for the data. It would have been desirable to give in the paper an indication of the underlying assumptions for the Weibull distribution. In the section on reliability estimates and tests of significance, the authors indicate some disagreement as to the validity of the quoted method. This matter will have to be clarified before a user can place faith in the indicated method. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability adds a new dimension to technical management

AUTHOR: (Editorial Matter--report of seminar on Reliability and Quality Assurance sponsored by American Management Association in New York City, April 1962)

SOURCE: Industrial Electronic Distribution, vol. 2, May, 1962, pp. 6-7

PURPOSE: To summarize the main points of the seminar.

ABSTRACT: In the past reliability was achieved through careful design and manufacture. In the last 12 years, the pressures of design and production have caused the science of reliability to be born. Reliability groups can profit from the experience of quality control groups who had problems in getting started. Reliability should be the responsibility of the designer; the reliability engineer should set standards, monitor performance, and advise the design engineer.

Reliability efforts must be scientifically programmed if they are to be effective. After a reasonable adjustment period, the program can save four to five times its cost.

Vendor quality control will have a great influence on product reliability. The importance of this problem has grown because purchases have grown from a low of 20% to a high of 85% of the sales dollar. Small vendors who have inadequate quality control can be aided by suitable manuals, specifications, progress reports, etc.

In order that a reliability effort be effective, it must have top management support. It sometimes reduces conflicts if the reliability group begins as part of a design group and does not break off from it until good accord is established. A reliability engineer should be well versed in design and some people in his group should be statistically minded.

REVIEW: These are typical management type papers. The brief historical survey in the first paper is rather debatable, but otherwise the material is good. For those already in the field, there is probably nothing new summarized here. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Buyers need more reliability and quality control reports

AUTHOR: (Editorial Matter)

SOURCE: Industrial Electronic Distribution, vol. 2, May, 1962, p. 24

PURPOSE: To describe a new feature of the magazine.

ABSTRACT: To help buyers and procurement engineers find sources of reliable products, this magazine is publishing a listing of quality assurance and reliability publications available from suppliers. Since not all companies publish documents of this sort, and since the ones who do, do not always publicize it, this column will be of help in finding the required information.

REVIEW: The purpose here is a good one. Those in need of this particular type of information may find the column of help. Eight items are listed in this first report. ##

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Codes 813;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: High reliability through control of design and piece parts selection

AUTHOR: Stanley A. Rosenthal, Head, Reliability Section, Arma Division, American Bosch Arma Corporation, Garden City, New York

SOURCE: Industrial Electronic Distribution, vol. 2, May, 1962, pp. 28-30

PURPOSE: To describe how Arma controls design and piece parts selection.

ABSTRACT: Seven key considerations in the control of design and piece parts selection are discussed with the aid of examples.

1) The reliability group conducts a design review beginning with the preliminary system specifications, and continuing through testing of the equipment. This group has a veto power. The design review covers all aspects including parts selection, use of simple reliable circuits, and design for maintainability. Standard circuits and worst case checking are an essential part of the program.

2) Marginal checking of prototype equipment helps reliability. It assures that circuit margins, parts' stresses and circuit simplification are adequate.

3) Statistically designed evaluation tests pick the best parts. For example, environmental stresses are increased on two types of a component until failures occur. The type with the best performance is chosen. The same can be done with different vendors' products.

4, 5) All parts for production use are sampled and tested under all applicable environmental stresses. Records are then kept of performance in the tests and of the disposition of the parts. Some parts have 100% nondestructive tests.

6) All failed parts are analyzed to determine the cause of failure. If it is caused by design or manufacturing defects, proper changes can be made. Specialized techniques such as X-ray photography and spectrographic analysis can be used.

7) Effective corrective action is a necessary function--otherwise the investigative activities are useless. A comprehensive program is in use.

REVIEW: This appears to be a rather complete reliability program. Those who are trying to set up a new program will find material of value in this article. Those who have an effective, established organization will probably find little if anything new here. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Epoxy encapsulation of high-speed armatures increases operating life

AUTHOR: (Editorial Matter)

SOURCE: Electrical Design News, vol. 7, May, 1962, pp. 52-55

PURPOSE: To describe a method for encapsulating the armature and the benefits of doing so.

ABSTRACT: Armatures which operate at 30,000 to 45,000 rpm have serious balancing problems since slight movements of wires (or core) can cause appreciable unbalance. The three important design factors for high speed armatures are (1) armature and coil design, (2) bearings to withstand the speeds, and (3) precision construction to prevent friction and chatter. Besides holding the wires permanently in place, the epoxy impregnant aids in even heat dissipation and eliminates hot spots on the winding; it also eliminates dirt, moisture, and coolant from the windings and thus prevents insulation deterioration. The armatures are vacuum impregnated with a rigid epoxy system. The mold, armature and exopy are preheated so that the resin will flow easily. After curing, the armatures are turned on a lathe to remove excess epoxy. The armature is then ready for processing in the normal manner.

This method of encapsulation is said to extend the service life by a factor of 8 to 10.

REVIEW: This article shows what one manufacturer is doing to increase the service life and reliability of his industrial equipment. ##

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Serial Number 325
Codes 813;816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The game of reliability-amateur or professional

AUTHOR: Robert P. Bosche', Chief of Reliability, AVCO Electronics and Ordnance Division, 2630 Glendale-Milford Road, Cincinnati 41, Ohio

SOURCE: 5 pp., presented at the National Winter Convention on Military Electronics, Los Angeles, California, February, 1962

PURPOSE: To discuss means of attaining effectiveness in reliability programs.

ABSTRACT: The achievement of an optimum reliability program is impossible unless adequate consideration is given to the reliability requirements and their relationship to other objectives and constraints prior to the release of requests for bids. Many weapon and space system reliability programs are doomed for the lack of adequate emphasis during this early critical period. Some of the major factors contributing to the downfall of these reliability programs are:

1. A lack of a basic knowledge or determination of the program "needs" which relate reliability to overall system effectiveness, maintenance and logistics costs, required availability, and the results of failure.
2. A lack of an adequate understanding on the part of many customer personnel of some of the basic "reliability facts of life".
3. Indecisiveness on the part of customer personnel in determining realistic minimum reliability requirements and providing for the statement thereof.
4. An inconsistency between the minimum reliability requirements and the funds appropriated to achieve those requirements.
5. The inability on the part of the customer to make a direct comparison between competing system reliability proposals.

The responsibility for curing these deficiencies rests squarely on the shoulders of the customer or procuring agency, including prime and lower tier contractors. These agencies must develop in their engineering, fiscal, and contracts personnel an understanding of some of the basic factors relating to reliability requirements and achievement, as well as an attitude of decisiveness and effective coordination in and between those personnel. Some of the most critical factors involved in the accomplishment of this are discussed. (Author in part)

REVIEW: This paper is directed toward those who are concerned with the implementation and management of effective reliability programs. It contains a frank statement of some of the major deficiencies existing in many programs, as well as constructive suggestions for overcoming these deficiencies. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability demonstration in proper perspective

AUTHOR: Robert P. Bosche', Chief of Reliability, Avco Corporation, Electronics and Ordnance Division, 2630 Glendale-Milford Road, Cincinnati 41, Ohio

SOURCE: 6 pp., presented at the 14th Annual National Aerospace Electronics Conference (NAECON), Dayton, Ohio, May, 1962

PURPOSE: To discuss certain factors relevant to system reliability demonstration.

ABSTRACT: When a reliability requirement has been established, both the customer and the contractor are intent upon a fair evaluation of the product, but each with a somewhat different outlook. This paper discusses the effects of these somewhat opposing views. The customer must determine the level of confidence he requires in the results of the demonstration (i.e., he must decide on an allowable consumer's risk). The statistician or reliability engineer can then develop a specific test plan to meet those customer requirements. An example is given.

It is the aim of the producer to assure himself that his design will be accepted if it meets the contractual reliability requirements. Since conclusions based on somewhat limited test data are subject to some risk, he must establish a risk factor acceptable to himself (producer's risk). In order for the contractor to assure passing the prescribed test he must design to some reliability value greater than that specified by the contract. The greater the increase in equipment reliability, the greater the chance of passing the test within any specified period of time. The specific margin (degree of reliability overdesign) required for any specified length of time and producer's risk can be determined statistically. An example is given.

The degree of reliability overdesign, or reliability design index (RDI) decreases as the total test time increases, and is a function of the maximum test time established by the customer. For relatively large systems, relatively long test periods and the associated lower RDI are often justified. For relatively small systems, for which significant design improvements may be justified, relatively long test times may not be necessary. There can be cases in which state of the art limitations or fund restrictions preclude the satisfying of both producer's and consumer's confidence requirements. In such cases it is usually necessary for the consumer to reduce his confidence requirement.

Contractual reliability requirements based on redundancy considerations should first be reduced to the comparable MTBF for a

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non-redundant system. Reliability demonstration for coupling and switching devices in redundant systems should normally be covered in design qualification tests and as an adjunct to the reliability test, rather than as a direct part thereof.

REVIEW: This paper discusses, at a rather general level, the responsibilities of both the customer and contractor in the development of requirements for system reliability demonstration. The paper does not deal with the statistical considerations involved in setting up test plans, and personnel involved with this aspect should be sure of having competent advice on it. In a private communication the author has indicated that the effect of customer-limited demonstration test time on the required overdesign index is an important consideration which should have been given more emphasis in the paper. ##

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Serial Number 327
Codes 830;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Has sophistication of military equipment gone too far?

AUTHOR: Harry Sanders, Vice Admiral USN (Ret.), Executive Vice President, Harbor Boat Building Company, 258 Cannery Street, Terminal Island, California

SOURCE: 5 pp., presented at the 14th Southwestern IRE Conference and Electronics Show, Houston, Texas, April, 1962

PURPOSE: To indicate the reasons why some weapon systems and equipment are too sophisticated.

ABSTRACT: The development of weapons and military equipment has proceeded at an increasingly accelerated pace. Associated with this development is the demand for higher and higher performance. The result is greater sophistication of equipment, calling for more electronic components, and more automatic devices. The need for routine maintenance and check-out procedures is increased, with a resultant increase in the required number of experienced technicians. This requirement presents serious problems. The ability to maintain equipment in proper operating condition in many cases lags far behind the progress in systems design. If reliability is not built into the design, it is forced into it as a result of failures on tests. There should therefore be more tests, particularly of equipment in an operational status.

The extent to which proper design can improve reliability is limited by the reliability of components, the available degree of excellence of workmanship, and the availability of competent technicians. The demand for increased performance can frequently be met only by pushing the state of the art, and by design practices which do not leave adequate factors of safety. In addition to reliability and performance, the factor of cost has a strong bearing on the success or failure of a weapon system. In an effective weapon system there is a need for a good balance between cost, reliability and performance.

REVIEW: This paper presents reasonable arguments to indicate that there is perhaps too much sophistication in many weapons and military equipment. The problem is undoubtedly important, but, as the author indicates, the remedy will be difficult to find. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The equivalent system technique for reliability demonstration

AUTHOR: Donald J. Kerins, Research and Advanced Development Division, AVCO Corporation, Wilmington, Massachusetts

SOURCE: 9 pp., presented at the 14th Southwestern IRE Conference and Electronics Show, Houston, Texas, April, 1962

PURPOSE: To present a reliability requirement situation typical of many ballistic missile programs, and to suggest a technical approach to reliability demonstration for a one-shot type of system.

ABSTRACT: This paper deals with reliability demonstration for one-shot systems. A hypothetical system is presented, together with a hypothetical set of numerical reliability requirements typical of some of those to be found in current ballistic missile programs. Three approaches to the demonstration of reliability for the hypothetical system are discussed.

1. Testing individual components to demonstrate with 90% confidence that the component reliability is at least equal to the apportioned minimum acceptable value.

2. Testing complete systems to demonstrate with 90% confidence that the system reliability is at least equal to the specified minimum acceptable value. (.950)

3. Testing both complete systems and individual components to demonstrate with 90% confidence that system reliability is at least equal to .950 utilizing the equivalent system approach.

The advantages and/or disadvantages of each approach are discussed. Particular attention is called to the economic aspects as related to the materials cost for test samples. (Author in part)

REVIEW: The problem of obtaining statistical confidence limits for system reliability using reliability data for individual components, which constitutes an important part of this paper, is a difficult one, and remains to be solved. Previous attempts have been made (see, for example, Abstracts and Reviews Serial Numbers 152 and 227), but have not produced a statistically sound solution. The approach in the present paper hinges on the unstated assumption that the product of several binomially-distributed variables is itself binomially distributed. This assumption is not valid. The reference to "well known statistical techniques" mentioned in the paper does not apply to the product of binomially-distributed variables. The reader is therefore warned that the "equivalent system technique" described in this paper does not have a sound statistical basis. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The physics of failure--basis for component part failure rates

AUTHORS: D. R. Earles and M. F. Eddins, Avco Corporation, Research and Advanced Development Division, Wilmington, Massachusetts

SOURCE: 10 pp., presented at the 14th Southwestern IRE Conference and Electronics Show, Houston, Texas, April, 1962

PURPOSE: To discuss the theory and postulates of the physics of failure.

ABSTRACT: In the current state-of-the-art in reliability there are few formal physical relationships, as most of the work has been empirical. In this paper it is shown that the few existing postulates provide a basis for the use of failure rates in reliability prediction. A failure is defined by Beltrami's postulate, which states that "a failure in an object occurs when the energy stored by a given mechanism exceeds a critical value." The consideration of failure rate leads to Pierce's postulate, which states that "In any object with a large number of flaws the strength is determined by the size of the largest flaw." The failure rate life characteristic or failure force is defined by Dakin and Malmlow's postulate, which is stated as follows: "The largest flaw changes with time due to the flow of energy and material. The change occurs as a rate reaction. Since strength is a function of the largest flaw, strength changes with time in accordance with the reaction equations."

Using the rate reaction equations, the failure rate life characteristic curve is formulated mathematically. This equation relates the strength to the load. Since it is almost impossible to determine the instantaneous values needed to solve the equation, empirical failure physics determinations must be used. The classic failure rate curve ("bathtub" curve) is discussed and related to the theory and postulates of the physics of failure. The relation of failure rate to life expectancy is explored. A "generic failure rate" is defined as the number of failures per unit of time occurring under ideal internal and external stress conditions. The observed life characteristic, debugging period, normal operating period, and wear-out period, are briefly explained in terms of the postulates enunciated.

REVIEW: This paper is a worthwhile attempt to relate failure rates to a theory of failure physics. More detail on this and related topics is to be found in the documents covered by Abstracts and Reviews Serial Numbers 330 through 333. ##

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Serial Number 330 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability physics (the physics of failure)

AUTHORS: D. R. Earles and M. F. Eddins, Avco Corporation, Research and Advanced Development Division, 201 Lowell Street, Wilmington, Massachusetts

SOURCE: Reliability Engineering Data Series, Avco Corporation, Research and Advanced Development Division, Wilmington, Massachusetts, March, 1962

PURPOSE: To discuss the theory of failure physics and correlations with failure rates.

ABSTRACT: The Physics of Failure is the science that treats of the phenomena associated with failure related to matter in general, especially its relations to energy, and the laws governing these phenomena.

Failure Physics encompasses five basic areas. They are
1. Failure Criteria
2. Failure Mechanisms
3. Failure Modes
4. Failure Stresses
5. Failure Rates

Failure criteria, as defined by Brown, Leve, and White in their paper, "Reliability Design Criteria," are the tolerances on the geometric or material properties which, if exceeded, will cause the performance to be degraded below an acceptable level, or alternatively, the criteria may be of a catastrophic nature such that when exceeded the system will fail.

Failure mechanisms are the physical or chemical reactions which take place to cause or effect failure of an object. 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. However, any attempted classification of chemical and physical agents poses a problem. Some chemical agents often act physically and some physical agents often act chemically, and both sometimes act in the two capacities simultaneously.

Failure modes are the way in which a strength capability may be exceeded in terms of geometric or material properties. The mode of failure describes the physical manner in which a failure occurs and the operating condition of the equipment or part at the time of failure.

The mode of failure combined with the environment producing failure (external of internal stress) is the type of failure.

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

The measure of an equipment's reliability is the frequency at which failures occur. If there are few failures, the equipment is reliable. If the failure frequency is high, the equipment is unreliable. Failure rate is then a frequency function. It has a statistical connotation as it is relative to the number of failures that would be expected to occur over a large number of cycles, or a long period of time, or in a large number of items. (Authors)

Under the heading of Theory and Postulates the topics covered are: The Physics of Failure, Strength-Stress, Conservation of Energy Law, Beltrami's Failure Postulate, Largest Flaw Concept, Pierce's Postulate, Dakin and Malmlow's Postulate, Reliability Equation, Failure Criteria, Strength-Failure, Mode of Failure, Failure Types, Failure Rates, Cause of Failure, Life Characteristics, Mean-Time Between-Failure, Life Expectancy (Longevity), Relationship of Life Expectancy to Failure Rate, Relationship of Life Expectancy to Mean-Time-Between-Failure, Debugging Theory, Mean Debugging Time, Debugging Constant of Proportionality, Useful Life Theory, Operating Stress Levels Vs. Failure Rate, Wear-Out Theory, Failure Force, Failure Frequency Distributions, Empirical Reliability Equation and Failure Rate Stablization Process.

Correlations between failure physics and failure rates are discussed under the headings: Generic Failure Rates, Observed Life Characteristics, Observed Debugging Period, Observed Normal Operating Period and Observed Wear-Out Period.

REVIEW: This document is the first in the Reliability Engineering Data Series, initiated by Avco Corporation for use by company personnel and interested individuals and organizations in government, industry and universities. It is to be commended as a very worthwhile effort. Interested individuals may request copies of the documents from the authors at the address given. ##

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OFFICE OF RELIABILITY AND QUALITY ASSURANCE
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400 Maryland Avenue S.W.
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Serial Number 331
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure criteria

AUTHORS: D. R. Earles and M. F. Eddins, Avco Corporation, Research and Advanced Development Division, 201 Lowell Street, Wilmington, Massachusetts

SOURCE: Reliability Engineering Data Series, Avco Corporation, Research and Advanced Development Division, Wilmington, Massachusetts, May, 1962

PURPOSE: To discuss failure criteria.

ABSTRACT: This is a continuation of the work covered by Abstract and Review Serial Number 330. The topic of Failure Criteria is presented under the headings Input and Output, Stress Levels, Strength-Stress Criteria, Strength Criteria Tests, Structural Failure Criteria Considerations, Electrical Strength Failure Criteria, Operating Parameter Failure Criteria, Environmental Strength Failure Criteria, Procedure for Estimating Failure Criteria, Failure Probability Criterion, Systems Failure Criteria and Failure Criteria Specifications.

REVIEW: This is the second document in the Reliability Engineering Data Series published by Avco Corporation. The comments in Review Serial Number 330 are applicable also to this item. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure mechanisms

AUTHORS: D. R. Earles and M. F. Eddins, Avco Corporation, Research and Advanced Development Division, 201 Lowell Street, Wilmington, Massachusetts

SOURCE: Reliability Engineering Data Series, Avco Corporation, Research and Advanced Development Division, Wilmington, Massachusetts, April, 1962

PURPOSE: To discuss failure mechanisms.

ABSTRACT: 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. However, any attempted classification of chemical and physical agents poses a problem. Some chemical agents often act physically, and physical agents often act chemically, and both sometimes act in the two capacities simultaneously. 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. (Authors)

The discussion is organized under the following headings: Adherence, Arcing, Backlash, Bleeding, Brinelling, Carburization, Composite Behavior, Contact Bounce, Contamination, Corona, Corrosion, Creep (Relaxation), Creep Rupture, Cross-Talk, Current Overload, Decarburization, Deterioration (Aging), Dielectric Breakdown, Diffusion, Drift & Shift, Dynamics Out-of-Limits, Errosion, Fatigue, Fretting or Galling, Frequency Effects, Fritting, Leakage, Magnetic Hysterisis, Mass Unbalance, Noise (Electrical or Radio Interference), Opens, Piezo-electric Effect, Radiation Damage, Secondary Currents, Seizure, Shorts, Silver Migration, Slip (Inelastic Action), Smearing, Sputtering, Sublimation, Temperature Shrinking, Voltage Breakdown, Voltage Overload and Wear.

REVIEW: This is another document in the Reliability Engineering Data Series, published by Avco Corporation. It contains a comprehensive listing of failure mechanisms, together with definitions or clarifying statements for each. The same comment as in Review Serial Number 330 regarding availability of copies applies also to this item. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure rates

AUTHORS: D. R. Earles and M. F. Eddins, Avco Corporation, Research and Advanced Development Division, 201 Lowell Street, Wilmington, Massachusetts

SOURCE: Reliability Engineering Data Series, Avco Corporation, Research and Advanced Development Division, Wilmington, Massachusetts, April, 1962

PURPOSE: To discuss failure rate concepts and to present an extensive tabulation of failure rates for a wide variety of components.

ABSTRACT: The concepts of failure frequency function and failure rate standards are discussed. The chronology of failure rate development is traced, and a listing of pertinent references dating from 1948 in chronological order is given. Failure rate normalization and standard installation environments are discussed. The environments considered include vibration, shock, temperature, and humidity. The method used in failure rate data analysis is described, together with the topics: failure rate modifiers, life expectancy data analysis, and life expectancy modifiers.

Application factors enabling the modification of generic failure rates for application stresses are presented graphically. Extensive tables of generic failure rates and generic life expectancies for a wide variety of components and parts are given.

(Included at the end of the book is a section on Failure Therbligs, the text of which is essentially the same as that of the paper covered by Abstract and Review Serial Number 286.)

REVIEW: This is another document in the Reliability Engineering Data Series, published by Avco Corporation. As indicated in Review Serial Number 330, copies are available from the authors at the address given.

An outstanding feature of this document is the tabulation of failure rates for a wide range of types of components. The authors claim that it is the most complete and current tabulation available at this time, and it seems unlikely that they will be challenged on this point. The work should be very valuable to designers and others concerned with component selection, etc. The authors and their company are to be commended for their effort in making these data generally available. ##

Serial Number 334
Codes 713;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Shock-resisting tungsten wire will improve the vacuum tube

AUTHOR: (Editorial Matter)

SOURCE: Machine Design, vol. 34, April 12, 1962, p. 36

PURPOSE: To publicize this Westinghouse development.

ABSTRACT: This new tungsten wire behaves well from -444°F to 4500°F and possesses high resistance to sagging and breaking from shock or vibration. It is expected to improve the reliability of electronic tubes. The new metallurgical and chemical conditions control the behavior and give it good room temperature workability.

REVIEW: There is little technical information in this brief note. Details can probably be obtained from Westinghouse in Bloomfield, New Jersey. If the potential reliability increase in vacuum tubes is realized in practice, the tube will be able to compete more effectively with solid-state devices. ##

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Serial Number 335
Codes 781;816;834

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Panel discussion on manufacturer-user problems

AUTHORS: (Reported by Ronald K. Jurgen, moderated by W. E. Vannah.) From September, 1961 Joint Industrial Electronics Symposium, Boston, Massachusetts

SOURCE: IRE Transactions on Industrial Electronics, vol. IE-9, May, 1962, pp. 66-77

PURPOSE: To discuss mutual problems of manufacturers and users of industrial electronic equipment.

ABSTRACT: (The panel covered many topics; only those pertaining to reliability are mentioned here.)

The item of greatest importance for the user is reliability since it directly relates to costs and product quality. The lifetime of controls is expected to be 20-30 years in some cases. Shutdowns at non-scheduled times can be very costly. Maintenance people are not always familiar with the latest electronic developments. Built-in testing devices are helpful if they do not decrease the reliability. Miniaturization for its own sake is rarely needed, but if it improves reliability or maintenance (or cost) it is welcome.

The equipment should be designed so that common human errors will not damage it. An example of good design might be blocking diodes in d.c. lines to prevent damage during reversed polarity.

The main purpose of machine tools is to remove metal rapidly and accurately. The controls designer should understand the machines and their purposes and functions. There has traditionally been some resistance, by maintenance people, to electronic controls. Servicing, even on simple equipment, can be a problem for electricians. The environmental problems: heat, shock, vibration, dust, chips and oil all contribute to unreliability if the equipment is not properly designed.

The reliability of electronic equipment, in the experience of one panelist, exceeded that of pneumatic controls.

REVIEW: The discussion seems to be typical of that expected from moderate sized users of industrial electronic equipment. It should be emphasized that even though industrial gear is not as complex or exotic as military systems, it does need to operate properly over long periods of time with little or no maintenance. ##

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Serial Number 336
Codes 852;831;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability improvement of semiconductor devices--a status report

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

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 1-7

PURPOSE: To summarize and to put into perspective some of the current thinking for achieving the reliability goals required of semiconductor devices in military electronic systems.

ABSTRACT: This paper begins by giving some factual data on the field reliability of semiconductor devices. Removal rates per 1000 hours vary from 10% for RF mixer silicon diodes and 5% for silicon and germanium transistors rated at over 1 watt to a minimum of 0.006% for small signal germanium diodes in digital circuits. Subminiature tubes and small signal transistors in linear circuits have experienced comparable removal rates. Variations in removal rates between different systems from 0 to over 200% indicate design shortcomings. Of those devices removed from equipment, 40% had no defect, 10% had mechanical failures, 25% had opened or shorted, and 25% had drifted out of tolerance.

Discussing qualification approval procedures, the author suggests improvements by better test specimen selection, improved rating verification tests, and statistical data sampling techniques. It is recognized that economics plays an important role in specifying the quality level of devices which is obtained using one of four approaches: the life-test sampling plan as per Method B (Mil-S-19500B), failure acceleration techniques, sequential life testing, and life test sampling based on the Weibull concept. This report concludes with a plug for an effective standardization program as a big step toward reliability improvement.

REVIEW: This paper is a somewhat brief summary of the results achieved and the opinions formed in the ARINC reliability programs under government sponsorship. The data are factual and the discussions reasonable, especially as regards the need for standardization and for economic and valid verification procedures. ##

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Serial Number 337
Codes 770;844;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Long term reliability analysis of germanium PNP alloy transistors

AUTHOR: Erwin A. Herr, Semiconductor Products Department, General Electric Company, Syracuse, New York

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 8-26

The text of this paper is essentially the same as that of the paper covered by Abstract and Review Serial Number 164.

The following review, prepared independently of the earlier one, is felt to be appropriate in the context of the collection of papers in which the work presently appears.

REVIEW: The data presented is of little direct value due to the small samples and the variety of conditions employed, but does serve as a good indication of what may be expected in long term variations of alloy germanium transistors. No attempt was made to correlate the changes noted with the physical mechanism involved. These data would have been valuable for process analysis. A point to question is the differences in the initial characteristics of lots D and E of the 2N396. For instance in lot D, $28 < h_{FE} < 88$, while in lot E, $28 < h_{FE} < 188$, both being initial readings at the same current level. ##

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Serial Number 338
Codes 770;833;837;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Profiles in failure rate vs. application

AUTHOR: Robert E. Pratt, Semiconductor Division, Raytheon Company, Newton, Massachusetts

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 27-37

The text of this paper is essentially the same as that of the paper covered by Abstract and Review Serial Number 134.

The following review, prepared independently of the earlier one, is felt to be appropriate in the context of the collection of papers in which the work presently appears.

REVIEW: This paper has a commendable purpose, that of suggesting that the device manufacturer should provide reliability information which is useful to the circuit designer. As is pointed out, the economics of this may be the most important factor. Whether the suggested method is the most desirable awaits further tests but it appears to be an excellent step in the proper direction. It may be hoped that such data will become common on transistor specification sheets. ##

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Serial Number 339
Codes 850;843;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability study of germanium alloy-junction audio transistors

AUTHOR: Leo Lampert, New York Naval Shipyard, Brooklyn, New York

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 38-50

PURPOSE: To present data accumulated from a statistical experiment involving alloy germanium transistors.

ABSTRACT: An experiment is in progress involving 3000 transistors of two types specified only as "odd" and "even" types. Over 10,000 hours of life test have been accumulated. The objective is to obtain data on parameter variations under a variety of conditions which may be used to develop median value and standard deviation curves as a function of time and to determine failure rates. Histograms and scatter parameter graphs are given for the data thus far accumulated as well as some failure analysis. It is interesting that the largest number of failures has been found for the lower collector voltages with all failures increasing with higher junction temperatures. The number of high limit beta failures appears significantly higher then the low limit failures.

REVIEW: This is an exhaustive study of little general value due to the specific device types employed and of little specific value since the device types are not specified. It may serve as an example which may be studied before other life tests are performed. Such data is best obtained by the manufacturer so that it may be applied in design as is suggested in the paper covered by Review Serial Number 338.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductor reliability predictions from life distribution data

AUTHOR: D. S. Peck, Bell Telephone Laboratories, Murray Hill, New Jersey

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 51-67

PURPOSE: To present the reliability prediction techniques which have evolved from studies of NIKE-ZEUS semiconductor devices.

ABSTRACT: The recognition of the log-normal life distribution, as opposed to the exponential distribution of times to failure, together with the use of the high stress testing technique, can cause many changes in life evaluation, or reliability studies. These changes show promise of improving our recognition of the processing factors which are most significant in controlling reliability, or our earlier detection of inferior portions of a product distribution. It is reasonable to expect that statistical evaluation of such tests may become a significant tool for quality control, rapid evaluation of processing changes, and guidance of design effort. The device designer should observe median lives, distribution spreads, and degree of stress dependence.

These conclusions were reached through an analysis of life test data on the 2N559 germanium mesa transistor being manufactured by the Western Electric Company for NIKE-ZEUS computer use. These techniques have been used to predict an initial failure rate of 2.5×10^{-6} percent per 1000 hours at $25^{\circ}C$ for vycor-gettered units. They have been proven by an observed failure rate of 0.004 percent per 1000 hours for an earlier batch of transistors which is consistent with the log-normal distribution for that batch.

REVIEW: These results are consistent with the high quality of the BTL reliability programs over a number of years in that they represent possibly the most complete, the best authenticated, and utilize the most advanced techniques applied to semiconductor devices. One may wish that the more complete story, including the feedback to the device designer, will find its way into print as a primer of reliable device design. ##

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Serial Number 341
Code 782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effects of nuclear radiation on electronic materials

AUTHORS: Dr. V. R. Honnold and Dr. C. W. Perkins, Ground Systems Group, Hughes Aircraft Company, Fullerton, California

SOURCE: Electronic Industries, vol. 21, February, 1962, pp. 99-101

PURPOSE: To present the effects of pulsed nuclear radiation on electronic materials.

ABSTRACT: This is the second article in a series on nuclear radiation effects. In a nuclear explosion there is a short prompt gamma ray burst and a slower broader pulse of fast neutrons. The operation of military equipment during this transient period is a source of concern. The radiation bursts can be simulated in the laboratory.

The fast neutrons (uncharged) collide with a nucleus and knock it out of position. The disturbed atom has enough energy to knock others out of place and so forth; a single primary event may give rise to about 900 displacements. Gamma rays ionize the atoms but do not displace them. Permanent structural changes in the molecules may result and there will usually be a transient drop in resistance due to the ionization.

The author divides materials into insulators (organic and inorganic), semiconductors, metals, gases, and miscellaneous. Emphasis is given to transient effects.

REVIEW: This is an introductory article on the subject; fifteen references are given for further study. The treatment is adequate for the purpose. ##

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Serial Number 342
Codes 815;816;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interpreting MIL Specs for system reliability--Part IV

AUTHOR: Anthony J. Finocchi, Director of Reliability Engineering, ITT Federal Laboratories, Nutley, New Jersey

SOURCE: Electronic Products Magazine, vol. 4, May, 1962, pp. 30-33

PURPOSE: To show how specifications for equipment designed for aircraft, guided missiles, and ships differ from those for ground equipment.

ABSTRACT: This article discusses the effect of the general building specifications on cost and delivery for: airborne (MIL-E-5400), missile airborne (MIL-E-8189), and shipborne (MIL-E-16400) equipment. MIL-E-5400 is briefly described; the classes and categories of equipment listed are cited. The procedure for the approval of the use of nonstandard parts is indicated. Other topics discussed are as follows: provisions for production by mechanized and semimechanized facilities, provisions for meeting explosion-proof conditions, and vibration specifications. MIL-E-8189 and MIL-E-16400 are briefly described, with particular emphasis on the significant differences between these and the specifications for ground electronic equipment.

REVIEW: This is the fourth paper in a series, the first three of which were covered by Abstracts and Reviews Serial Numbers 218, 251, and 252. It contains further useful information and advice for contractors regarding specifications for electronic equipment. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Structural vibration in space vehicles

AUTHORS: Kenneth Eldred, Western Electro-Acoustic Laboratory, William Roberts, and Robert White, Northrup Corporation, Norair Division

SOURCE: The Journal of Environmental Sciences, vol. 5, June, 1962, pp. 18-22

PURPOSE: To report on a research project on structural vibration sponsored by WADD, Dynamics Branch.

ABSTRACT: Attention to structural vibration is an increasing requirement for space vehicles. This increased attention has been forced by an increased number of failures, suspected to originate from excessive vibration. Significant advances made in the analysis and control of vibration have lagged behind the creation of new problems, each more formidable than the previous one. This paper considers the reasons for this lag and the trend which may be expected in the future.

This research was sponsored by WADD, Dynamics Branch, mainly (1) to survey the structural vibration field, (2) to provide a method to predict structural vibration, (3) to provide an overall understanding of the sources of vibration, and (4) to relate this information to testing and specifications. The report is being published as WADD TR 61-62, and this paper gives only part of the whole work.

The principal sources of vibration in space vehicles are listed in the order of their strength as mechanically transmitted thrust oscillations from the rocket, cavity resonance, rocket noise, oscillating shocks, buffet, base pressure fluctuations, wakes from drag devices or projections, turbulent boundary layer noise, and laminar boundary layer noise. Brief discussion of these sources is given. The principal results in structural response predictions, obtained through the empirical correlation approach, are summarized. Some of the complexities in qualification testing are cited. The fatigue problem is discussed, together with recent progress made in dealing with it.

The following conclusions are listed: (1) The cost of providing overall reliability by test should be balanced against the cost of mission failure, (2) The scope of activity of the vibration engineer must be enlarged, (3) The techniques of vibration control must be adopted at the inception of each new design, (4) Communication between the contractors and with the government agencies must be accelerated, and (5) Expanded vibration research is needed to develop better analytical and experimental tools. (Authors in part)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This paper has material which should be of value to the designer of space vehicles and associated systems in which vibration problems are encountered. More detail will be found in the technical report mentioned in the ABSTRACT. ##

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Serial Number 344
Codes 711;830

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: Microelectronic-interconnection design

AUTHORS: G. L. Branch and R. Y. Scapple, Hughes Aircraft Company, Culver City, California

SOURCE: Electro-Technology, vol. 69, March, 1962, pp. 76-79

PURPOSE: To describe a successful technique for interconnection.

ABSTRACT: This paper describes the design of a high density interconnection assembly for thin film wafers. The wafers are joined by a thin flat cable that both holds them and provides electrical contacts. The soldering of microjoints is easy under a microscope and virtually impossible without it. The wafers are 0.030 in. x 2 in. x 3 in. of Fotoceram. It has good toughness, chemical inertness and thermal-shock resistance and does not break when dropped 36 in., whereas soft glass sometimes breaks in handling. Ultrasonic machining is used to make the positioning grooves. The solderable electrical contacts are from chemically deposited nickel followed by electroplated gold. Brush-on silver paint with electroplated copper was also satisfactory. Vacuum-deposited Permalloy and copper followed by electroless nickel and gold was unsatisfactory and so was brush-on solderable silver paint. The nickel is 0.15 millinch thick and the gold is 6 microinches thick. An alloy of 1/4 indium, 3/8 lead, and 3/8 tin is used for tinning. It has good wetting and physical properties and can be dip soldered. The flux is Kester 1544. The soldering of the leads is done by the electrical resistance method. The probes are used for positioning as well as electrodes.

Tensile test failures occurred in the wire next to the solder connection; strength was 90% of that of the wire. A ninety-degree peel test caused failures at the wire/solder interface. Flexure tests showed a life well in excess of that required for handling and servicing.

REVIEW: This paper seems to be a good description of a process which has potential for high reliability. No mention is made of the behavior in production or service. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The role of environmental testing in satellite reliability

AUTHOR: John H. Boeckel, Associate Chief, Test and Evaluation Division, Goddard Space Flight Center, Greenbelt, Maryland

SOURCE: 15 pp., presented at the 1962 National Telemetering Conference, Washington, D. C., May, 1962

PURPOSE: To discuss the reliability and environmental testing problems applicable to scientific satellites as distinguished from spacecraft used for manned flight or military purposes.

ABSTRACT: The problem of satellite reliability centers about the fact that a level of performance must be attained which balances the high costs of an individual firing against the need for obtaining timely accurate data with a package of minimum weight containing exotic instrumentation. The application of mathematical reliability analysis to satellites is hampered by the absence of large samples and uniform populations. Mathematical models of satellite systems can be used to highlight those elements of the assembly which have the greatest impact on system performance rather than to make accurate quantitative predictions. In this situation, rigorous testing of the actual units to be flown becomes a necessity.

The systems test program for a satellite has six goals:

(1) Verification that novel or unproven designs meet performance requirements and have a satisfactory life expectancy.

(2) Verification that particular samples of previously employed hardware are suitable in a new application.

(3) Elimination of defects in design, material or workmanship (i.e. finding the weak links in the chain).

(4) Discovery of unexpected interactions between subassemblies when the system is exposed to environmental stress.

(5) Training of personnel who will be responsible for the satellite at the launching site and those who will be responsible for data reduction and analysis.

(6) Generation of information which will serve as a guide in making new designs and in assessing their reliability.

The degree to which these goals may be attained depends heavily on the fact that at most only one prototype and two flight units are available for test. The test philosophy must be based on a model of the failure pattern to be expected.

The systems test program is directed chiefly at eliminating failures due to major design weaknesses or to defects in material or workmanship. Mathematical reliability analysis is probably the best guide to expected performance after infant mortality has been accounted for. While wear-out caused by exposure to mechanical environments is often covered in the test program, wear-out caused

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by other factors is usually best attacked at a materials, component, or subassembly level because of the extreme cost of conducting extended systems tests.

Tests on the prototype system are directed toward the qualification of a design. Major design weaknesses should be eliminated in this series of tests. A 99% probability level in these tests is desirable, but the accomplishment of this is hampered by the lack of adequate data. Tests of the flight units are directed toward the acceptance of a particular system for flight. Defects in material or workmanship should be discovered in this series of tests. Test levels for the flight units are usually set at the 95% probability level. The 95% level is usually taken to imply a condition which is supported by the most severe valid data which has been obtained. The 99% level is then set at an assumed mean value plus one and one half times the difference between the mean and the 95% level, a procedure which is approximately correct for a normally distributed variable.

A clearly defined environmental testing program is essential to prevent errors and omissions during the drive to get acceptable flight units. The procedures which must be included in the test plan are outlined. Considerations regarding the selection of environmental exposures are discussed. The exposures included are: dynamic balancing and spin, acceleration, vibration, shock, temperature, humidity, and thermal-vacuum. Experience with evaluation programs is summarized.

REVIEW: This paper is a discussion of the rationale or philosophy behind the establishment of an environmental test program for satellites. As such it does not go into specific details on test procedures. The discussion should be helpful in establishing guidelines for those who are concerned with setting up such testing programs. ##

Serial Number 346
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Status of microminiaturization

AUTHORS: E. F. Horsey and P. J. Franklin, Diamond Ordnance Fuze Laboratories, Washington, D. C.

SOURCE: IRE Transactions on Component Parts, vol. CP-9, pp. 3-19, March, 1962 (also presented at the I.E.E. Conference on Components and Materials used in Electronic Engineering, London, England, June, 1961)

PURPOSE: To give a summary of the various techniques available for microminiaturization.

ABSTRACT: The status of microminiaturization is summarized under the following three headings: 1) assembly of pretested conventional or specially designed component parts, 2) printing or vapor deposition of multicomponent assemblies on flat insulating substrates, and 3) preparation of complete circuits from a solid block of semiconductor material.

Under the first heading, assembly of parts in three-dimensional (3-D) soldered structures, in 3-D welded structures, in imitation 2-D-type structures, and in structures of disciplined geometry is briefly described. The latter structures now include not only the Micro-module but also new pelletized parts.

Under the second heading, the original 2-D thin-film type of construction is briefly summarized and then the evolution of this system into experimental circuits containing all thin-film passive parts is shown. The logical next step, preparation of circuits containing thin-film active as well as passive parts, is in even earlier stages of research.

Under the third heading, new developments in integrated and functional circuits are presented. The trend of current work points to the conclusion that equipment available commercially in the next decade will probably take the form of hybrid structures comprising both individually fabricated parts, and single-process parts arrays, all mounted or processed onto an insulating substrate. (Authors)

REVIEW: This is a good review of the state of the art which will be useful to those who are interested in the field. There are 25 figures and 41 references which increase the value of the paper. The subject is so broad that each phase cannot be treated in any depth; the references should be of help. ##

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Serial Number 347
Codes 770;833;844;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: For alloy transistors--proving long term reliability

AUTHORS: J. H. Scrivner, Heavy Military Electronics Department, General Electric Company, Syracuse, New York and J. R. Willey, Defense Electronics Products, Radio Corporation of America, Camden, New Jersey

SOURCE: Electronic Industries, vol. 21, May, 1962, pp. 102-106

PURPOSE: To find the number of failures in 10,000 hours for transistors 2N357 and 2N396 under typical use conditions.

ABSTRACT: The tests were designed for failure rate and derating information. All tests were performed at 25°C and 50 minutes on plus 10 minutes off. The voltage levels were 6, 12, 16 and 20 volts for both the 2N357 and the 2N396. The power levels were 75, 150, 200 mw for the 2N396 and 50, 100, 150 mw for the 2N357. There was no shock or vibration. Failures were catastrophic. A factorial method, designed to give an 80% confidence with ± 20% accuracy, was used to determine the number to be tested at each level; 10,500 transistors of each type were used. The measurements made were:

A) 0, 125, 250, 500, 1K, 2K, 3K, 4K, 5K, 6K, 7.5K and 10K hours - h_{FE}, I_{CBO}, I_{EBO}, BV_{CEO}, BV_{EBO}, BV_{CBO}

B) 0, 2K, 5K, 10K hours - f_{ab}, r_b, C_{ob}

C) 0, 10K hr. - common emitter, collector saturation and common emitter input characteristics

(The life test equipment is described, along with some of the test difficulties.)

The life test gross average failure rate over all conditions lumped together is 0.17%/1000 hr. for the 2N357 and 0.12%/1000 hr. for the 2N396. The failures have been due to such things as poor soldering, poor workmanship and moisture in the case. Three of the figures show h_{FE} and I_{CBO} (10, 50, 90 percentile curves) and failure rate as a function of time.

REVIEW: A large effort such as this is to be commended. The paper itself is not clear in a few places--especially in the discussion of results. The distribution of the parameters as a function of time will be especially helpful in calculating the number of drift failures in a circuit. Unfortunately, the curves given in the paper do not state the particular test conditions--they may be the gross curves for all conditions. For very high drift reliability calculations, the more extreme percentiles should be included. It is to be hoped that when the tests are finished, a more complete analysis will be available. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Machines that grow

AUTHOR: Richard R. Landers, TAPCO Research Development & Engineering, Thompson Ramo Wooldridge Incorporated, Cleveland, Ohio

SOURCE: Machine Design, vol. 34, July 5, 1962, pp. 114-118

PURPOSE: To describe the characteristics of electronic devices which are self-healing, self-adapting, and self-supporting.

ABSTRACT: The term dybology is introduced; it means the area of science between biology and engineering and is generally used to describe inanimate, but lifelike, things. The machines under consideration are electronic ones, the mechanical parts are the usual kind. Instead of using very reliable components, the machine would use untested, cheap,short-lived ones just as the complex, reliable animal is made of cheap, disposable cells. The cells for this machine are called dyblocs and their most efficient shape is a 14-face solid which can be nested with others of like shape. These dyblocs are circulated throughout the system and replace failed units where necessary. The main parts are a director unit, controller unit and a function output unit plus, of course, an input and output. The dyblocs are held in place by probes which have the necessary properties for proper functioning. The scheme is explained in the paper and a simple example is given.

REVIEW: This is a philosophic, concept-type article in which the imagination is allowed free run. The one example is quite restricted from the general case presented, probably from necessity. Whether or not such schemes as this turn out to have practical value will depend on many circumstances. Much conceptual thought remains to be done before the worth of the idea can be assessed. The article is not intended to assist the present day designer with his contemporary problems. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction of fatigue failure using ultrasonic surface waves

AUTHOR: Jens Gert Rasmussen, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Massachusetts

SOURCE: Nondestructive Testing, vol. 20, pp. 103-110, March-April, 1962

PURPOSE: To describe the use of ultrasonic surface waves in predicting fatigue failure, especially for polished aluminum parts.

ABSTRACT: Since fatigue failures generally start at a surface, measurements on the surface have been tried to predict the onset of failure. X-ray analysis and electron microscopy have been used, but are cumbersome and expensive. Experiments were performed using ultrasonic surface waves in electro-polished 2024ST3 aluminum alloy which was stressed in reversed bending. The life time range which was investigated was 10^5 to 10^6 cycles. The occurrence of microcracks could be detected at about 40% of the life and seemed to be independent of life. The damage was detected earlier when measurements were made on the stressed part rather than when it was unstressed.

A barium titanate crystal at 4 Mc was used in a Krautkramer MOB probe which was glued to the specimen. The Krautkramer ultrasonic equipment has narrow pulses, short dead zone, linear amplifier and 5 - 10% high frequency left undemodulated at the screen picture. (A description is given of the technique for generating the surface waves and pictures are shown of the oscilloscope traces of the echoes.)

The testing of actual parts is expected to present difficulties not found in the laboratory specimens. The part should have free surfaces and have low ultrasonic attenuation. It might be possible to monitor vital components of an aircraft while it is in flight. Care should be taken that surface corrosion inhibitors do not damp out the waves. If higher frequencies and outputs were used, better sensitivity could be obtained.

REVIEW: This seems to be a good report of a carefully performed experiment. The assumptions and limitations seem to be adequately explained. The subject of fatigue failures is very important and a further extension of this work would be appropriate.

In a private communication the author has called attention to another of his papers in this field. The paper is cited in the reference below.

REFERENCE: "Ultrasonic inspection of turbine and compressor rotor blades for

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

cracks and other flaws," Nondestructive Testing, vol. 16, pp. 228-236, May-June, 1958 ##

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Codes 761;775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mechanisms of failure

AUTHOR: Leonard L. Schneider, Reliability Engineering Associates, Skokie, Illinois

SOURCE: Nondestructive Testing, vol. 20, pp. 111-113, March-April, 1962 (also presented at the Society's Annual Convention, October, 1960, Philadelphia, Pennsylvania)

PURPOSE: To describe some nondestructive tests which are useful in eliminating defective components.

ABSTRACT: The reliability of components can be improved by subjecting them to nominal stresses and rejecting parts which are defective. The stresses are low enough not to harm normal components. All parts were given the normal incoming inspection. The additional rejects ranged from about 1/2% for some transistors and resistors to 27% for hermetically sealed transformers (Figure I lists data for 17 components). The mechanism of failure is listed for each type of component along with the type of test.

The lot-to-lot variation is sometimes as great as vendor-to-vendor variation and precludes the use of fixed criteria for rejection. One future possibility is to find the frequency distribution of the component parameters of interest and to truncate the distribution at some number of standard deviations.

REVIEW: Some of the rejects in this 100% inspection are probably the result of a consumer's risk in the incoming inspection plans. The other rejects show the need for a revision, along the lines indicated by the author, of the standard inspection schemes when high reliability is needed. Since the time this paper was originally presented there have been other trends and methods developed in the search for more-reliable components. Nevertheless, the information presented here will be of use to those whose reliability effort is small or new. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System evaluation or reliability in economic perspective

AUTHOR: Edmond S. Winlund, General Dynamics/Astronautics, San Diego, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, May, 1962, pp. 1-3 (presented at the General Dynamics Reliability Panel, Canadair Ltd., Montreal, Quebec, Canada, September 1, 1960)

PURPOSE: To show that reliability cannot be considered by itself but must have economic justification.

ABSTRACT: The primary interest of a system user is the annual net Benefit he obtains from the complete man-machine system. This Benefit is the annual Worth of his use of the system, minus the annual Cost of having and using the system.

System and engineering design effort must be allocated according to potential Benefit development or improvement. This is so obvious that it is often dismissed as "done intuitively." But for complex systems intuition can be far from adequate. Anything less than analytical design for best Benefit leaves the producer wide open to competitive design that provides far better Benefit.

Management allocation of funds, whether to projects or functional groups, must be identically guided. Management support on any other basis inhibits profit, growth, and even survival. Reliability improvement effort therefore must compete with other kinds of design improvement, according to potential user Benefit. Pure "reliability improvement" is not much of a justification to Management. But predictable user Benefit in annual savings, resulting from reliability improvement, cannot be ignored. If such Benefit can compete with that from other investments, it will have full Management support. (Author)

REVIEW: The paper presents a mathematical model approach for evaluating the benefit of a system to a user. The model is implicitly assumed on the basis of logic to represent reality. Economic considerations are important and this paper gives a simplified approach to them. The adequacy of this approach is not known.

In a private communication the author has called attention to a later, somewhat expanded version of this article, cited in the reference below.

REFERENCE: E. S. Winlund, "System evaluation for economic reliability," 5 pp., presented at the 1962 National Winter Convention on Military Electronics, Los Angeles, February 9, 1962. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: KEWB--A radiation burst test facility

AUTHORS: J. W. Flora and R. K. Stitt, Atomics International, a division of North American Aviation, Inc., Canoga Park, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, May, 1962, pp. 4-8 (presented at the 1961 IRE WESCON Convention)

This paper was covered by Abstract and Review Serial Number 89.
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Codes 822;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A computer application to reliable circuit design

AUTHOR: Leo Hellerman, Data Systems Division, Development Laboratories, International Business Machines Corporation, Poughkeepsie, New York

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, May, 1962, pp. 9-18

PURPOSE: To show how a computer is used in a Monte Carlo process for the analysis and modification of circuit design.

ABSTRACT: The problem is to estimate the distribution of values of the performance of a circuit as determined by the distributions of values of the component parameters in the circuit. Before the advent of high-speed computers, the solution was virtually impossible to calculate in most cases. The Monte Carlo method of calculation is simple, but rather long. It is the one to be described here. First, a mathematical model of the circuit performance, amenable to insertion into the computer, must be available. If there are several performance criteria, there must be a model for each. The component parameter distributions may be estimated from a few measurements. Uniform distributions are often used, though the method and computer program allow for the specification of arbitrary distributions. A random variable is associated with each component of the circuit. Now the performance of a randomly "put together" circuit can be calculated. This is repeated for as many random circuits as desired. The accuracy of the distribution estimation improves with more trials. Several examples are given of the method, including one where the nominal value of a critical parameter is adjusted, by the computer (program), to give good circuit performance. In general, the tails of the performance distribution are of the most interest since they will contain the undesired performance values. The best circuit may be too expensive to find or to use so two criteria are used in design. (1) No circuit should have failures. (2) Of all the mutually dependent performance measures, one should be near failure.

Some details of the programming are given.

REVIEW: Once a model for performance and models for parameter distributions are available, this is a good technique to use. As the author says, it may be slow and expensive in complicated cases. Having performance models that are realistic may be more difficult than anticipated and is, by itself, a subject for investigation. The problem of performance vs. time drift of parameters is not explicitly covered here. Some of the drifts may be correlated somewhat and they must somehow be combined with initial tolerances. This paper is implicitly limited to completely uncorrelated parameters; such would be the case when initial performance only is desired. It is a clear exposition of the method and the author's company will undoubtedly be willing to furnish details on applications to specific problems. ##

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Serial Number 354
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A survey of applications of radioactivity to electronics

AUTHOR: A. J. Moses, Atomics International, a division of North American Aviation, Inc., Canoga Park, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, May, 1962, pp. 19-23 (presented at 1961 WESCON, San Francisco, California)

PURPOSE: To give examples of the use of radioactivity during the development, production, and testing of electronic components.

ABSTRACT: After a review of the nature of radioactivity and its detection, typical applications of radioactivity are presented in research, development and quality control with emphasis on the field of electronics.

Topics discussed include the efficiency of cleaning operations, determination of impurities in semiconductor materials, detection of leakage of air into sealed units, wear of relay contacts, isotopic dating of products, pre-ionization of gases, dissipation of electrostatic charges, location of hidden splices, and verification of installation of small components. (Author)

REVIEW: As indicated in the title, this is a survey of some illustrative topics. The non-expert should seek advice before using radioisotopes. While their proper use is no more hazardous than that of ordinary chemicals in most situations, the beginner may need advice on proper use. Caution should also be exercised on accelerated tests; there is usually no guarantee that initial trends are representative of overall performance. ##

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Serial Number 355
Codes 813;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Which road to satellite reliability

AUTHOR: Richard H. Myers, Manager, Reliability Assurance, Aerospace Group, Hughes Aircraft Company, Culver City, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, May, 1962, pp. 24-32 (presented at the 1961 American Society for Quality Control Convention, Philadelphia, Pennsylvania)

This paper was covered by Abstract and Review Serial Number 209.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On models for reliability prediction

AUTHOR: Richard S. Robins, Aerospace Corporation, El Segundo, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, May, 1962, pp. 33-43

PURPOSE: To review critically the general models for system reliability.

ABSTRACT: Reliability prediction has taken two directions; one is models for reliability as a function of time and the other is probability equations (will it work next time?) for go-no go situations.

The exponential law is a one-parameter function, and in spite of its simpleness, does reasonably well in many situations. The Weibull distribution has two parameters and thus is more likely to give a better fit to the data. The physical basis for these models is rather shaky, but they are reasonably tractable for statisticians. The gamma distribution has been used elsewhere and so is familiar to theoreticians, who then see if it can be applied to the reliability problem. The normal, log-normal and truncated versions of either have an enormous background. They are two-parameter models and so can be fitted to many situations. The use of any one of these is usually accompanied by general plausibility arguments rather than firm physical reasoning.

The problems of switching networks have been treated with some rather powerful mathematical methods and important models have been derived. Many switching circuits behave differently when going going "on" than when going "off;" the problem of balance of the on/off situation has been theoretically solved but without a guarantee of practical engineering simplicity.

The engineering art of predicting reliability is fairly well developed, but the scientific theory has a long way to go. Good data are becoming available within reasonable times. The area between lifetimes and single-shot approaches contains room for development. The specific physical basis of failure and the natures of intermittency and interaction need to be explored thoroughly and deeply.

REVIEW: This is a good critique of the general models being used for reliability predictions. There are 35 references for documentation purposes; they may also be useful for more detailed study. The problem of accelerated testing and reliability prediction therefrom was not mentioned, perhaps intentionally. This paper, while it contains no specific design information, can give the design engineer some philosophy and background for his reliability problems. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving the reliability of digital devices with redundancy: An application of decision theory

AUTHOR: Edward J. Farrell, Remington Rand Univac, Division of the Sperry Rand Corporation, Univac Park, St. Paul, Minnesota

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, May, 1962, pp. 44-50

PURPOSE: To obtain the optimum design of a decision element for use in a computer system made up of redundant subsystems.

ABSTRACT: The reliability of complex digital systems can be increased by increasing the reliability of the components of the system or by inserting redundant components into the system. Since it is often prohibitively expensive to obtain successively higher levels of component reliability, inserting redundant components may be the only reasonable way to satisfy future digital system requirements.

The reliability of a given computer subsystem may be improved by adding redundant subsystems of the same sort having the same inputs, and entering the several outputs into a decision element designed to produce the, most probably, correct final output. This paper deals with designing the decision element.

The optimum design is obtained for several different types of systems. The decision element that maximizes the "reliability" is derived when the a priori probabilities of various outputs are known and when they are unknown. The optimum element is unique when the a priori probability is unknown. (Author)

REVIEW: This is a mathematical paper which deals with the derivation of decision rules that will maximize the average utility of the outputs in the cases considered. As such, it will be of more interest to the theorist than to the design engineer.

The paper includes a bibliography of some 22 works on redundancy, which may prove useful to those working in this area. ##

Serial Number 358
Codes 761;816;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: High reliability through control of procurement and vendor surveillance

AUTHORS: R. G. Stenecker and B. Ford, American Bosch Arma Corporation, Arma Division, Garden City, New York

SOURCE: Industrial Electronic Distribution, vol. 2, March, 1962, pp. 20-22

PURPOSE: To describe how Arma uses vendor controls in their reliability program.

ABSTRACT: High reliability is as much a problem of vendor controls as it is of design. Many parts are purchased rather than made in-plant and their quality/reliability must be maintained. Many MIL specs are not strict enough, nor are the vendors' own quality requirements. This paper details the purchasing and inspection procedures that Arma uses for their Inertial Guidance Systems. In order to compare lots, progressively higher testing stresses are used until at least some failures are obtained. Screening, by applying tests which are not detrimental to normal units, will weed out potential defectives; these tests are usually done on 100% of the units.

REVIEW: Each one of the phases in producing high reliability equipment is necessary, but no one is sufficient. Usually design is listed as the limiting factor, but actually all the phases are limiting. The product can be no better than that allowed in each step: design, purchasing, production, etc. This paper does bring out the need for designers to specify properly and completely what they need. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design trends in L.F. plugs and sockets for electronic equipment

AUTHOR: S. C. Schuler, Royal Radar Establishment (England)

SOURCE: Radio & Electronic Components, vol. 3, pp. 493-497, June, 1962

PURPOSE: To present some history of connectors and their present day reliable forms.

ABSTRACT: The stringent environmental and reliability requirements associated with modern civil aviation, military and professional electronic equipment have led to some important changes in connector (plug and socket) design. This article reviews some connector designs with high-temperature resilient insert materials and removable crimped contacts, which have an improved performance over conventional connectors with rigid inserts and soldered contacts. An outline is given of the general-purpose connector types which are currently being standardized for Defence Electronic purposes.

The use of resilient insert materials in the connector designs reviewed permit reliable operation over a wide range of temperatures. High insulation resistance after prolonged humidity exposure, improved moisture sealing and voltage ratings are other useful features. These aspects, together with small physical size, represent a notable advance in plug and socket design.

The crimping of wires on contacts instead of soldering has several advantages. Crimping reduces wiring costs, and little skill is required to make a fully-reliable joint.

With this type of connector, the crimping operation and final assembly of the contacts into the connector is made by the equipment manufacturer. Since it is difficult to check for voltage proof, contact alignment and sealing on the completed connector at this stage, it is important that rigorous inspection procedures and quality control are applied to contacts and connector bodies by the connector manufacturer. Careful attention to detail in the use of tools for insertion and withdrawal of contacts by the equipment manufacturer is essential if a high standard of reliability is to be achieved. (Author)

REVIEW: This article gives a quick once-over of the multipin connector field. It is excellent for background material, but is not suitable for design information. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The use of triple-modular redundancy to improve computer reliability

AUTHORS: R. E. Lyons and W. Vanderkulk, International Business Machines Corporation

SOURCE: IBM Journal of Research and Development, vol. 6, April, 1962, pp. 200-209

PURPOSE: To describe and to give examples of the use of a particular kind of majority-voting logic.

ABSTRACT: In triple redundancy a voting circuit compares the output of three circuits which are nominally the same. The output of the voting circuit corresponds to that of the two or three inputs which are the same. The voting circuit (V) is not redundant. In triple-modular redundancy (TMR) the V's are triplicated also. In either of these two types of circuits, the best improvement occurs when the circuits are rather reliable in themselves. For a given reliability of a non-redundant non-voting system (R_o) the overall reliability can be improved to any desired degree by making the voting modules small enough. If the voting circuit reliability (R_v) is less than one, there is an optimum number of subdivisions of the computer which is $\ln R_o/\ln R_v$. In the case of constant failure rates for the modules and under fairly general assumptions, the subdivisions should be of such size that their reliability is the same as R_v. For maximum reliability, this will multiply the non-redundant computer size by six. The reliability curve is fairly flat near the maximum so that using modules twice the optimum size increases the unreliability by 12.5%.

Under some conditions, such as a timing generator (very reliable) which feeds many circuits, it may be better not to use the TMR concept. Some examples are worked out.

A Monte Carlo solution for the reliability of a computer using various degrees of TMR is described and the results are shown in graphical form.

REVIEW: This is an excellent and rather complete basic treatment of this design concept. It is probably not yet in suitable form for the ordinary circuit design engineer, but should be of interest to him. One limitation is that the reliability of a circuit is assumed to be independent of the fan-out or fan-in; this will not be true in general, especially for drift failures. The examples are probably limited, implicitly, to catastrophic failures. This is a theoretical rather than a "practical" paper. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimate of space-radiation effects on satellite solar-cell power supplies

AUTHORS: J. M. Denney, R. G. Downing, S. R. Lackman, and J. W. Oliver, Space Technology Laboratories, Incorporated, Los Angeles, California

SOURCE: IRE Transactions on Military Electronics, vol. MIL-6, pp. 14-20, January, 1962

PURPOSE: To combine a theoretical treatment and experimental laboratory results so that degradation effects in solar cells can be predicted.

ABSTRACT: The charged-particle intensity and energy distribution at the heart of the inner and outer Van Allen belts is compared with the experimentally determined radiation sensitivity of silicon solar cells. Energy dependence of the radiation damage and solar-cell characteristics is included in the lifetime estimate of spacecraft solar cells. Use of charged-particle range-energy relations and the differential intensity of the Van Allen radiation results in an estimated effectiveness of thin protective shields. Comparative advantages of thin shields, advanced cell designs, solar efficiency, and solar-cell system over-design are discussed with respect to radiation resistance of spacecraft power supplies. (Authors)

The primary cause of radiation damage is the reduction of minority carrier lifetime in the base cell-material. Present theory implies that the reduced lifetime is due, in turn, to the introduction of recombination centers by the point defects which are produced in the scattering process. The results of the theoretical analysis and experimental observations are self-consistent. Shielding can improve the radiation resistance somewhat, but the same weight might also be used for more solar cells. A considerable number of trade-offs are feasible in cell selection and shielding. Some types of cells, initially less sensitive, have better life characteristics.

Radiation damage in solar cells is usually of concern, but cells with increased efficiency and radiation resistance can be anticipated.

REVIEW: This paper gives some background on solar-cell degradation. It contains little design information, as such, but does convey a considerable understanding of the problems involved. ##

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Serial Number 362
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Slicing the pie

AUTHOR: J. A. Barker, Capt., USN, Department of the Navy, Washington, D. C.

SOURCE: Industrial Quality Control, vol. 18, June, 1962, pp. 4-6 (presented at 15th Annual ASQC Convention, Philadelphia, Pennsylvania, June, 1961)

PURPOSE: To emphasize the dependence of reliability on people.

ABSTRACT: Reliability is being included, quantitatively, in the design, manufacture, and procurement of equipment. The demonstration of this reliability is fairly expensive, especially for very complex, small-quantity equipments. In this case, indirect means are used to evaluate the reliability instead of, or in addition to, direct measurement. It is important that our ability to estimate be improved. Some ways of doing this are to adhere to voluntary or specified guide lines in management, design, production, and testing. In all of these aspects, the reliability of the people is paramount, and we need to know what makes these people do good or poor jobs. There must be sound organization, a good physical and procedural environment, an analysis of product interfaces, and proper recommendations of implications of changes or new things.

"The procurement dollar is often presented as a pie, ... In cutting a slice for reliability, particularly for the low volume, long MTBF products, there must be a share saved for those areas that are important to improvement in the reliability of the people creating the product."

REVIEW: One of the most important problems in reliability today is how to predict the effect of an action now on the actual reliability of a product. Demonstration of reliability usually assumes that there is no prior knowledge of the reliability. Obviously, this is rarely the case, or the equipment could not have been properly built. The reliability of people does have a measurable effect on quantitative reliability if only we knew what to measure and how to measure it. ##

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Serial Number 363
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Controlling inspection for better quality and improved reliability

AUTHOR: Harold L. Gilmore, Research and Advanced Development Division, AVCO Corporation, Wilmington, Massachusetts

SOURCE: Industrial Quality Control, vol. 19, July, 1962, pp. 7-9

PURPOSE: To show how the Westinghouse Electronics Division runs its inspection system.

ABSTRACT: The first step is to plan the inspection and test. What is to be tested, the defects to be looked for, the relative importance of defects, an acceptable quality level, inspection and test procedures are all carefully planned and furnished in written and visual form to the inspectors. The instruments they use are maintained accurate by a conventional setup of identifying each one and being sure it is calibrated at prescribed intervals. A final group analyzes the records. This is one of the tasks of the reliability group. They can then make recommendations to improve the product quality if that should be feasible. This group calculates costs of defectives, etc., so as to present data of maximum usefulness.

REVIEW: The article describes what, hopefully, is a reasonably standard type of inspection philosophy where high reliability is necessary.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: What to know about severe environmental potentiometer applications

AUTHOR: John Arnold, Borg Equipment Division, Amphenol-Borg Electronic Corporation, Janesville, Wisconsin

SOURCE: Electronic Industries, vol. 21, March, 1962, pp. 92-94

PURPOSE: To describe the environmental resistance capabilities of present potentiometers.

ABSTRACT: Today's potentiometers can withstand more severe environments than those of ten years ago. Temperatures of standard units can go to 125°C and up to 175°C. The power dissipation must be taken into account along with the heat-transfer ability of the mounting method. Vibration, acceleration and shock resistance have been improved. Vibration frequencies are 10 to 20 kc with 20 g acceleration. Shock is up to 100 g in some cases. Acceleration requirements of 50 g to 100 g are common. The main problem is to maintain electrical contact during exposure. This is accomplished by proper design. Humidity and moisture tests can be steady state or cycling. They accelerate corrosion, insulation deterioration, moisture condensation and electrolysis (when dc voltage is present).

The reliability problems are mainly infant mortality. The service life is followed by wearout and most units that survive infancy will have a wearout failure. This behavior allows a burn-in type of processing to insure very reliable potentiometers.

REVIEW: This is intended to be a tutorial article, sponsored by the Precision Potentiometer Manufacturers Association. It does give some background for the understanding of reliability problems, but it lacks concrete application data that might be of direct use to a designer. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Must all packages be welded?

AUTHORS: Joseph Ritter and David J. Houck, Electronic Modules Corporation, Timonium, Maryland

SOURCE: Electronic Design, vol. 10, March 15, 1962, pp. 78-81

PURPOSE: To defend soldering against the attacks of "welders."

ABSTRACT: There is a trend in some circles to blithely assume that welding is the best way to join modules and there is considerable propaganda to this effect. The contention is not correct as this article is to demonstrate.

Reliability is of prime concern. Most of the claims for welding are based on mechanical strength and extrapolated reasoning. In a potted circuit, the mechanical strength needs only to be adequate. The potting prevents fatigue. Improved developments in components, their leads, and soldering methods have eliminated the heat problem. If proper fluxes are used, there is no corrosion problem. In welding, a bare copper wire may be attacked by some hardening agents in the potting compound.

The electrical performance of a soldered joint is as good or better than the welded. Even though solder has a high resistivity, the geometry is such that the resistance is low. The control of either process is a matter of proper attention to details; either can produce poor or good results. Soldering seems more amenable to semi-automated techniques. Soldered joints can be looked at to see if they are good; welded joints must be destructively tested.

Welded modules have the potential for a slightly greater density, but in practice either is as good as the other when all things are considered. The same is true for the weight advantage.

A soldered package may well be more economical and any production changes in it are likely to be easier to make.

REVIEW: This is another paper in the current controversy of soldering vs. welding. The points seem to be well made. A general conclusion so far seems to be that reliability is limited more by the care taken in design and production than by the "inherent" reliability of either soldering or welding. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designer's check list for reliable transistor circuits

AUTHORS: Arthur Murphy and Robert Liggett, Motorola, Incorporated, Scottsdale, Arizona

SOURCE: Electronic Design, vol. 10, March 29, pp. 40-43; April 12, pp. 52-55; April 26, pp. 62-65; May 10, pp. 66-69; May 24, pp. 82-85 (1962)

PURPOSE: To provide check lists for designers of various kinds of transistor circuits so that they do not miss a vital factor affecting the circuit reliability.

ABSTRACT: The article is in five parts as shown above. The titles are:

1. Parameter variations and safety margins--March 29
2. Broadband IF and UHF Oscillator circuits--April 12
3. Counting multivibrators and blocking oscillators--April 26
4. Audio and video amplifiers--May 10
5. Series regulators and inverters--May 24.

The basic problem with the designing of transistor vs. tube circuits is that the transistors are much less predictable than tubes. The parameters which are not mentioned on transistor data sheets are subject to unknown preselections. The parameters which are guaranteed (as well as those which are not) have drifts with temperature and time and these are not known very well either in direction or in magnitude. A table lists the variations which may be expected (consensus of transistor circuit designers). Very roughly, one must allow a factor of two in the worst direction for any minimum or maximum rated value. The circuits need to be designed to operate under these extreme variations. For maximum reliability, the transistor should be derated, especially for voltage. Breadboard tests should be provided for worst case situations. If the proposed circuit cannot function with the proposed safety margins, several courses are open, the safest of which is a redesign of the circuit.

A list of seven design features and two test procedures are given for IF circuits. The key transistor parameters and their safety margins are listed. Similar points are made for oscillator circuits.

A comparison of features of blocking oscillators vs. one-shot multivibrators is given for pulse generation. Again there is a brief listing, for each, of the design approach, the key transistor parameters, the safety margins for them and finally a few breadboard tests.

The final two articles give similar information for the topics listed.

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REVIEW: Of necessity, the treatment is rather brief for each type of circuit. The information will be of value to the circuit designer and he should reconcile any differences found with his own procedures. There is obviously a need for more standard circuits, with safety margins listed, so that there is not so much repetition every time a different person designs a similar circuit. No mention is made of the possible adverse system consequences of worst case design. These might be, for example, (1) increased number of stages, (2) increased power dissipation, (3) greater chance for catastrophic failure, and (4) larger size and weight. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Try feedback for better failure reports

AUTHOR: Sidney A. Greenberg, The Mitre Corporation, Lexington, Massachusetts

SOURCE: Electronic Design, vol. 10, July 19, 1962, pp. 58-61

PURPOSE: To suggest that field service people be informed about actions taken on their failure reports.

ABSTRACT: When there were much fewer electronic equipments in service, the field reporting was fairly well under control. Today, failure reporting is even more important, but most everyone seems to have trouble with it. Various kinds of simplified forms have not solved the problem. A new approach is to consistently and routinely inform the field service man of the action taken on his report. Field service reporting is likened to a communications system in which feedback from output to input can improve the system. The report form illustrated here is traditional for the field service "filling-in." The form provides for routing the repaired part (or information about the part) back to the originator. The final copy goes to the reliability group. It is expected that the quality of field reporting will improve under this system.

REVIEW: Field service reporting is a real problem. The paper mentions that the serviceman feels that many times his reports are ignored. Unfortunately, this is probably true in many cases (with or without good reason for the non-attention). If this system will encourage the submitting of meaningful reports and encourage their study, it will certainly be a big contribution to the reliability program.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Locating intermittent failures with vibration testing

AUTHOR: Norton J. Levenson, Westinghouse Air Arm Division, Baltimore, Maryland

SOURCE: Electronic Design, vol. 10, July 19, 1962, pp. 80-83

PURPOSE: To describe a method of weeding out potential failures in printed circuit boards.

ABSTRACT: Intermittent failures are difficult to find. The intermittents in an airborne digital data processor were successfully found by vibrating the boards in the proper way. The vibration spectrum should not cause failures and should find the existing intermittents; some means must be available for distinguishing between the two. Good circuit boards were selected and tested in the proposed spectrum (0.01 g^2/cps, over a range from 20 cps to 20 kc). They were found to be good during and after the test. One hundred boards were then tested after being carefully resoldered; 39 modules showed malfunction during the test. There were 31 failures (13 boards showed no failure on the bench): ten solder connections (transistor leads), 13 internal diode shorts, four transistors with open base, three broken resistors, one unknown. Close examination suggested that no failures were caused by the test. A very significant improvement was noted in the MTBF.

REVIEW: It would have been helpful if the actual improvement in MTBF were indicated. While this method is not new, case histories are helpful to other engineers who are interested in reducing the number of potential failures. A more rigorous conclusion about the test not harming the boards might be that any reduction in life caused by the vibration was not detectable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Beware: fallacies in life testing

AUTHOR: F. F. Yanikoski, Sigma Instruments, Incorporated, South Braintree, 85, Massachusetts

SOURCE: Industrial Electronic Distribution, vol. 2, July, 1962, p. 7

PURPOSE: To point out some of the problems in the life testing of relays.

ABSTRACT: Laboratory tests, sometimes accelerated, are often used to decide which relay to use. But care must be taken because a nominally accelerated test may actually be a decelerated one. Where possible, the tests should be run under actual operating conditions. Some points to watch out for are:

1. Cycling rate: Temperatures reached by the relay parts, especially the coil, are important and they may vary with cycling rate. The rate also affects the build-up of gases at the contacts. If arcing occurs, the contacts will have longer life if they are allowed to cool. Sticking is greatly affected by cycling rate.
2. Temperature tests: The relays should be mounted on heat sinks and the temperature of the sink taken as the ambient. If relays are not hermetically sealed, the atmosphere may contaminate the contacts.
3. Humidity: High humidity may increase life by improving lubrication.
4. Mounting position: It should be such that debris will fall off the contacts.
5. Voltage overdrive: The use of a high impedance source can shorten life because the voltage overdrive results in quicker, more violent contact action.
6. Coil voltage: Low coil voltages are used to check sensitivity of the relay, but high voltages should also be used to test for coil deterioration due to heating.
7. Load inductance: Relay contacts normally have a non-inductive rating. If inductive tests are run, the circuit should be carefully analyzed to be sure the desired effects are actually being obtained.

REVIEW: This article, while about relays specifically, is a good reminder that life testing under "artificial" conditions can be very tricky. The cautions about relays seem very appropriate and those concerned with relay testing will want to heed them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Wide application of AGREE testing seen

AUTHOR: (Editorial Matter)

SOURCE: Industrial Electronic Distribution, vol. 2, July, 1962, p. 13

PURPOSE: To describe briefly the nature of AGREE testing.

ABSTRACT: Before building equipment to be processed under AGREE tests, the producer should thoroughly understand the four principles involved.

1. Statistically efficient tests must be used to reduce time and costs.

2. All test data must be carefully recorded and available to the customer.

3. All failures must be thoroughly analyzed to determine their causes. They must be traced to a chemical, physical, design or workmanship origin or, possibly, a test equipment/operator failure.

4. Corrective action must be taken before the test can continue. This results in a continual upgrading of the product.

REVIEW: This is a non-technical discussion of the philosophy, principles, and problems of AGREE testing. It will be valuable to those not familiar with these requirements. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life test sampling plans for normal and lognormal distributions

AUTHOR: Shanti S. Gupta, Bell Telephone Laboratories, Incorporated, Allentown, Pennsylvania

SOURCE: Technometrics, vol. 4, pp. 151-175, May, 1962

PURPOSE: To present sampling plans for truncated life tests from the normal and lognormal distributions.

ABSTRACT: Sampling plans for truncated life tests from the normal and lognormal distributions are obtained. The tables of this paper give the minimum sample size necessary to assure a certain mean or median life when the experiment time is fixed in advance. The modification necessary to assure any other quantile (percentile) of the distributions is obtained. Thus, sampling plans for establishing other percentiles of the distributions are shown to be obtainable from the tables of this paper. The operating characteristic functions of these plans are obtained and for a wide range of values of practical interest these functions are graphed in order to facilitate selection of an appropriate plan in a given situation. Producer's risk is discussed and a table is given for the ratio of the true median life to the specified median life (or the difference between the true mean life and the specified mean life) to insure that the producer's risk does not exceed α = .10, .05. An approximation is given for the minimum sample size. The use of tables and graphs is illustrated by examples. (Author)

REVIEW: This paper will be of value to engineers and statisticians concerned with designing or evaluating sampling plans for life testing. The plans are of an attribute type, and their orientation relative to similar plans for other distributions is indicated. Twelve pertinent references are cited.

A related paper based on the gamma distribution was covered by Abstract and Review Serial Number 157. Papers dealing with sampling plans based on the Weibull distribution were covered by Abstracts and Reviews Serial Numbers 46, 202, and 208. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A general model for the reliability analysis of systems under various preventive maintenance policies

AUTHOR: B. J. Flehinger, IBM Thomas J. Watson, Research Center

SOURCE: The Annals of Mathematical Statistics, vol. 33, pp. 137-156, March, 1962

PURPOSE: To present a general model for predicting the reliability of a system from data on components, when certain maintenance policies are in effect.

ABSTRACT: The problem treated is that of predicting the reliability characteristics of a complex system from data on individual components. A general model for systems maintained over a period of time is proposed, based on the idea that every system failure is induced by a component failure and corrected by the replacement of a single component. Moreover, it is assumed that components are sometimes replaced even when the system is operating correctly, in order to prevent unscheduled interruptions in operation. The assumptions which define the general model cover a number of different preventive maintenance policies, among them the following:

(a) Block Changes: All components of a given type are replaced simultaneously, at times determined by a renewal process.

(b) Individual Component Replacement on the Basis of Age: If a component reaches some given age without failing, it is preventively replaced.

(c) System Check-Outs: If a component is used only intermittently and it fails while it is not being used, it does not induce a system failure until it is called into use. At regular intervals, those components which have failed without inducing system failure are located and replaced.

(d) Marginal Testing: At regular intervals, a test is conducted to locate those components which are still operating satisfactorily but which are expected to fail in the near future. All components located by this test are replaced.

It is assumed that preventive removals are regeneration points and that the performance of a component may be described by a distribution function $F(x:y)$, the probability that a component is removed by time x, given that it enters the system at y, where x and y are both measured from the time of the last preventive removal. $F(x:y)$ is the sum of $A(x:y)$ and $B(x:y)$, where $A(x:y)$ is the probability that the component is preventively removed by x and $B(x:y)$ is the probability that the component induces a system failure by x. The integral equations which determine the following measures of system performance from $F(x:y)$, $A(x:y)$, and $B(x:y)$ are developed:

(1) the expected number of failures in a given time interval

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

(2) the expected number of preventive removals in a given time interval

(3) the reliability function; i.e., the probability of no failure in a given interval following a given system age.

Results from Renewal Theory and the Theory of Regenerative Stochastic Processes, developed by W. L. Smith, are applied to the problem of exploring the asymptotic behavior of these quantities.

Conditions sufficient for maintenance policies a, b, c, and d to meet the assumptions of the general model are precisely formulated, and the analysis necessary to derive F(x:y), A(x:y), and B(x:y) is carried out for each policy. (Author)

REVIEW: This paper is a contribution to the mathematical theory applicable to the prediction of the reliability of complex systems from data on individual components. The proposed model takes into account a number of factors for which allowance was not made in the models previously available. These factors include the changes in component survival probability with age, the effects of preventive maintenance procedures, and the effects of intermittent component usage. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A Markovian model for the analysis of the effects of marginal testing on system reliability

AUTHOR: Betty J. Flehinger, IBM Thomas J. Watson Research Center

SOURCE: The Annals of Mathematical Statistics, vol. 33, pp. 754-766, June, 1962

PURPOSE: To formulate and analyze a particular model of a system subject to marginal testing.

ABSTRACT: In a previous paper (see Abstract and Review Serial Number 372), the author postulates and analyzes a general model for the reliability analysis of systems under various preventive maintenance policies. The integral equations that determine the expected number of failures, the expected number of preventive removals, and the survival probability function are developed. In the present paper, a particular model of a system subject to marginal testing is considered and explicit values of these performance measures are obtained.

Under a marginal testing policy, the system is maintained in operating condition by replacing all failed components as soon as they fail and, at regular intervals, conducting a test to locate those components which are still operating satisfactorily but which are expected to fail in the near future. All components located by this test are replaced.

In this model, it is assumed that a component may be in any one of $n + 1$ states, $0, 1, \ldots, n$, and, during normal operation, these states constitute a continuous-parameter Markov process in which state n is the failed state. When a component enters state n, it is immediately replaced by one in state 0. The marginal test detects the state and states $k, k + 1, \ldots, n - 1$ are considered marginal. The test is performed at fixed intervals, and, if a component is found in the marginal state, it is replaced by one in state 0.

Since this model provides for transitions from any operative state to any other state, recovery from the marginal state to the good state is permitted, a characteristic which was not allowed in the model of the previous paper cited above. In addition, a choice of the level at which the component is considered marginal is permitted. The loss of generality lies in the assumption that the process is Markovian. As in the previous paper, it is assumed that there is no dependence between transitions in different component positions and that every system failure is corrected by the replacement of one component, so that the problem of determining system performance measures is reduced to the problem of determin-

ing the corresponding quantities for a single component position. (Author in part)

REVIEW: This paper extends the work of the one covered by Abstract and Review Serial Number 372. It provides a mathematical model for a system maintained in operating condition by immediate replacement of failed components and periodic marginal tests. In these papers, relatively sophisticated mathematical techniques are brought to bear on a problem of current interest in reliability, namely that of predicting system reliability from data on components. ##

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Codes 771;783;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interpreting MIL Specs for system reliability--Part V: Environmental tests

AUTHOR: Anthony J. Finocchi, Director of Reliability Engineering, ITT Federal Laboratories, Nutley, New Jersey

SOURCE: Electronic Products Magazine, vol. 5, June, 1962, pp. 44-48

PURPOSE: To give an idea of the complexity and scope of MIL environmental tests.

ABSTRACT: Environmental tests can be both expensive and time-consuming. As an example a small piece of gear may have a $28,000 cost for environmental testing over a period of four to nine weeks if nothing goes wrong. If failures do occur, the costs and time can be expected to double. The headings under which the topics are discussed are: Testing time, Design parameters for ground equipment, Vibration and shock tests, Comprehensive specification, Temperature tests, Humidity, Altitude, Salt fog, Vibration tests, Fungus resistance tests, Sunshine resistance test, Artificial rain tests, Sand and dust tests, Explosion proofing, Shock tests, and Cost of tests.

There are four tables which list the major specs in each category, but are far from complete. The categories are Shock and Vibration; Radio Interference; Altitude, temperature and humidity; and Dust, explosion, fungus, rain, salt spray, sand, sunshine, and wind.

REVIEW: This is the fifth paper in a series, the first four of which were covered by Abstracts and Reviews Serial Numbers 218, 251, 252, and 342. It is a good introduction to the myriad problems of MIL Specs for environmental tests for the beginner in this area. It does not claim to be complete, but many references are given. The non-beginner may also find the article helpful. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Detecting fatigue cracks in notched fatigue specimens by changes in electrical resistance

AUTHORS: J. O. Lyst and C. F. Babilon, Alcoa Research Laboratories, New Kensington, Pennsylvania

SOURCE: Materials Research & Standards, vol. 2, pp. 485-489, June, 1962

PURPOSE: To describe an electrical resistance method of detecting fatigue cracks and to study crack propagation using this method.

ABSTRACT: The electrical-resistance method of crack detection permits the analysis of some interesting features of crack initiation and propagation. The crack depth and change in resistance are dependent upon stress level and number of cycles of stress. The change in resistance and crack area or crack depth increase with the percentage increase in normal life consumed in the test. This method of crack detection is sensitive enough to differentiate between cracks which are about one third as deep as those observed by the authors' earlier method. It can be depended upon to detect cracks in 0.330-in. diameter specimens as small as 0.005 in. deep, or changes in resistance as small as 2.5 per cent.

Fatigue cracks propagated slowly until the crack area covered about 5 per cent of the cross-sectional area, after which the rate of propagation increased rapidly to failure. All specimens after testing were found to have cracks at the base of the notch. These cracks ranged in severity from very small to almost complete failure, depending upon both the applied stress and the percentage of normal life. (Authors)

The resistance measurements ranged from 4 to 7 microhms for the notched specimens machined from 7075-T6 rod. The indicated change in resistances ranged from zero to 3 microhms. A Leeds and Northrup Type K-3 potentiometer, a very sensitive galvonometer and a standard (0.001 ohm) resistor were used to measure the resistance.

REVIEW: This seems to be a very careful piece of work and the curves show a good correlation between the crack area and the resistance change. It is obviously intended for laboratory work rather than field monitoring. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Ball-bearing survival

AUTHOR: Eugene Shube, Chief Mechanical Engineer, Dorne and Margolin Incorporated, Westbury, Long Island, New York

SOURCE: Machine Design, vol. 34, July 19, 1962, pp. 158-161

PURPOSE: To show how to calculate bearing life as a function of survival probability.

ABSTRACT: The life of a bearing (10% failures) is inversely proportional to the cube of the load. Ball bearings are always assumed to fail in fatigue and the spread in life is rather large. The constant failure rate law does not apply for bearings; the Weibull distribution must be used. Manufacturers of bearings give the "10% failure" life. If the Weibull curve is to be calculated, one other point must be known since there are two parameters to determine. The median life (50% failures) is usually assumed to be five times the 10% failure life. Some actual experiments showed an average of 4.08 instead of 5. Using these two points, the parameters of the distribution can be calculated, or the curve (straight line) can be drawn on the special "Weibull" graph paper. Once this is done, it is a simple matter to calculate the fraction of bearings failed for any desired life time. (Some calculations and examples are given.)

REVIEW: The actual arithmetic in this paper seems to be correct, but a novice in the field might get some erroneous ideas about the use of statistics. The use of the factor 4.08 (given to three significant figures) implies a precision which is probably not present. It is apparently an average of several numbers which might have had a wide spread. The assertion that there is no 0% or 100% failure point refers to the mathematical model (i.e. the Weibull distribution); how well bearings follow this model is something else again. (Although the two-parameter Weibull distribution has been universally accepted by the bearing industry, in many bearing tests there are so few points that a distribution such as the lognormal may fit the data as well.) Care should be taken in extrapolating very far from the region in which the manufacturer actually made his tests. The procedures outlined here are good for very casual estimates. More sophisticated comparison of the model with reality should be made if specifications are involved. ##

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Serial Number 377
Code 835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Printed-circuit failures

AUTHOR: R. P. Noble and N. J. Eich, Sandia Corporation, Sandia Base, Albuquerque, New Mexico

SOURCE: Machine Design, vol. 34, July 19, 1962, pp. 169-175

PURPOSE: To point out the problems that can arise in the manufacture of printed-circuit boards.

ABSTRACT: Printed-circuit boards can be made poorly like anything else. If so, they will have a short life. The designer and specifier of production procedures play very important roles.

Imperfections such as fissures, resin starvation and resin deterioration in the boards will cause contamination problems. Lubricants must not be used during machining since they cannot be removed. Resin-alcohol flux must be thoroughly removed. The boards should be stored and shipped in heat-sealed polyethylene bags.

Poor definition and undercutting of the conductors are both bad if present in excess. The conductor surfaces should be very smooth for switch plates or connectors and fairly smooth for ordinary applications. Poor dip soldering may cause voltage flashover. The conductor must be well bonded to the substrate, both for strength and for heat transfer.

Plated-through holes and eyelet connections should be done in certain ways (these are listed).

REVIEW: This is a good summary of some of the problems in the design and production of printed-circuit boards. The points made are very practical. The article is not intended to be all inclusive--many other problems can arise. The question of flux removal was hotly debated at one time--it may have since been resolved. ##

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Serial Number 378
Codes 711;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability challenge

AUTHOR: Robert B. Feuchtbaum, Hughes Aircraft Company, Culver City, California

SOURCE: Insulation, vol. 8, February, 1962, pp. 43-46

PURPOSE: To show how dielectrics must be tested in order to select the most reliable ones.

ABSTRACT: The failure of a dielectric insulation is the most important single cause of electronic equipment failure. The cost of complete knowledge of a dielectric is high, but the cost of guessing can be even higher. There are five categories in which knowledge is necessary.

1. Compatibility: The insulation must not corrode, contaminate or otherwise adversely affect the rest of the circuit.
2. Reactions to the environment: The effects of pressure, temperature, moisture, and other vapors and gases are the most important.
3. Interactions with the component or system: An example is the change in inductance of a magnetic system when the potting compound is influenced by temperature. Some components can be processed first with a foam, then potted more ruggedly.
4. Raw material control
5. Process control: Since this involves the willingness/ability of people to perform tasks properly, the workers and their supervision must have the necessary knowledge and motivations.

REVIEW: While the contention that dielectric insulation is the most important single cause of malfunction might be debatable, there is no question that insulation is very important and that it is taken for granted where it should not be. The admonition to the insulation industry to avoid extravagant claims and to give exact properties under many conditions is probably more than justified. The author states that his company is willing to share any information that it has. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Casting reliability (a series of seven articles)

SUBTITLES AND AUTHORS:

(1) What is reliability? Robert H. Herrmann, Associate Editor

(2) How to design reliable castings, John B. Caine, Foundry Consultant, Cincinnati, Ohio

(3) Quality control and reliability, Jack C. Miske, Associate Editor

(4) Prevent defects ... and you control quality, Dorian Shainin, Rath and Strong Incorporated, Management Consultants, Boston, Massachusetts

(5) Quality control leads to guaranteed castings, W. M. Dalton, President and J. J. Shellabarger, Vice President, Dalton Foundries Incorporated, Warsaw, Indiana

(6) How one foundry meets reliability standards, Lawrence S. Krueger, Works Manager, Pelton Steel Casting Company, Milwaukee, Wisconsin

(7) You can sell your quality control, T. E. Barlow, Foundry Sales Manager, Eastern Clay Products Department, International Minerals and Chemical Corporation, Skokie, Illinois

SOURCE: FOUNDRY, vol. 90, March, 1962, pp. 67-95

PURPOSE: To discuss the several facets of improving the reliability of castings.

ABSTRACT: (1) Reliability is the probability that a product will perform as intended for the required time under the specified conditions. If there are several factors contributing to the reliability, each one must have a higher reliability than the final desired figure. For example, 11 factors contribute to the reliability of a sand casting; these range from molding sand (95.0% rel.) to casting design (99.9% rel.). The net reliability is only 85.0%, by the statistical combination of reliabilities. Some customers are classifying foundries on the basis of their facilities and programs; bid requests, then, only go to properly qualified foundries. Some buyers are also expecting the foundry to certify the quality of its castings.

(2) There are two kinds of design objectives in a casting: The casting must be pourable without defects and the sound casting must not be so weak that it fails in service. These two requirements are generally compatible. Proper casting design can greatly ease the pouring problems, can reduce stress concentrations and can increase the fatigue life of the part. Sharp corners and the meeting of ribs are two of the most common causes for poor castings and for consequent failure. Many needless failures can be designed away by following a few simple rules. (The important rules are

discussed in the paper.)

(3) Quality control and reliability are related as mother and child; you cannot get the second without the first. Quality control regulates the materials and processes so that a part with long life is produced. There are a great many tests of the finished product which can be used to assure that the casting has the required properties which will assure the reliability. Destructive tests are sometimes necessary--especially during the research and development phases. Nondestructive tests (NDT) are usually less expensive and more effective for parts to be shipped. One can sell parts which were tested by NDT, but parts which are destroyed are scrap. Radiation by X and gamma rays is very common and effective. Magnetic particle inspection and dye penetrants are useful for finding surface cracks. Ultrasonic testing is newer and more tricky, but can be used.

(4) The causes of defects can be found by variation research. In this method, several variables are changed at the same time and the ones which cause the most change in the product can be determined. This can save time by eliminating from consideration those things which are causing little or no trouble. Important interactions between variables can also be shown up this way. The demand for parts of 99.995% reliability may be with us soon. The usual way of proving this number would require the testing of tens of thousands of pieces. By using the methods described here, this could be reduced to less than 100. The principle of the variability of strengths is used and the necessary safety factor is calculated. One way of narrowing a casting problem is to see if it is caused by within-casting variations, changes from casting to casting, or differences from time to time. Operator influences may also be important. (Several examples are given of the use of the variations method in a casting problem.)

(5) The Dalton Foundries are participating in a plan with Cummins Engine Company, and have extended it to other customers, in which an extended guarantee is given on each casting. If defects are revealed during machining, the foundry not only replaces the casting--as is usual--but also reimburses the customer for his machining costs. The foundry and customer agree on a small surcharge for each casting which will reflect the added cost for a certain quality level. If the foundry does better than this, it makes more profit and the customer gets better parts; so both gain. The foundry can use some of this money to improve its quality control even further. (The plan is discussed in more detail in the paper.)

(6) No quality/reliability program can be effective without the active support of all levels of management. Management must (1)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

want to improve quality, (2) provide necessary facilities and people for it, (3) insist on application of scientific research, (4) support supervisors and staff in their efforts, and (5) be willing to scrap poor quality castings. The appropriate charts have to be kept and action has to be taken to correct causes of poor quality when it occurs.

(7) More customers are requiring good quality and they expect to pay no more for it. Many people have found that good statistical quality control not only produces good products but that it more than pays for itself. Sources of high quality castings are hard to find--yet foundries go out of business for lack of customers. The competition is high and a customer can use a non-cast part to replace a cast one; many people are vying for his business.

REVIEW: This series of articles is generally good. A distinction is made in most of them between initial quality and reliability (quality during lifetime). While the whole of foundry practice cannot be covered in a short series, there is a good emphasis on the factors which might affect reliability. The statistics and probability theory used in the first and fourth articles contain assumptions which are not stated. Some of the assumptions seriously limit the validity of the applications. In the first paper, the probabilities are all assumed to be independent of one another. If they are not, the product rule does not apply and the method is incorrect. Some attention should have been paid to justifying the assumption.

In the fourth paper, the proving of very high reliabilities is discussed. A suggestion is made for reducing the amount of testing by a factor of 1000. The approach is presented as entirely rigorous and, indeed, it is, if the implicit assumption is true. This assumption is that the form of the distribution is known and, in this case, is "normal" or Gaussian. A discussion of this problem is also given in Abstract and Review Serial Number 131. Briefly, the difficulty is in proving that the actual distribution can be approximated by the desired one to the proper accuracy. This is most difficult in the tail region for less than 1% probability and virtually impossible in the tail region for less than 0.1% probability. To talk about using it at the 0.005% level without an enormous amount of testing is ridiculous. One can use the Chebyshev Inequality which says that the probability of an individual's being further than k standard deviations (on either side) from the true mean is less than $1/k^2$, but it is very weak compared to the usually-used Gaussian distribution properties. (To use it for the case of a probability less than 0.02% (0.01% on either side), one would need a safety margin of 100 standard deviations.) The concept of a safety margin which is measured in terms of a standard deviation is a good one. Design and development based on this safety margin concept will give much better results than the usual safety factor or guessing. The difficulty arises when one tries to make a quantitative estimate of the reliability that has been achieved in this way. It is strongly suggested that a competent statistician, or group of statisticians, be employed to advise on any statistical procedures. This is not meant to imply any criticism of the method of variation research; it is a good and useful tool. ##

Serial Number 380
Codes 833;852

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Comparison of field experience with accelerated life test on precision etch electrochemical transistors

AUTHORS: W. P. Cole and B. Zuckerman, Philco Corporation, Lansdale, Pennsylvania

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 68-80

PURPOSE: To compare transistor field experience with accelerated life tests.

ABSTRACT: Life data were collected both from the field (largely computer use) and from accelerated acceptance tests (used in production) on the transistor families represented by the 2N345, 2N393 and 2N501. Accelerated test failures (drift) occur when the current gain drops below, or the collector leakage current exceeds some preset limits. Several hundred failures in about 20 million transistor hours were reported for each type on life acceptance tests. The failure rates are plotted against temperature and seem to show the usual "chemical reaction rate" behavior. This would appear to confirm that the failures are governed by a chemical mechanism. The failure rates were extrapolated (point estimate) to 30^{o}C. These estimates are somewhat higher than field experience. This is believed mainly due to greater handling on life tests, to the elimination of debugging failures in field results and to the differences in failure criteria. Some acceptance tests for later batches show an appreciable improvement due to process changes.

About the best failure rate that can be expected is 0.002%/1000 hr. with proper design.

REVIEW: These data seem to show good agreement between storage and operating tests. As the defects are remedied and production processes are improved, this may no longer hold. Some evidence has been more recently claimed for that viewpoint. It should be remembered that the data were collected for transistors made in 1960; present day transistors, hopefully, are better. The restrictions on achieving a 0.002%/1000 hr. reliability should be firmly kept in mind for anyone trying to achieve this figure. The mathematical/statistical assumptions in the data analysis are not all given; for example, the type of failure distribution that is assumed is not known (although it was probably the Poisson or exponential since "transistor-hours" is treated as a parameter). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A study of optimized package content

AUTHOR: E. G. Shower, Sperry Semiconductor Division, Sperry Rand Corporation

SOURCE: Electrical Design News, vol. 7, July, 1962, pp. 60-65

PURPOSE: To discuss how one arrives at a means for deciding on an optimum size of a non-repairable electronic unit.

ABSTRACT: The advent of integrated circuitry brings with it the problem of the optimum size of the throwaway block or package. The answer is based on a series of tradeoffs which will involve the reliability of the assembly, the cost, the volume, and the power density. A few examples are given as to how these might apply to a configuration of NOR circuits in the arithmetic unit of a computer. Other circuits and systems might require different assumptions and the results might then also be different.

REVIEW: The assumptions made to illustrate the points are quite arbitrary, but the approach to the packaging size problem is pointed out. Not all possible variables are discussed, but the ones mentioned are important. Reliability and lifetime seem to be confused with each other. There is some confusion as to when the author is talking about conventional components and when about his company's proprietary products. The main value of the paper is to indicate a direction in which one might look to solve the "package-size" problem. ##

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Serial Number 382
Codes 810;833;834;
836;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Potential applications of reliability techniques in commercial product lines

AUTHOR: Richard M. Jacobs, Sylvania Electronic Systems (Eastern Operation), Waltham, Massachusetts

SOURCE: Industrial Quality Control, vol. 19, August, 1962, pp. 11-14 (presented at the 1961 Radio Fall Meeting of the Electronic Industries Association and the Institute of Radio Engineers, Syracuse, New York, October 30, 1961)

PURPOSE: To review briefly certain techniques which have potential applications in commercial reliability programs.

ABSTRACT: Reliability techniques which may be applicable in one form or another to commercial products include (1) Reliability prediction or estimates, (2) Maintenance prediction and study, (3) Component part selection, (4) Design of experiments, (5) Design reviews, and (6) Field data analyses. Each of these techniques is being used on products supplied to customers requiring a high level of reliability. They have been successful in providing long periods of failure-free operation at minimum cost. The paper lists the major advantages that each method appears to have in qualifying use on commercial product lines.

Prediction aids in determining warranty periods for products, as well as in deciding which of many designs are most applicable to a particular function. Maintenance analyses are essential in today's competitive electronic marketing functions. The importance of component part selection problems is increased by maintenance and repair requirements. Statistically-designed experiments have been found to effect a lowering of design costs over those required by less sophisticated methods. Design reviews also result in savings and in the elimination of many of the effects of human errors. Value engineering concepts can be effectively applied in the design stage as well as in the production phase. Good data collecting is essential to the evaluation of product reliability and is also needed as the back-up for the advertisement of product quality.

REVIEW: This paper is a qualitative discussion of the advantages of the techniques mentioned. As such, it has a message for those who may not be convinced of the value of these procedures. For information on the technical aspects, the reader will find 13 pertinent references listed at the end of the paper. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Organization, man and reliability

AUTHOR: Frank Nixon, Rolls-Royce Limited, Derby, England

SOURCE: Industrial Quality Control, vol. 19, August, 1962, pp. 15-21 (presented at the 11th Annual ASQC Aircraft and Missile Division Conference, Los Angeles, California, November, 1961)

PURPOSE: To discuss the distinction between the roles of Man and the Organization in the developments in the fields of quality and reliability.

ABSTRACT: Quality Control was conceived almost simultaneously in the United States and in Great Britain, about 30 years ago. The subsequent history of the subject has, however, been very different in the two countries. In the United States there is a lusty activity, with a thriving and still growing ASQC, actively supported by business executives, government organizations, and officials. In Great Britain, the overall activity is only a fraction of the American movement. Much the same conditions hold in the allied field of Reliability. A study of the reasons for these conditions has led to a study of the whole background of industrial developments and thinking in the two countries.

The typical American approach is to formalize a subject, have it recognized and adopted as respectable, and then to make it a part of a neat, tidy, and effective organizational system. In Great Britain there is a tendency to avoid the discipline involved in the formal organization, with a preference for flexibility and individual enterprise. Past achievements have shown that both of these approaches have merit. The American approach has tended to reduce emphasis on the human side, whereas in the British approach there is a tendency to lean too much on individuals. There are advantages to be gained from a fuller realization of the importance of Man, the factor common to every activity, in whatever field.

The present situation in the United States and Great Britain is reviewed. Kinds of organization for reliability are described. The factors of pride in product, enthusiasm and sense of responsibility, teamwork, originality, and the importance of asking why are discussed. It is concluded that if we are to raise the standards of quality and reliability, we must make effective the phrase "quality is everybody's business." This includes every individual in the organization and every firm in the nation's industry. It is important to foster and develop those human talents which can be stifled by too much organization, the human and questioning approach of the true engineer. There is a need in industry for the restoration of the true function of the foreman. Valuable progress might be made by breaking down large organizations into

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smaller units. Some thought should be given to "Selling Quality to the Worker," in contrast to the present emphasis on "Selling Quality to Management." (Author in part)

REVIEW: For those concerned with organization for quality and reliability, this article contains food for thought. The comparison of the American and British approaches, and their relative strengths and weaknesses, has a potential contribution to make to the determination of sound and economical practices. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Space--a new environment for materials

AUTHOR: W. H. Colner, Aerospace Group, Hughes Aircraft Company, Culver City, California

SOURCE: Materials Research & Standards, vol. 2, pp. 656-660, August, 1962

PURPOSE: To describe the program at Hughes Aircraft Company on the effects of the space environment on materials.

ABSTRACT: The requirements on materials have been growing more severe; the space environment introduces an entirely new factor--the almost perfect vacuum. Any molecule which leaves the surface is not likely to return. The absence of an atmosphere means that the radiation is very high in the ultraviolet. There are also many charged particles. Hughes has set up laboratory facilities to simulate the high vacuum and the uv radiation. In one system materials are exposed to 10^{-7} mm Hg and the outgas/decomposition products are collected. The temperature can be adjusted over a wide range. Another system exposes the materials to 10x solar radiation intensity at 10^{-6} mm Hg; the specimens are water-cooled to keep the temperatures down. A new chamber will get down to the 10^{-10} mm Hg region. Wires and cables are rated in a long tube at a pressure of 10^{-5} mm Hg. A chamber at 10^{-9} mm Hg is used to heat cycle some materials. Some materials were exposed to vacuum and to Co-60 radiation; the energy absorbed--regardless of the form of the particle radiation--is all that is important.

Some data on Mg alloys are given in a table; they do fairly well in a vacuum. Cold welding of steel was possible at 5×10^{-9} mm Hg only when the surfaces had been heated to 1650°F; even freshly broken surfaces rapidly got a coating which prevented cold welding. Organic materials containing volatile substances will lose them. Teflon in a vacuum is not harmed by radiation. Lubricants are a problem. Living organisms and electronic components were also tested, but the results are difficult to generalize.

Work is also being done on a plastic to be foamed in vacuum and a plastic to be formed and cured in space.

REVIEW: This paper should be of interest to designers who want to learn how the materials are being tested. The equipment described is similar to that described in the paper covered by Abstract and Review Serial Number 378. It should be noted that the major output of a Co-60 source is gamma rays, not charged particles, and that the effects of radiation on materials are influenced by other factors than just the energy absorbed. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Stop transistor failures in magnetic deflection circuits

AUTHOR: Ralph S. Hartz, Bendix Semiconductor Division, Bendix Corporation, Holmdel, New Jersey

SOURCE: Electronics, vol. 35, August 3, 1962, pp. 37-39

PURPOSE: To show where the energy comes from that causes failure of these transistors.

ABSTRACT: In a magnetic deflection circuit, the transistor acts as a switch which cuts off the current to the magnetic coil. This coil is shunted by some capacitance. The current does not instantaneously reduce to zero through the transistor when the base is cut off, because of stored base charge. The reaction voltage across the magnetic coil is in such a direction as to put energy into the transistor. If the current cut-off time is long and the voltage rise is sharp, the power into the transistor will be appreciable -- enough to burn it out even though the time involved is a few microseconds. The cause of failure is this energy, not the reverse voltage breakdown as had been suspected earlier. The 2N1073B is ideal for this type of switching.

REVIEW: The mathematical analysis is intended for someone already quite familiar with these practical deflection circuits. For example, reference is made to third harmonic tuning, but no circuits for it are shown. The analysis does not make clear that it is forward voltage across the transistor that causes the heat damage. It would have helped to show the voltage waveform across the transistor. This type of analysis of part failures is very helpful. More articles like this are needed.

Most transistor specifications do not give this critical value of energy that will cause burn-out; it may be difficult to specify a meaningful rating. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability theory in chemical system design

AUTHOR: Dale F. Rudd, University of Wisconsin, Madison, Wisconsin

SOURCE: Industrial & Engineering Chemistry Fundamentals, vol. 1, pp. 138-143, May, 1962

PURPOSE: To show how probability theory can be applied to chemical system design.

ABSTRACT: Some chemical processes involve certain steps which are rather unreliable. For example, consider a process in which a special freshly-made ingredient must be added at a certain stage. The making of this ingredient is difficult and not all of the batches turn out well. If this ingredient is not available, the whole process breaks down and material up to that point is lost. If the sub-step involving the special ingredient were made redundant, the reliability of the whole process would be improved. There may be several of these unreliable sub-steps, and it is desirable to have a method for deciding on the optimum redundancy for each in order to optimize the output. The output may be profit or some other factor. In this paper, reliability theory is applied to the economic design of such chemical processing systems. The failure characteristics of a single process are discussed. The effects of these failures on the performance of a processing system are determined in terms of the interrelations of processes in the system. The use of redundancy as a design counter measure is discussed and methods are given to determine the optimal redundancy for series processes. Dynamic programming is used to determine the optimum parallel redundancy. The problem of determining the reliability of a general system is also presented.

REVIEW: The ideas in this paper are good, and constitute a unique application of some of the theory normally associated with reliability. The presentation would, however, have been better if the author had stated the underlying assumptions in that theory more explicitly. For example, there is an implicit assumption that the failure of any process is independent of that of any other process in the system. While this may be true much of the time, there could be cases in which it is not true. A reader having such a case in mind should be duly warned of this restriction. Similarly, Bayes' Theorem could have been stated more completely, as reference to p. 122 in the second item of literature cited by the author will indicate. Such points are undoubtedly clear to the author, and are omitted for the sake of brevity in the paper. But they may not be as clear to some readers wishing to make use of the ideas. It is very important in a mathematical presentation to list explicitly the assumptions that are necessary for the treatment to be valid. Otherwise it is too easy to misapply the theory.

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RELIABILITY ABSTRACTS
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In the derivation where the output is to satisfy a fixed demand, it is incorrectly assumed that the reliability of the process times the number of batches will be the output; it will be the average output. If one wishes to have a certain confidence that a minimum number of batches will be produced, then further calculations, involving binomial probabilities, must be made. ##

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Serial Number 387 -1
Codes 831;833;837;
838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maximizing reliability for one-shot space missions

AUTHOR: S. C. Morrison, Space Technology Laboratories, Inc.

SOURCE: Aerospace Engineering, vol. 21, March, 1962, pp. 54-60

PURPOSE: To compare the reliability of present space missions with those of hypothetical future ones, and to suggest ways for improvement.

ABSTRACT: The reliability problems for one-shot space missions are very great due to the problems of thorough design and testing on a limited budget and schedule. Examples are given of calculations on Explorer VI (August, 1959), Pioneer V (March, 1960), and Surveyor (design). The equipment is separated into three parts: power; telemetry, tracking and command; experiments. A table lists the kinds of equipment in each vehicle. Another table shows the number of each kind of part. Redundancy is necessary to improve the reliability, but results in more weight. Functional redundancy may be used, e.g., three TV cameras. Parts failure rates used for space conditions are shown. The lifetime of the missions compared favorably with the estimates, although the discrimination was not sharp.

The remedy for the unreliability problem is really to do what everyone says and knows should be done: failure modes analyzed, reliable components used, adequate margins of safety, debugging, etc. These need more than lip service or moderate attention. In addition, special efforts such as even larger safety margins, more derating and better redundancy must be brought into play.

Not only must the spacecraft be reliable, but the boosters also, and the booster-spacecraft combination should be matched from the reliability point of view. A final possibility is redundancy of the entire system--several craft along with boosters, etc.--all ready to go if a previous shot fails. This will increase the overall probability of success. Estimates of prospects for success of various types of future missions are included.

REVIEW: There are many interesting data in this paper, and the author is repeating what many have said. A real problem, of course, is to get people to do the "optimum thing," except that there are many different ideas of what is optimum. The comments about "practicing reliability as well as we know how" are very timely and should be taken to heart. The discussion of redundancy is valid only for catastrophic failures, not the drift type. For example, AGC improves the drift reliability of a receiver without using redundancy. The effectiveness of redundancy depends not only on where it is applied, but on the reliability of the switching and sensing networks.

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

In a private communication the author has stated that "redundancy is proposed specifically for communications channels which can be monitored and switched from the ground independently, avoiding the reliability problem of sensing and switching equipment." ##

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Serial Number 388
Codes 711;770

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Cryogenic temperatures up fatigue strengths of Al-Mg alloys

AUTHORS: J. G. Kaufman and F. G. Nelson, Assistant Chief & Research Engineer, Mechanical Testing Division, Alcoa Research Laboratories, Aluminum Company of America, New Kensington, Pennsylvania

SOURCE: Space/Aeronautics, vol. 38, July, 1962, pp. 91-96

PURPOSE: To give the results of low temperature fatigue tests of a few Al-Mg alloys.

ABSTRACT: It has been assumed on the basis of the behavior of other alloys that the Al-Mg alloys would have better fatigue strength at low temperatures than at room temperature. This gap has been filled by tests on 5083-H113, 5086-H32, 5454-H32 and 5456-H32 plate at room temperature and -320°F. All specimens were tested in axial fatigue, tension only. Some specimens were notched, some welded, and some both. Several tables and graphs show the results of the tests. For smooth specimens, the fatigue strength (at 10^5 to 10^6 cycles) was 12% to 50% higher at low temperatures. The notch sensitivity (at 10^5 cycles) was less at the low temperatures. The room temperature fatigue strength (at 10^5 to 10^6 cycles) of welded specimens was about 20% less than that of smooth ones.

REVIEW: This is a worthwhile test and the results are encouraging in that they substantiate the earlier suppositions. A minor criticism is that the fatigue strength should have been called a median fatigue strength to show the probability of survival. (The strengths obviously would be different for other probability levels.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability means more than a low parts count

AUTHOR: Marvin Loeb, Senior Group Engineer, General Dynamics/Astronautics, 5001 Kearny Villa Road, San Diego, California

SOURCE: Space/Aeronautics, vol. 38, August, 1962, pp. 83-89

PURPOSE: To analyze the factors which favor reliability in digital computers.

ABSTRACT: A simple criterion used in assessing the reliability of electronic equipment states that reliability decreases as the parts count increases. On the basis of this criterion one could assume that the way to increase reliability is to cut the number of parts. This criterion is not always valid, however, especially in the case of digital computers. Some important computer characteristics which tend to improve reliability are:

(1) A digital computer uses only relatively few types of circuits, which can be optimized and standardized to a large extent.

(2) As a result of the on-off use of circuits in digital computers, out-of-tolerance failure rates tend to be lower than for circuits which must work at or near specified nominal points.

(3) Transients in the signal waveform of the digital computer are less significant than in other types of electronic equipment, since switching can be done when the signals are in a relatively steady-state condition.

(4) A digital computer does not have to work perfectly every time, since techniques are available for detecting and correcting errors.

It is shown how limiting the types of circuits can improve the reliability of digital circuitry. Safe regions of operation for bistable devices are discussed. The importance of operating speed as a factor in reliability is considered. It is noted that logic equations should be prepared so that they are completely representative of physical circuits. Such equations can contribute to reliability by standardizing circuits and interconnections and make circuit behavior more predictable. In developing physically representative circuits, it helps to completely define the waveform characteristics. Many techniques are available for detecting and correcting computer errors, and these should be used wherever possible. Reliability is improved as the number of errors a computer is allowed to make goes up. Unless bit-for-bit error correction via codes is used, system accuracy will fall off as the errors increase. However, with careful design this degradation can be kept within acceptable limits. (Author in part)

REVIEW: This paper explains that a large parts count does not necessarily imply unreliability. The author develops methods and formulas for taking advantage of other factors which favor reliability.

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While the discussion is specifically related to digital computers, the basic ideas may well have applicability to other types of electronic systems. ##

Serial Number 390
Codes 720;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Moisture exclusion from encapsulation of long-life transistors

AUTHOR: R. I. B. Cooper, Cambridgeshire College of Arts and Technology, Cambridge, England

SOURCE: Proceedings of the IRE, vol. 50, pp. 141-147, February, 1962

PURPOSE: To show that moisture is a main cause for transistor degradation and to describe means to reduce the damage caused by moisture.

ABSTRACT: The requirement for long-life transistors places stringent demands on sealing processes. There are empirical reasons for believing that water content is a critical factor and should be preserved at a very low value.

The first consequent problem is to design the sealing operation so that the encapsulate is sufficiently dry at the beginning of life. A practicable solution demands the use of moisture getters and the properties and usage of these are compared.

The rather expensive transistors can be baked and simultaneously exhausted in order to remove moisture. The getter will also then be rather dry. This is the best method, but cannot be afforded for the common transistors. For these, the best method is to seal them in a can which contains a getter--usually of the molecular sieve type. The whole process is done in a dry box.

The second problem is to reduce later leakage of water vapor into the can to a low level. The radioactive method of leak detection is shown to be the most satisfactory to use for controlling the quality of the high-grade packages required. (Author in part)

REVIEW: This paper is good, especially for those who are interested in the process of transistor manufacture but are not attached to a manufacturing group, and thus do not have ready access to this information. As a description of the processes employed in England it will also be of general interest. There are no data on the effects of varying amounts of moisture; the paper concerns itself with a description of processing methods to achieve various moisture goals.
##

Serial Number 391
Codes 782;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Minimum size and maximum packing density of nonredundant semiconductor devices

AUTHORS: J. T. Wallmark, Radio Corporation of America Laboratories, Princeton, New Jersey and S. M. Marcus, Defense Electronic Products, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings of the IRE, vol. 50, pp. 286-298, March, 1962

PURPOSE: To explore the limitations on minimum size for semiconductor components in microelectronic circuits.

ABSTRACT: It is shown that there exists an absolute lower limit to device size and an absolute upper limit to packing density of nonredundant semiconductor devices, whether integrated or nonintegrated, based on fundamental physical phenomena such as statistical variations in impurity distribution, maximum resolution of semiconductor fabrication methods, power density and influence of cosmic rays. The influence of these phenomena falls in two categories, namely failures that appear during the fabrication of the devices (impurity distribution, dividing operation) and failures that appear during use. The latter may be temporary failures (cosmic ray ionization, carrier fluctuations) or permanent failures (atomic displacements by cosmic rays, heat generation).

For a medium size computer (10^5 components) with a reasonable life expectancy (1 month mean time between failures), the minimum device size under reasonable conditions is approximately $(10\mu)^3$, which is not far from devices now in the planning stage and within reach with existing techniques. It is within a factor of 2-5 of the dimensions of the active region of many devices of today.

As microminiaturization by mere reduction in size appears headed for a not too distant limit it appears necessary from a device point of view to consider remedies which also have been suggested from a system point of view, namely redundancy, self-organizing systems, negative feedback, etc. (Authors)

REVIEW: This is a very thorough treatment of a specific situation. The assumptions and approximations are very clearly stated. The question of how soon practical devices will be limited in this manner is debatable. The authors feel that it may be soon; others would guess that it might be ten years before practical marketable devices are so limited. During this period, other developments, as yet unsuspected, may take place, which will require an analysis of a rather different problem. It should certainly be kept in mind that the authors have carefully stated the problem they have analyzed, and that, of course, the answers can be different if a different problem is considered. ##

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Serial Number 392
Codes 000;800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability and quality control field from its inception to the present

AUTHOR: Clifford M. Ryerson, Vice President, EL-TEK Corporation, Hawthorne, California

SOURCE: Proceedings of the IRE, vol. 50, pp. 1321-1338, May, 1962

PURPOSE: To present a history of the quality control and reliability fields.

ABSTRACT: Starting with a brief discussion of the implications to Reliability of the parallel accelerated growth of modern technology the history of Reliability is traced through four decades. Following the early groundwork of the years before 1940 the decade of the 30's has been described as the Standardization Decade. Here the new emphasis was on specific standards of all kinds. The following decade of the 1940's had been described as the Quality Control Decade. This new field was developed with emphasis on process control and the uniformity of product. This was followed by the Reliability Decade during which the new emphasis was on the inherent reliability of design and the time degradation of performance. The 1960's have ushered in a new decade and new emphasis on coordinated controls in all areas and phases of design, development and production. The new decade has been described as the Product Assurance Decade, wherein the emphasis is being placed on assurance to management and to the customer that all the important product characteristics are being optimized and that all the technical specialties involved in providing the highest value product on schedule are being integrated effectively. This new emphasis is on coordinated programs embracing all the related control specialties sometimes referred to as the Big R approach. These specialties include Reliability Engineering, Maintainability Engineering, Total Quality Assurance, Value Engineering and System Integration among others. (Author)

REVIEW: This was written for the IRE's fiftieth anniversary issue and does an excellent job of summarizing the activities in the fields of quality control and reliability. One is struck by the early recognition and statement of factors which are still problems. It would seem that reliability could be much better if we just did as well as we know how, right now, regardless of future advances.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On a random failure mechanism

AUTHOR: Harry J. Gray, The Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania

SOURCE: Proceedings of the IRE, vol. 50, p. 1836, August, 1962 (letter to editor)

PURPOSE: To point out a mathematical connection between stress-failure data taken over a short period of time and the failure rate of a component occurring in service.

ABSTRACT: The following assumptions are cited as a basis for a mathematical connection between random failures and random stresses.

(1) The stress is a random variable with unvarying statistics.

(2) The degradation rate of a parameter is directly proportional to some function of the stress.

(3) The change (in a parameter) that is necessary for failure is a random variable.

(4) The rate at which the parameter degrades, for a given stress, is a random variable.

A general expression for the probability of failure is given as a double integral. Additional assumptions are made in order to evaluate the integral and obtain the failure rate as a function of time. Suggestions are then made for reducing "random" failures.

REVIEW: It is difficult to see that the four suggestions made at the end of the paper follow directly from the material presented earlier. This may be due at least in part to the brevity of the presentation. There are several misprints which make the mathematics somewhat difficult to follow.

In a private communication, the author has indicated the view that component failures have definite causes and that our use of statistical methods results from our lack of knowledge of the deterministic mechanism that must exist in a world subject to physical laws. Accordingly he feels that there exists a causal connection between environment and "random" failures and that this paper contained at least a plausibility argument supporting this point of view. ##

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Serial Number 394
Codes 720;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Selection of germanium transistor parameters by control of moisture at low levels within the device encapsulation

AUTHORS: Robert J. Gnaedinger, Jr., Steward S. Flaschen, Marie A. Hall, and Edward J. Richez, Semiconductor Products Division, Motorola, Inc., Phoenix, Arizona

SOURCE: Journal of the Electrochemical Society, vol. 109, pp. 589-595, July, 1962

PURPOSE: To present the results of new experimental studies of the effects of moisture on the parameters of germanium transistors.

ABSTRACT: Experiments have been carried out which indicate that moisture in air at levels below 1% relative humidity (200 ppm H_2O) has a strong influence on the surface recombination velocity of germanium and on the parameters of transistor devices derived from it. By controlling the moisture partial pressure at any of various given levels within hermetically sealed transistors, it has been found possible to preselect different ranges of several, stabilized, device parameters, such as h_{fe}, I_{CO}, and I_{EO} without changing the device fabrication procedure. A method for controlling the moisture partial pressure using pairs of inorganic compounds is presented together with data obtained from its application to large-scale manufacture. In addition to showing the practical value of these controlled moisture materials, these results emphasize the need for a more precise knowledge of the moisture level present in the "dry" gaseous ambients commonly used in studies of semiconductor surface properties. (Authors)

REVIEW: Surface properties of semiconductor devices are re-emphasized by a new experimental technique for stabilization of moisture partial pressures within device encapsulation. The authors have chosen significant device parameters to characterize the effects of moisture level control as a production technique, and the statistical inferences about these parameters lead one to be very optimistic about obtaining a more reproducible product. However, more knowledge about the influence of this technique upon device parameters under environmental aging is needed. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Industrial/Military tube reliability data report

AUTHOR: --

SOURCE: Raytheon Company, Industrial Components Division, January, 1962, 20 pp.

PURPOSE: To publish failure data on some Raytheon tubes.

ABSTRACT: The failure rates are based on intermittent life testing per MIL-E-1D. The tests are designed to approach the extremes of temperature and power rating for the tube applications and are near the maximum ratings. The failure rates have been calculated on the basis that average failure rate is constant over the first 1000 hours and all data are from 1000-hr. tests. The average failure rates should not be assumed constant after 1000 hours. The tests here are considered, overall, to be more severe by a factor of two than in the usual application.

The failures are separated into sudden death and gradual failures. The gradual failures are based on transconductance degradation. Examples are given for confidence estimate calculations.

Results are given for the following Raytheon tube types:

6AN5WA	CK5703WB	CK6088
CK5654/6AK5W	CK5744WB	CK6111
CK5670	CK5814A	CK6111WA
CK5678	CK6021	CK6112
CK5702WB	CK6021WA	CK6418
CK5703WA		

REVIEW: This is a good presentation of reliability data. The failure rates range from about 0.2% to 1% per 1000 hr. (maximum likelihood estimates). Since the number of failures is 4 or less, nominal failure rates will be substantially higher if 90% confidence levels are used. For multiple-section tubes it is not stated whether the failures are for sections or for the entire tube. It is to be hoped that the work will be extended for more failures and for more tube types. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Diode quads--a reliability trap?

AUTHOR: Yale J. Lubkin, Loral Electronics Corporation, New York, New York

SOURCE: Electronic Design, vol. 10, August 16, 1962, pp. 48-51

PURPOSE: To show that diode quads can be less reliable in some cases than single diodes.

ABSTRACT: If the failure probability (fp) of a single diode is 10^{-3}, then the fp for a quad is 1/250 of 10^{-3}. This is a tremendous improvement and is worth trying for. The assumptions in this analysis are that diodes fail by opening or shorting; the results may not be valid if the assumptions are not valid in the particular case at hand. Consider the design of a NOR block with diode coupling. In the example in the paper, a fan out (FO) of 4 is possible with single diodes. If quadding is used the FO drops to 3 or even 2 depending on the design. Obviously a logic circuit built with blocks having FO of 2 will be more complicated (and most probably less reliable) than one built from blocks with FO of 4. The reason that quadding has not increased the reliability is found in the assumptions. In this case (NOR block) the forward drop of the diodes is important and the circuit no longer fails only by open or short; it can fail by too large a forward drop. This example graphically shows that a cookbook approach to reliability may be detrimental. Remember "The most reliable portion of equipment is the part you have designed out."

REVIEW: This is an excellent paper in that it concisely shows that the blind following of special purpose rules can result in very poor design. This principle holds true in general whenever rules (or "laws") are used to solve problems. If the restrictions made (or assumptions used) in deriving the formula (or principle) are not valid for a particular problem, the formula (or principle) is not likely to be valid for that problem. There are many areas of reliability engineering where seemingly general formulas are limited and they may not apply. One might even say that the assumptions made in deriving a principle are more important to remember than the principle itself. ##

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Codes 770;833;844;
850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Investigation of electron tube reliability in commercial airline applications--final report on Controlled Test 13

AUTHOR: E. R. Jervis

SOURCE: ARINC Report #411, 62 pp., March 15, 1961, ARINC Research Corporation, a subsidiary of Aeronautical Radio, Inc., 1700 K Street, N.W., Washington 6, D. C. (Publication No. 2247-1-221)

PURPOSE: To report on a test designed to measure the reliability of tubes as used in two commercial airline applications.

ABSTRACT: Controlled Test 13 was instituted in 1956 for the purpose of comparing the behavior of certain ARINC preferred tube types produced by six different manufacturers at different times and used in navigation or communication equipments of six commercial airlines in the United States and Canada. The test ran for about three years, during which time more than half a million equipment hours and more than ten million tube hours were accumulated. The conditions of operation, cycling, and maintenance were such that the results of the test may be regarded as typifying the behavior of similar tubes or devices in airline use.

As the variability from the over-all average is greater when the figures are grouped by airline than when they are grouped by equipment type, it may be said in general that the reliability of these equipments is more affected by the operating requirements and maintenance conditions prevailing in the airlines than by the design or the quality of manufacture of the equipments themselves. The predominant effects of operation and maintenance have been observed in ARINC Research Corporation investigations of military equipments as well.

Although the navigation receivers were more complex than the communication receivers, they had, in general, a longer mean life than the communication receivers. This finding was attributed largely to the fact that the pilot could clearly identify a malfunction in the navigation set (by means of a flag indicator and other visible indications) but had no means of distinguishing between a set malfunction and other trouble with the communication set. A study of the cases in which communication sets were totally inoperative revealed that complaints were due less to actual equipment defects (say, open heaters) than to the operator's desire for a very high level of performance--a desire not always completely justified.

The maintenance man was found to follow the highly perfectionist philosophy of the operator by repairing and replacing parts and tubes at a very much higher rate than the one considered strictly necessary to good operation. He probably was pushed in this direc-

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tion by the desire to forestall trouble by performing preventive maintenance, as well as by the necessity to eliminate existing trouble.

In spite of the above conditions, the mean time between equipment repairs due to operator complaints was 1100 operating hours for navigation equipment and 570 hours for communication equipment. These figures correspond to an average of one malfunction every three months for each navigation receiver and one every two months for each communication set. If only catastrophic failures are considered, these would occur, on the average, every one and a half years for navigation receivers and every six years for the communication receivers. The wide divergence between the last two sets of figures is in large part due to the highly critical attitude of operators and maintenance personnel.

Analysis of the tubes removed by maintenance personnel revealed that the policy of trying to achieve the highest possible equipment performance was very disadvantageous from the point of view of tube usage. In fact, by following the strict removal practices described above, the airlines used only one third of the life existing in the tubes involved in the test. The removed tubes of a typical tube type had an average transconductance approximately 14 percent below the bogie value and an average life of 3300 hours. If the tubes had been left in the equipment until they reached the minimum specification value, their average life would have been extended to at least 10,000 hours.

The most important conclusion to be drawn from this test is that, through their policy of attempting to get the highest performance from the equipment, the airlines now take advantage of barely one third of the life existing in present-day electron tubes. Excessive tube usage has come about partly as a result of operator complaints which--though they may be unjustified--the maintenance man feels bound to acknowledge by performing some preventive maintenance. These findings should be carefully considered in view of the rapid development of transistorized equipments. If the present over-critical maintenance policies were applied to transistorized equipments, the cost of maintenance would be indefensibly high, and set performance would probably be worse than that of tube-using equipments. (Author in part)

REVIEW: This is an excellent report on the reliability of equipment as influenced by the tubes--and associated maintenance practices--in it. It would be very helpful to electronic designers if information such as this found its way more often into the general electronic literature. It is highly recommended that everyone concerned with the design or maintenance of electronic equipment read the entire report. The planning of the test and the analysis of the results seems to have been done with great care and thoroughness.

One of the feelings one gets from reading the report is that the life of tubes would be increased, without appreciable sacrifice in performance, if they were operated at a reduced (by 10%) heater voltage. Obviously, tube manufacturers could change the heater characteristics to accomplish the same thing if they felt it was wise. There have been several articles in the past by tube manufacturers which explain why the present heater ratings are optimum. A further extended discussion of the problem would be appropriate. ##

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Serial Number 398 -1
Codes 821;824;831;838;
844;850;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of radio-electronic equipment (a collection of seven articles)

SUBTITLES AND AUTHORS:
(1) Operational reliability of the standard elements of the BESM, V. A. Zimin, pp. 1-17 (Codes 844;851)
(2) Service life of electronic tubes in the standard elements of the BESM, V. A. Zimin, pp. 18-26 (Code 844)
(3) On the problem of reserves in radio-electronic systems, M. A. Sinitsa, pp. 27-52 (Codes 821;838)
(4) Underheating and noise parameters of the progressive deterioration of tube characteristics, S. M. Levitin, pp. 53-64 (Code 844)
(5) On the criterion and method of estimating the reliability of radio-electronic system elements, S. M. Kuznetsov, pp. 65-83 (Code 850)
(6) On methods of calculating the reliability of systems, G. V. Druzhinin, pp. 84-94 (Code 831)
(7) On the reliability parameters of electronic systems, A. A. Babenko, pp. 95-103 (Codes 824;850)

SOURCE: "Soviet Radio" Publishing House, Moscow, 1958; translated from Russian; published for the National Science Foundation, Washington, D. C. and the Department of Commerce by the Israel Program for Scientific Translations, 1960. Available from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., OTS 60-21823, price $1.25

(1)

PURPOSE: To describe the failure experience for a two-year period on the BESM computer.

ABSTRACT: This computer belongs to the Academy of Sciences of the USSR. It has about 6,000 tubes, 10,000 germanium diodes, 30,000 each resistors, capacitors, etc. The machine is constructed of seven standard blocks, e.g., trigger, pulse shaper, pulse gate, phase inverter; there are also four dual combinations of these blocks which are used as units. This program was carried out from June 1952 until May 1954 and about half the time was spent on setting and adjusting the computer. Marginal checking by changing supply voltages--especially the filament supply was used extensively. Preventive control takes about 20% of the computer time, and interruption losses about 8%. The maximum working period without interruption is 42 hours. As was expected, the failures during the operation period were substantially lower than during installation. Graphs and a discussion are given of the performance of each type of block. Resistors and capacitors caused negligible failures. A very complicated failure mechanism was faulty contacts--many of

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

which were soldered joints. The conclusions of the article are: (1) Standard elements of the calculating machine BESM are sufficiently reliable, if (a) the conditions of their use correspond to the given technical specifications and (b) a check of the working capability of the standard elements is done systematically and under operation conditions of the machine. (2) The service life of standard elements of BESM is between 3,000 and 8,000 hours, depending on type. (3) Reliability of standard elements can be judged by the number of blocks put out of operation. Under steady conditions the number of rejected blocks tends to a minimum value. In April and May 1954 about 3% of the total number of blocks were taken out of the BESM, while the monthly average for five months of 1954 was 6.8%, and for 1953--9.1%. (4) A frequency of rejection of standard blocks, which is higher than two in one year, normally indicates an irregularity in the part of the circuit in which the unit is working (defective wiring or mounting, nonstandard form of the input signal, abnormal load, and similar). (Author in part)

REVIEW: The article is undoubtedly about an outdated computer, but by the time the article is published, then translated, many years go by. The description of the failure arithmetic is fairly complete and the Russian experience is interesting.

(2)

PURPOSE: To describe the behavior and life of tubes which are used in a computer

ABSTRACT: Computer tubes are used as high speed switches. Several tube types were tested and showed considerable variation with year of manufacture. The conclusions given are as follows.

1. In the BESM computing machine, tubes usually work in an S class or with a zero bias on the grid with respect to the cathode. They are activated by signals of relatively large amplitude. Together with this, the output signal must have a nominal amplitude, regardless of the amplitude of the input signal.

2. Working conditions of the tubes in electronic automation systems are determined by the operation performed at a given moment. In accordance with these operations tubes may remain for a considerable time with a large negative bias of the control grid, or inversely, with a zero or even positive bias. Often the working conditions of the tubes change between extreme limits with a frequency between 0 and 1,000 kc.

3. The average values of the basic parameters of electronic tubes are somewhat lower than the nominal values.

4. During the life service of a tube the average value of the anode current decreases. At the beginning this decrease is relatively rapid, and then slowly approaches 0.5 of the nominal value. At the same time fluctuations in the value of the anode current

occur within the limits of 10% of its nominal value.

5. Productional defects in the tubes are discovered during the first hours of operation. Influence of accidental causes in otherwise acceptable working conditions on the replacement of tubes is rather rapid. Thereafter replacement of tubes has an increasingly regular character.

6. The tubes of the types 6Zh4, 6P9, 6P3S and 6N8S, which are used in the BESM, have an average service life of about 15,000 hours. The service life of the tube is defined by the moment the tube is considered unsuitable for use. The service life is hardly related to the type of block in which it is used. (Author in part)

REVIEW: The Russian experience suggests a linear, rather than exponential, survival curve for the tubes. The slope seemed to stay the same even after marginally defective tubes were removed. Note that lifetime is the time for half the tubes to be replaced.

(3)

PURPOSE: To describe and analyze several methods of redundancy.

ABSTRACT: Redundancy is necessary for reliable operation of very complex equipment. This redundancy can be achieved on a components or system level; the component level is shown to produce higher reliability. Units can be put in parallel, but this causes difficulties. It is more effective to replace a failed unit by a good one. The conclusions given are as follows.

1. The proposed classification of reserving methods and of means of connecting the reserve is comparatively simple and, at the same time, covers the ground of possible methods of reserving fairly well. Of course, more complicated reserving methods may be encountered in practice, but, from the point of view of reliability, they can be easily subdivided to fit the suggested classes.

2. On the basis of this classification a general method for the calculation of the reliability of units with reserves has been obtained. The method can be directly related to that of calculating the reliability of complex units without reserves.

3. The permanent connection of reserves and connection by replacement are in general not equivalent. If the stand-by conditions of the reserve are "easier" than the working conditions, then reserving by replacement is in principle more effective than reserving by permanent connection. The advantages of the replacement method increase with more relaxed stand-by conditions and with greater multiplicity of reserving.

4. In the general case, the gain in reliability with the replacement method of reserving depends on the stand-by conditions of the reserve, on the multiplicity of reserving, on the reliability of the elements and on the form of probability distributions.

5. The superiority of reserving by replacement over the

constant connection method is greater with the working elements of lower reliability.

6. Separate reserving together with replacement connection is the most effective method of reserving. It enables, in principle, to obtain a very high degree of reliability in the operation of radio electronic systems.

7. From the consideration of the advantages and the disadvantages of the replacement method of reserving, its use can be recommended in stationary ground systems which require a high reliability for long periods of time. Such systems are radio systems of aeroplane landing, radio relay lines, dive..e supervized communication amplifier stations, drifting automatic hydro-meteorological stations and any other systems which must function without checking for extended periods of time. (Author in part)

REVIEW: This is a mathematical paper. The Russian definition of reliability is the same as that used in this country. Several different distributions are used in the examples--and the exponential case is one of them. Many examples and graphs are shown.

(4)

PURPOSE: To try to find a way to predict the failure of electron tubes.

ABSTRACT: Reducing the filament voltage and then measuring the tube parameters will not enable the elimination of tubes about to go bad. It was noted however, that a tube early in its life has a smaller change in parameters (when the filament power is reduced) than near the end of its life. The conclusions given are as follows.

1. An investigation of the physical nature of static and noise parameters at underheating has been carried out. It has been shown that noise parameters are the most complex of all known tube parameters.

2. Experimental measurement data on the noise parameters of 12Zh1L, 4Zh11 and 6Zh4 pentodes in service life tests have been obtained.

3. It has been experimentally shown that upon extended operation the deterioration of the noise parameters of the investigated pentodes, particularly the noise parameters measured upon underheating, as a rule precedes the deterioration of the basic static parameters.

4. It has been proposed to measure noise parameters upon normal heating and underheating in order to detect unreliable tubes whose characteristics gradually deteriorate (for predicting of the gradual tube failures).

5. Circuits of a comparatively simple arrangement for measuring noise parameters of tubes in the low frequency range were developed and portable device--a noise meter for predicting failures of electronic tubes directly in systems--was constructed.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

6. The possibility of checking directly in circuit the noise parameters of tubes of an amplifier without taking it out of operation (with some modification in the amplifier circuit) has been shown by the example of a UHF stage. (Author in part)

REVIEW: This seems to have been a reasonably complete investigation of the noise behavior of tubes as a function of their life. How useful this method would be in practice is not known.

(5)

PURPOSE: To define reliability and to prepare the way for its estimation by the knowledge of the behavior of materials and people.

ABSTRACT: Reliability is usually defined as the probability of successful performance under stated conditions for a predetermined time. This is not good enough. Every piece of equipment has a transfer function which is affected by the many elements that make up the equipment. The reliability can then be defined in terms of the probability that this transfer function does not change excessively. A general expression is obtained for reliability in terms of functions of these parameters. Some discussion is given of the physical and human factors which may cause changes in this transfer function.

REVIEW: This is a very general article; much of the mathematics does little to clarify the situation. The author essentially says that the reliability can be expressed in terms of the physical situation and is thus solved--if only we knew what the physical situation was.

(6)

PURPOSE: To analyze methods of calculating system reliability and to suggest ways of improving that reliability.

ABSTRACT: Catastrophic failures are more frequent under more severe environments. The calculation of failure probabilities is fairly simple (an example is given). There is presently no agreement on the probability function for these failures. There are two parts to a reliability calculation: (1) calculation of element reliability from experimental data, and (2) calculation of system reliability from element reliability. General formulas are given for both of these. A graphical approach to failure rates is shown and the "bathtub" curve is suggested. If the failure rate curve vs time is known, maintenance and "burn-in" can be properly scheduled.

REVIEW: This is a fairly elementary paper. Some general equations are developed, but they cannot be evaluated since the data are not known.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

(7)

PURPOSE: To discuss some of the factors involved in reliability needs and estimation.

ABSTRACT: Reliability methods should be simple and accurate so that they can be effectively applied. Statistical methods are usually necessary. Maintenance can be planned and unplanned; at times the equipment will have undetected failures. Some simple expressions for up-time are given. In some cases, calculations can be made using the exponential reliability formula. Redundancy is considered in some detail.

REVIEW: This is a fairly general article. The dream of simple and accurate reliability methods is not realistic. The calculations are all fairly straightforward.

OVERALL REVIEW: These papers are all about five years old and are undoubtedly not representative of present activity by the USSR in the field of reliability. The papers that give failure data and mechanisms are probably the most worthwhile. The others are typical of many ideas which have been presented in this country and none of these papers seem to be outstanding examples of good work. It is to be hoped that a shorter time lag will exist in the dissemination of later Russian work in reliability. The printing of this brochure is not the best. There are quite a few errors and many diagrams are hard to read. ##

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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: Measles and reliability

AUTHOR: (Editorial Matter)

SOURCE: Electromechanical Design, vol. 6, August, 1962, p. 32 (see also Industrial Electronic Distribution, vol. 2, August, 1962, p. 27, "Reliability technique uses circuit schematic")

PURPOSE: To show a method that is used for a graphic representation of failure location.

ABSTRACT: To locate, diagnose, and correct elusive troubles in circuits and components, Westinghouse Defense Center's Air Arm Division has developed a new technique in which a schematic diagram is marked with a dot near the schematic symbol of a failed part. Dots are color-coded--thus the name "measles" chart--to differentiate between true failures,handling failures, and test errors. The charts aid in design of new circuits and act as a constant check on circuit reliability.

The idea for "measles" charts was suggested to the originator, C. D. Jeffcoat, Air Arm reliability engineering manager, by a traffic map. Just as the concentration of red pins on a traffic map indicates the presence of a traffic control problem, so the concentration of dots indicates a circuit reliability problem area.

Plotting the failures on the "measles" chart helps the engineer visualize the problem more effectively and eliminates the need for constantly referring to failure reports. Also, it shows at a glance the parts that have not failed.

Failures can be plotted on the schematics either as the failures occur, or can be plotted later from accumulated failure reports. Field failures are differentiated from factory failures by a letter that precedes the failure report number.

Proven through trial use over the past few years, the "measles" charts are now standard at Westinghouse Air Arm for pinpointing equipment trouble areas. The charts speed correction of errors which normally are found only after extended field use of a large number of equipments. (Author)

An example is given.

REVIEW: This is another method of emphasizing reliability to the designer and assisting in trouble shooting. An important contribution of this type of "trick" is to help people work at reliability as well as they know how instead of not applying large portions of what they know. ##

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Serial Number 400
Codes 431;432;872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Repairman problems

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

SOURCE: Studies in Applied Probability and Management Science, edited by Kenneth J. Arrow, Samuel Karlin, and Herbert Scarf, Stanford University Press, Stanford, California, 1962, pp. 18-33

PURPOSE: To investigate certain mathematical questions related to the repair of equipment.

ABSTRACT: Suppose that we are given m identical machines independent of one another and supported by n spare machines. Unless otherwise stated, we assume that all machines are initially operating. Suppose that each fails according to a distribution F. Furthermore, suppose that we have a repair facility capable of repairing s machines simultaneously. Obviously, we could consider the facility as consisting of s repairmen. The following queue discipline is observed. If all repairmen are busy, each new failure joins a waiting line and waits until a repairman is freed. We assume that the repair times are also independent, identically distributed random variables.

Various problems arising from servicing models have been treated by a number of authors. Relevant references are cited.

One reason for studying repairman problems is to determine how reliability can be improved by using redundant units. In these cases it will be convenient to say that a total failure has occurred when all machines are being repaired or waiting to be repaired. In this paper, the following questions, among others, are answered for a variety of models.

(i) What is the probability that k machines will be operational at time t?

(ii) What is the distribution of time until a total failure occurs?

(iii) What is the expected number of total failures in (0,t)?

The exponential case is treated as a special birth-and-death process. Several telephone trunking and queueing models in the published literature are identified as repairman problems.

REVIEW: This paper is a contribution to the mathematical theory related to servicing models. The orientation of the work relative to other papers in this area is indicated in a brief literature review. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Planned replacement

AUTHORS: Richard E. Barlow, Stanford University and General Telephone and Electronics Laboratories and Frank Proschan, Boeing Aircraft Company

SOURCE: Studies in Applied Probability and Management Science, edited by Kenneth J. Arrow, Samuel Karlin, and Herbert Scarf, Stanford University Press, Stanford, California, 1962, pp. 63-87

PURPOSE: To determine optimal replacement policies with particular emphasis on a finite time span.

ABSTRACT: It is assumed that a unit is to operate continuously over some finite time period [0,t], and one wishes to characterize the replacement procedure which minimizes the total cost of failures and planned replacements. When the usage period extends into the indefinite future, the expected cost per unit time is minimized.

Three replacement policies are considered:

(a) strictly periodic replacement,
(b) random periodic replacement, and
(c) sequentially determined replacement.

It is shown that among policies of class (a) an optimal policy exists. General formulas for determining the optimal policy are provided and two examples are given in some detail.

Similarly, it is shown that an optimal policy exists in class (b). Renewal-type equations are obtained for the various quantities of interest such as the expected cost, the expected number of actual failures, the expected number of planned replacements, and so on.

For sequential replacement policies, which include policies of classes (a) and (b), the replacement interval is determined at each removal in accordance with the time remaining to the time span. One can attain or improve upon the cost under the optimal periodic policy by a simple conversion to a sequential policy. It is then proved that given any sequential policy there always exists a nonrandom sequential policy with no greater expected cost. The existence of an optimal sequential policy is demonstrated, and it is shown to be continuous and increasing as a function of time remaining. Functional equations are given for the computation of the optimal policy. Under the assumption that the failure distribution has an increasing hazard rate, planned replacement is required when the time remaining is greater than a certain critical value; otherwise it is not. Finally, the optimal sequential policy and expected cost are computed for the same example used for computing the optimal strictly periodic policy. The expected costs and lengths of the replacement intervals are compared for

the two policies; the differences between the two policies are very small.

REVIEW: This is a theoretical paper concerning optimal replacement policies. The new feature of this article is that optimal policies are obtained for a finite time span. The results may be of considerable practical value when failure of a unit during actual operation is costly or dangerous and where the failure rate increases with age. The latter assumption is not required for the results to be applicable. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimal replacement and inspection of stochastically failing equipment

AUTHORS: R. Radner and D. W. Jorgenson, University of California, Berkeley, California

SOURCE: Studies in Applied Probability and Management Science, edited by Kenneth J. Arrow, Samuel Karlin, and Herbert Scarf, Stanford University Press, Stanford, California, 1962, pp. 184-206

PURPOSE: To obtain an optimal replacement and inspection policy for stochastically failing equipment whose state of operation is known only at the times it is replaced or inspected.

ABSTRACT: Two classes of problems are considered: (1) optimal replacement and inspection policy for single-part equipment with an arbitrary distribution of times to failure and whose state is known only upon replacement or inspection, and (2) optimal replacement and inspection policy for a two-part system, one part of which is monitored (continuously inspected) and another part of which is like the equipment of class (1) above. It is assumed that (1) inspection and replacement times are fixed constants, (2) for equipment of two parts the time required to replace both parts simultaneously is greater than or equal to the time required to replace either, and less than or equal to the time required to replace both separately, (3) time down is the only loss associated with inspection and replacement actions, (4) any machine or part that is replaced (repaired) is as good as new at the end of the replacement action, and (5) the part does not age during inspection.

For the first class of problems it is shown that an optimal replacement policy is strictly periodic, and for an optimal replacement interval the reliability of the equipment when replacement is started is equal to the average proportion of time good (not in failed state) during the replacement cycle. In the special case of exponential distribution of times to failure a similar result is obtained for an optimal inspection policy. Thus for the case of an exponential reliability function, an optimal policy consists of either a series of inspections, with replacement after inspection if the equipment has failed, or a series of replacements without previous inspection.

For the second class of problems, and the case in which the second part can be inspected only when it is replaced, and the time required for replacement of both parts simultaneously is less than the sum of the times required for replacement of each part separately, it may be possible to reduce time down for replacement by pursuing a policy of opportunistic replacement. The central feature of such opportunistic policies is that the action to be taken

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with respect to the nonmonitored part is conditional on the state of the monitored part. It is shown that, provided the distribution of times to failure of the monitored part is exponential, the optimal policy for replacement of the nonmonitored part has a structure denoted (n,N). That is, if the monitored part has not failed, the nonmonitored part is replaced if a certain time N has elapsed; if the monitored part has failed, the nonmonitored part is replaced if a certain time n has elapsed. Furthermore, $0 \leq n \leq N$, where the second inequality reduces to an equality if and only if the time required for replacement of both parts simultaneously is equal to the sum of the times required for replacement of each part separately.

A similar problem of class (2) is discussed in which it is assumed that both parts have an exponential failure time distribution and that the nonmonitored part is inspected so that replacement is not made needlessly. The same (n,N) policy is optimal. For nonexponential distributions the optimal policies typically will not be of the simple (n,N) type.

REVIEW: This paper provides a good theoretical discussion of optimal replacement and inspection policy and contains a brief review of the pertinent literature. Some 20 references are cited. ##

Serial Number 403
Codes 821;860;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weapon system design and supportability, a function of failure prediction

AUTHOR: Vernon J. Taylor, Material Evaluation Group, DCS-Systems and Logistics, Headquarters United States Air Force

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 13-17 (presented at the Northeast Electronics Research and Engineering Meeting (NEREM), Boston, Mass., November 15, 1961)

This paper was covered by Abstract and Review Serial Number 198.
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Serial Number 404
Codes 802;821;831;
840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A survey of techniques for analysis and prediction of equipment reliability

AUTHORS: H. E. Blanton, Raytheon Company, Bedford, Massachusetts and R. M. Jacobs, Sylvania Electric Products, Incorporated, Waltham, Massachusetts

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 18-35 (presented at the Northeast Electronics Research and Engineering Meeting (NEREM), Boston, Mass., November 14-16, 1961)

This paper was covered by Abstract and Review Serial Number 191.
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Serial Number 405
Code 810

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability's role in management

AUTHOR: Harold L. Gilmore, Research and Advanced Development Division, Avco Corporation, Wilmington, Massachusetts

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 36-37

PURPOSE: To show what a reliability group should do in an organization.

ABSTRACT: Reliability's role in management is to advise on its employment, provide service within the scope of its responsibility, nurture its own development and grow as an engineering function, and to formulate long-range plans based on future requirements. All of these things being carried out in the light of over-all corporate objectives and responsibilities. Until all of the foregoing aspects have been considered Reliability's role in management has not been fulfilled. (Author)

REVIEW: This is another typical "management" type paper except that it has the virtue of being quite short. It contains little that is new. There is mention several times to the effect that there is too much statistics in reliability and there is an inference that not much statistics is necessary. It may well be true that, when introducing the subject to a new group, the non-mathematical side of reliability should be emphasized and that specialists should offer their assistance when statistical help is needed. A successful reliability group, however, must be aware of and able to use some reasonably sophisticated statistics. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: IDEP--Year one at Librascope

AUTHOR: Leonard G. Rado, Reliability Department, Librascope Division, General Precision, Inc., Glendale, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 38-42 (presented at the IRE Professional Group Meeting on Reliability and Quality Control, Los Angeles, California, November 20, 1961)

PURPOSE: To show how Librascope is using the IDEP reports.

ABSTRACT: The Interservice Data Exchange Program (IDEP) is an important new tool in the reliability test effort of General Precision's Librascope Division. IDEP's effectiveness for Librascope has expanded rapidly through use of a summary which codes salient features of pertinent test reports. The summary, issued semi-annually, has helped reduce wasteful duplication of tests already conducted by IDEP member organizations. The program's manifold benefits, as reviewed in this paper, have saved Librascope about $8000 to date. While IDEP is still not functioning perfectly, the company sincerely believes that certain minor changes in the manner of failure-rate data exchange, for example, will prompt even greater benefits in the future. (Author)

REVIEW: It is gratifying to read that the IDEP is a successful program because it seemed to have great promise when it was started a few years ago. This paper supplements an earlier one by the same author (see Abstract and Review Serial Number 56). Further information on the IDEP may be obtained from the Armed Services Technical Information Agency (ASTIA) at Arlington Hall Station, Arlington 12, Virginia. Some of the IDEP reports are now being abstracted in a separate section of the semi-monthly ASTIA Technical Abstracts Bulletin (TAB). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical distributions in reliability

AUTHOR: John E. Nylander, Transport Division, The Boeing Company, Renton, Washington

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 43-53

PURPOSE: To introduce the common statistical distributions that might be used in a reliability analysis.

ABSTRACT: This paper gives an introduction to the important probability models and statistical techniques that can be used in reliability studies.

In Section I several important ideas are stressed. They are
1) That it is generally impossible to fit a statistical distribution from data alone, but that one must usually select first a family of distributions based on some theoretical and/or physical considerations and then estimate the parameters in this family of distributions.
2) That it is important to know something of the properties of the estimators used since not all estimators are necessarily good and could possibly be worse than just picking a value for the estimate at random.

In addition to the above points important statistical quantities are defined and discussed. Also, in Section I the ideas of testing hypotheses are discussed and illustrated. (Author)

In Section II the important discrete distributions are presented: binomial, multinomial, geometric, Pascal, and Poisson.

In Section III the probability distributions which are of interest in life testing are discussed: exponential, mixed exponential, gamma, Weibull, log normal, normal, and extreme value family.

Section IV discusses at some length the assumptions that can lead to the log normal and to the Weibull distributions. The use of the conditional failure rate (empirically observed) to help choose the distribution function is pointed out.

There are 19 references to both books and periodicals.

REVIEW: This article is suitable for a person who has a little background in probability theory or statistics and wishes to learn more about distributions or better still, one who has learned it once and wishes to refresh his memory. There is nothing new here; the paper is a tutorial one. The discussion is rather short for each distribution so that it is usually more for reference than for learning.

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There are at least three misprints: the distribution functions for the log normal and the normal are incorrect. Therefore, each formula should be checked before putting much reliance on it.

The paper gives the impression of being part of a series since mention is made of points which will be discussed later--but never appear. It ends rather abruptly with a typographical omission. In a private communication the author indicates that the series was intended only for in-company consumption, and that the typographical omission is "Birnbaum-Saunders paper." He also states that a correction and acknowledgement sheet will appear in a later edition of the journal.

All in all, while the article is quite competent in many ways, the range of readers to whom it will appeal is rather limited. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Tolerance limits for the output of systems of cascaded elements

AUTHOR: Richard E. Beckwith, Aeronutronic Division, Ford Motor Company, Newport Beach, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 54-58

PURPOSE: To present a method for combining tolerances of cascaded elements and thus calculating the tolerance limits of the output.

ABSTRACT: A methodology is given for analyzing the cumulative effect of a cascaded system of transducers on an input signal, where the transducers themselves activate peripheral activities, and are designed to leave the input signal unchanged, except for random magnification perturbations. Relationships are developed which relate component tolerances with the system output tolerance, and hence with system reliability. Examples are given which illustrate the type of problems that are amenable to solution by the general methodology developed, in electronics applications and otherwise. They include the determination of system output tolerances from given component tolerances, a system reliability determination when the input represents a binary digit, and a determination of minimal component precisions that are required to achieve given system tolerances. Care has been given to present the basic methodology in a complete, detailed, and self-contained manner. (Author)

In all the examples and in part of the derivation, the approximation is made that the percentage deviations for any element are small.

REVIEW: A paper such as this can be judged in two ways: how well the mathematics is done and how well reality fits the model that has been assumed. The author claims that both are quite good.

The paper contains quite a few misprints and/or errors. The most obvious examples of these in the mathematics are:

(1) Equations 10 and 11 are not the variance, but the standard deviation.

(2) Equation 10 is not an estimate, but is an exact calculation--if the assumption of normality is justified.

(3) The approximation--the log of a parameter value is normally distributed if the value itself is--is true only when the relative deviations are small. It is equivalent to ignoring the second order terms in the expansion of log(1+x). There is then little point in trying to retain non-linear terms by using the log and $\tanh^{-1}$ in Equation 11 since they are not exact unless log(1+x) is normally distributed. Equation 5, which uses the linear approximation for the answer is probably as accurate as the derivation

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

allows.

(4) Example 2 has some misprints and the answer appears to be incorrect. The method of solution is far too complex since the double integral can be reduced to a single one by standard methods. The resulting single integral is simply a cumulative Gaussian distribution which can be evaluated from the tables.

In terms of fitting reality, the assumptions are unduly cumbersome for the derivation and only justified in special cases of component parameters:

(1) The assumption is made in most of the paper that the distribution of element values is Gaussian and that the tolerance interval specified is $\pm$ 3 standard deviations. This is only likely to be true for parts where there has been no sorting and where the accuracies are closer than a few percent. In any event, the manufacturer of the parts should be consulted.

(2) If the log of the values had been assumed to be normally distributed (instead of the values themselves), the model would fit most any physical situation just as well and the derivation would have been vastly simplified.

The whole derivation can be done more simply by using the following three theorems.

(1) The mean of the sum is the sum of the means.

(2) The variance of the sum is the sum of the variances (for independent quantities).

These first two theorems are independent of the distributions of the several variables.

(3) The sum of several Gaussian variables is itself a Gaussian variable.

The result of the above classical derivation is rather well known and is widely used for the combination of random (and uncorrelated) errors. The restrictions should be kept firmly in mind. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Individuality in small-plant reliability

AUTHOR: Irvan J. Bearer, Martin Marietta Corporation, Baltimore, Maryland

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 59-69

PURPOSE: To show that a central reliability group may be more expensive for a small business than distributing the reliability function throughout the effort.

ABSTRACT: Increases in performance requirements and environmental severity, coupled with customer demands for analysis, review, testing, demonstration, training and documentation have pushed reliability costs to a critical stage. To prevent short-cutting an adequate program, reliability manpower costs must be reduced. The contrasting situations between plants with independent reliability organizations and plants with the reliability tasks distributed among existing departments will be discussed. The work atmosphere that is characteristic of many small plants and its adaptation to the organizational technique of task integration will be described. Examples will be presented of reliability work assigned according to engineering planning and procedures to those departments with personnel capable of doing the work. Guidance, unity, strength and control of a task-integrated reliability program will be shown to be the responsibility of a management staff representative. Replies to a questionnaire on the distribution of reliability manpower will be analyzed with respect to the principle that, in small plants, reliability activities are performed by each of the major departments. (Author)

REVIEW: It is undoubtedly more effective to have each person on every phase of a project well acquainted with the problems and requirements of a higher reliability program. In general, it is difficult to train or find people in this area. That is the reason for the specialist groups--to give advice to those who need it. In the course of years or decades, upgrading in reliability will come from self-training, company educational programs and formal education.

This paper is directed toward management planning of a reliability program. ##

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Serial Number 410 -1
Codes 840;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relationship of field reliability to AGREE bench-test reliability

AUTHORS: J. F. Thiel and H. J. Kennedy, ARINC Research Corporation, Washington, D. C.

SOURCE: IRE Transactions on Reliability and Quality Control, vol. ROC-11, July, 1962, pp. 70-85

PURPOSE: To report on a test for the purpose of trying to relate AGREE bench-test results to field-test results.

ABSTRACT: The purpose of this test was to establish a quantitative relationship between AGREE bench-test results and field-test results, as measured in terms of mean time-between-failures (MTBF). The scarcity of field data on AGREE-tested equipments and the variations in field conditions and definitions of failure prevented direct comparison of field and bench results. Therefore, AGREE results were compared with composite field data on many airborne equipment types, the comparison being made in terms of a factor reflecting the relationship between equipment complexity and observed MTBF. The comparison took into account 1) two levels of test severity, 2) two degrees of optimism in interpretation of test results, and 3) differences between tubed and transistorized equipments.

Comparison shows that the observed field MTBF was generally higher than the observed bench MTBF for similar equipment types. These findings are reasonably indicative of what might be expected when additional AGREE and field test data are accumulated. In order to improve feedback of information to AGREE, it is recommended that methods and definitions used in military-sponsored field tests be standardized. These changes would appreciably increase not only the predictive value of bench tests but also the usefulness of future field evaluations to all users of field data. (Authors)

REVIEW: The authors have done well with a most difficult subject. The paper is somewhat difficult to read, but this stems from the complexity of the problem rather than the authors' ability. The recommendations on better and different field failure reporting systems are good, but this particular problem has many difficult ramifications. Many articles have been written on it and many different things have been tried to improve the reporting situation.

Further study is needed on their suggestion that any operator dissatisfaction should be considered a failure even if further investigation shows the equipment to be good. There are two different systems to be considered. One is the operator and equipment and the other is the equipment with an "impersonal operator" such as one has in laboratory tests. These two systems might well

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

have different failure experience. Perhaps the operator could have a "failure rate" associated with him.

When "least squares" straight lines are fitted to points, the line gives an estimate of the average behavior. Beside the line equation, it is of interest--and importance--to know the degree of uncertainty in the estimates of the line parameters and to know some measure of the population scatter about this line. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A selected bibliography on reliability

AUTHOR: Harold S. Balaban, ARINC Research Corporation, Washington, D. C.

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 86-103

PURPOSE: To offer a selected bibliography on reliability.

ABSTRACT: The bibliography presented in the following pages lists over 200 books, articles, and reports dealing with various aspects of reliability. Also listed are periodicals, conventions, and symposia which are sources of information on this subject.

This selection of publications represents only a small part of the literature that can be considered to be within the scope of the general subject of reliability. Undoubtedly some excellent references have been overlooked. For further reference material on particular subjects, the reader is advised to consult the reliability bibliographies included in the following list, as well as the bibliographic material in those listed items that deal with the subject of interest.

Most of the references cover the period from 1957 through 1961. Reference 207 contains over 750 references concerning material published prior to June, 1956. (Author)

REVIEW: This is an ambitious undertaking and it will be useful to those who have not been long active in the field. There are very few articles listed from the "popular" magazines. Virtually all are books or publications of professional societies or government agencies. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The role of components in satellite reliability

AUTHOR: J. A. Morton, Bell Telephone Laboratories, Incorporated, Murray Hill, New Jersey

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, July, 1962, pp. 104-106 (presented at the 8th National Symposium on Reliability and Quality Control)

PURPOSE: To discuss the principles used in certifying components for high reliability applications.

ABSTRACT: In satellite and submarine cable installations, the cost of the electronics components is not a large portion of the system cost. In these cases, then, almost nothing is spared to select for use only those produced items which are most likely to succeed. The wide variety and range of thermal, chemical, mechanical, etc. stresses makes the selection of types very difficult. The type can be designed so that wear-out failures are not a problem. Infant mortality can be reduced by constant engineering attention to the training and supervision of operations personnel and to the design and maintenance of the manufacturing facilities. This must be coupled with extensive testing and statistical quality control techniques throughout the process. The product is then aged to maturity before being used. The failure modes of the remaining parts are many and varied. The parts must be applied under the conditions of certification or less and they must be handled with care during further production.

REVIEW: This is a rather general and interesting summary of the philosophy of producing very reliable equipment where the parts cost is small compared to the system cost. The Bell Laboratories have had considerable experience and success in this area and thus can speak with authority. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic packages vs. space torture

AUTHOR: Arnold Pollack, General Manager, Aerotest Laboratories, Incorporated, Deer Park, L.I., New York.

SOURCE: Environmental Quarterly, vol. 7, October, 1961, pp. 20-23

PURPOSE: To discuss the thermal problems in packages in space.

ABSTRACT: In space, heat is transferred by conduction and radiation only; convective heat transfer is negligible because there is no atmosphere. Absorption and emission of radiation by warm bodies is a function of temperature and wavelength. The greatest part of ultraviolet (uv) radiation is absorbed in the ozone layer and never reaches the earth's surface. Out in space, the uv is very intense and many things must be protected from it. Inside the skin, the temperature will change as the radiation changes. Facing the sun, there is an influx of heat, facing cold space, there is an outflow. If the thermal mass is high, there will be a time lag in the temperature changes and,if the lag is long enough, the changes will be reduced. The heat flow by conduction is impeded by even very thin joint spacings. Spaces in heat paths should be filled with alumined-powder-packed vacuum grease. Aluminum is a much better heat conductor than magnesium. The vacuum heating (cooling) environment of space can be simulated by vacuum chambers which have radiation sources and sinks. In some chambers, special features are provided such as satellite rotation.

The testing crew is an important part of the chamber facility. When hotspots show up, they can correct them.

REVIEW: This is an introductory type article and summarizes thermal design and testing for vacuum environment quite well. Anyone who wishes detailed information will have to get it elsewhere. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Allowing for device variables in semiconductor circuit design

AUTHOR: R. E. Roberts, Military Electronics Division, Motorola, Incorporated, 8201 E. McDowell Rd., Scottsdale, Arizona

SOURCE: Space/Aeronautics, vol. 37, January, 1962, pp. 107-115

PURPOSE: To point out that semiconductor devices have odd parameter distributions and that these must be allowed for in circuit design.

ABSTRACT: The parameters of semiconductors vary with time, temperature and other circuit conditions as well as with the supplier and the lot. There is little information on some of these variations and some of the information is not guaranteed. Two parts with the same type number but made by different methods may both meet specifications but have widely different non-specified behavior. The distributions of parameter values are very distorted because of selection. Some parameter changes can be allowed for by proper circuit design; the effects of others can be reduced by compensation techniques. Trying to find just what the distributions are can be difficult. Tests may give some clue and the manufacturer may have some information. The important thing is to be sure that the allowance for parameter variations is adequate.

REVIEW: The purpose of this article is worthwhile and it is hoped that designers are aware of these points. Perhaps manufacturers can concentrate some effort in narrowing parameter spreads and making the distributions reproducible. Here is one area in which tolerance limits cannot be assumed to be the $\pm$ 3 sigma limits for a normal distribution of the parameter values. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dependence of power transistor failure on their energy characteristics

AUTHOR: Ralph P. Miller, Semiconductor and Materials Division, Radio Corporation of America, Erlton, New Jersey

SOURCE: Semiconductor Products, vol. 5, July, 1962, pp. 15-17

PURPOSE: To describe some experiments about a particular cause of power transistor failure.

ABSTRACT: The effect of energy absorption in a transistor is observed as a degradation of the voltage characteristics as a function of both collector current and the time duration of the pulse. For particular base termination, the integration of the volt-ampere product with time at the boundary where an abrupt change in voltage is observed is recognized as the energy limit. This energy limit is shown to be inversely related to reverse base current. The rate of change of voltage with time is observed to be a function of the thermal characteristics of the device, and the final limit of failure is a function of the collector-base diode. (Author)

REVIEW: The article is concerned with a very worthwhile subject, but it is very difficult to get any real information from it on account of its brevity. If the paper were two to three times as long, most of a reader's questions would probably be answered. ##

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Codes 615;817;838;
882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Least-cost allocations of reliability investment

AUTHOR: John D. Kettelle, Jr., Kettelle & Wagner, Paoli, Pennsylvania

SOURCE: OPERATIONS RESEARCH, vol. 10, pp. 249-265, March-April, 1962

PURPOSE: To present techniques for determining optimal redundancy allocation in a multi-stage system.

ABSTRACT: This paper presents two complementary techniques for determining optimal allocation of reliability investment in a multi-stage system. The first is a step-wise dynamic programming algorithm, which has proved to be a simple and direct means for obtaining the exact solution to the basic problem of least-cost allocation of redundancy. The second technique is an explicit solution to the investment allocation problem if the unreliability of each stage decreases exponentially (and continuously) as its cost increases. This solution is based on an inequality, which for reasonably reliable systems justifies minimizing the sum of the stage unreliabilities instead of the system unreliability. (Author)

REVIEW: This paper explains the application of a dynamic programming technique to the solution of a problem in redundancy allocation in a multi-stage system. An example is given and other applications are discussed. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dependability of a complex system

AUTHORS: C. Mohan, R. C. Garg, and P. P. Singal, Naval Research Group, Defence Science Laboratory, Delhi, India

SOURCE: OPERATIONS RESEARCH, vol. 10, pp. 310-313, May-June, 1962

PURPOSE: To obtain an expression for the pointwise availability of a complex system.

ABSTRACT: This paper examines the behavior of a complex system consisting of n components of constant failure rates λ_i and repair rates μ_i ($i = 1, 2, \ldots, n$). The probability that the system is operating at time t is obtained. The probability that it is in outage stage i at time t is determined. A particular case where the μ_i's are equal is also considered. (Authors in part)

REVIEW: This is a brief mathematical paper which will be of more interest to the theorist than to the design engineer. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimum preventive maintenance policies when immediate detection of failure is uncertain

AUTHORS: G. C. Noonan* and C. G. Fain, Technical Operations, Inc., Burlington, Massachusetts (*Now with International Electric Corporation, Paramus, New Jersey)

SOURCE: OPERATIONS RESEARCH, vol. 10, pp. 407-410, May-June, 1962 (letter to the editor)

PURPOSE: To develop the preventive maintenance schedule that will optimize system performance when immediate detection or repair of failures cannot be assured.

ABSTRACT: In the derivation of preventive maintenance policies it is generally assumed that system failures are detected and repaired immediately. In a complex system the failure of one component may impair the functioning (or reduce the effectiveness) of the system in such a way that immediate detection of the failure cannot be guaranteed. When failures are detected, repairs may be delayed by the unavailability of components or repairmen. It is shown in this note that under these conditions, even for exponential failure rates, optimum preventive maintenance schedules exist.

REVIEW: This is a mathematical note which extends the theory of optimum preventive maintenance policies. The material is clearly presented and relevant references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thin-films increase computer reliability

AUTHOR: Barry Miller, Assistant Avionics Editor

SOURCE: Aviation Week and Space Technology, vol. 77, September 24, 1962, pp. 59,63

PURPOSE: To describe the use of thin-film microcircuits to increase overall system reliability in a special-purpose space-borne computer.

ABSTRACT: Many conventional computers currently in use in space systems are fabricated by the cordwood technique, in which components are assembled like a stack of cordwood with their terminations soldered to etched circuit boards. The use of thin-film techniques in such computers is expected to increase reliability through a reduction in the number of hand-made interconnections, made possible by evaporating arrays of resistors and conductors. The thin-film unit also offers significant size and weight savings. A computer employing thin-film microcircuits is currently being built by the Solid State Physics Laboratories of Lear Siegler, Inc. under subcontract from Airborne Instruments Laboratory. The computer is to be used in an Air Force space system.

The approach to evaporating thin-films of passive elements on dielectric substrates was chosen because of (1) low production cost, (2) reproducibility in quantity, (3) ease of tooling fabrication processes to the company's proprietary circuitry, (4) growth potential for other system applications, and (5) availability of a number of thin-film sources. The computer employs vacuum-deposited nichrome resistors for all resistors except where values over 100,000 ohms or tolerances closer than 1% are required. In these exceptional cases, discrete resistors are added to the circuit. Discrete add-on capacitors, micro-diodes, and micro-transistors are also employed. Packaging and construction techniques are briefly described.

REVIEW: This paper is a brief qualitative description of an example of the use of thin-film microcircuitry in a space-borne system. Designers would require a more complete treatment than is given in this editorial-type article. The potential advantages of thin-films in terms of reliability, size, and weight are worthy of careful consideration. Consideration should also be given to the fact that thin-film circuits must be tested to see if they fail in some unsuspected way. In the current state of our knowledge, the reliability of parts made by a new method cannot be assumed to be high just because many conventional failure mechanisms are eliminated.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation effects in semiconductors

AUTHOR: Gunther Wertheim, Bell Telephone Laboratories, Murray Hill, New Jersey

SOURCE: NUCLEONICS, vol. 20, July, 1962, pp. 47-50

PURPOSE: To acquaint the reader with radiation effects in semiconductors by describing the basic concepts of radiation-induced defects.

ABSTRACT: Radiation effects in semiconductors can be characterized by measurable changes in the electrical properties of the irradiated material. Some of our knowledge about these effects has been gained by a simple resistance measurement across a semiconductor specimen exposed to short pulses of radiation. From the resistance measurement, conductivity can be obtained and excess carrier concentrations and lifetimes can be determined from conductivity. Changes in the electrical properties depend in part on the nature and energy of the incident radiation. For example, when a charged particle passes through matter, energy dissipates mainly in the production of ionization and to a lesser degree in the production of atomic displacements. The excess carrier lifetime due to ionization characteristically has values in the range from 10^{-3} to 10^{-7} sec. This relaxation time is due to the fact that hole-electron pairs recombine mainly through the agency of crystalline defects which have electronic energy levels in the forbidden gap. The only permanent changes produced by bombardment of semiconductors result from the displacement of atoms and arise from the direct interaction of incident particles with nuclei. The number of the displacements depends on the nature and energy of the incident particles and on the minimum energy required to remove an atom from a lattice site. These defects can be detected even in low concentrations (10^{10} defects/cm^3) since they have energy levels in the forbidden gap similar to those of chemical donors and acceptors.

REVIEW: This article is directed to those readers with a passive knowledge about the theory of solids. The author describes basic mechanisms which help explain radiation effects in semiconductors with special attention given to detecting and analyzing these effects. Although written as an introductory article, the subject matter is well documented for more detailed information. Also there are references for those desiring a more general treatment of radiation effects in semiconductors and other solids. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation effects in semiconductor devices

AUTHOR: James W. Easley, Sandia Corporation, Albuquerque, New Mexico

SOURCE: NUCLEONICS, vol. 20, July, 1962, pp. 51-56

PURPOSE: To describe how various semiconductor devices react to radiation exposure by characterizing the radiation-sensitive regions and mechanisms of the device.

ABSTRACT: The subject matter is primarily devoted to characterization of three general classes of radiation effects in semiconductor devices. Displacement, surface, and ionizing effects are considered with a brief discussion of current knowledge concerning the origin of each.

Displacement effects are discussed in terms of minority carrier lifetime and conductivity of the semiconductor. In addition displacement effects in four classes of semiconductor devices are characterized. Radiation-induced effects in silicon rectifiers which degrade device performance are described in terms of changes in conductivity, and reduction of minority carrier lifetime. Radiation-induced defect-energy levels in the energy gap between the valence and conduction bands determine the behavior of the Esaki Diode in a radiation environment. Radiation exposure reduces diffusion length; therefore the power output for a solar cell under a given illumination intensity is reduced when irradiated. For transistors the most pronounced effect of displacement is reduction of current gain. Reduction of minority carrier lifetime in the base region is generally the major contributing factor. Changes of conductivity can also alter device characteristics. Changes in the parameters of these devices resulting from irradiation are discussed as to cause and effect with graphical representation of the orders of magnitude to be expected.

The last two sections are brief in scope and content with only the transient radiation-induced current due to ionization receiving appreciable attention.

REVIEW: The author has condensed a considerable amount of information into a general discussion of radiation effects in semiconductor devices. However, failure mechanisms for each device are explained in detail with sufficient qualification. Extrapolation of the information presented to applications employing specific diodes or transistors can at best yield approximate ranges for device failure. An extensive bibliography is included for those desiring more detailed information. ##

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Code 711

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effects of stretching on the fatigue strength of 2024-T4 aluminum alloy

AUTHOR: J. O. Lyst, Alcoa Research Laboratories, New Kensington, Pennsylvania

SOURCE: Materials Research & Standards, vol. 2, pp. 751-753, September, 1962

PURPOSE: To describe fatigue experiments on stretched aluminum alloy.

ABSTRACT: It is known that moderate cold working does not usually damage the fatigue properties of either ferrous or nonferrous alloys. Little information is available on the effects of large amounts of tensile cold work on the fatigue of aluminum alloys. Samples of 2024-T4 rod were stressed after heat treatment to an area reduction of 5% to 25%. Axial-load fatigue specimens were then machined from the stretched specimens. Two curves are shown of the results. Below 10^5 cycles (life) an area reduction of about 18.5% increased the life. Above 10^5 cycles, there is little or no effect. The cold working was sufficient to cause minute cracking of the alloying constituents.

REVIEW: This is an interesting piece of work--especially in view of the fact that minute cracks did not cause a drastic reduction in fatigue life. A question that might be further explored is the effect of machining the specimen and thus removing the surface. The points on the S-N curve are not labeled as averages, yet there are more data than are shown. No statistical tests were used to analyze for an effect. The data shown in the graph of area reduction vs life (all at one load) would seem to indicate little, if any, significant effect (depending on the normal scatter) until about 15%-20% reduction. Since the paper is rather short, the author can probably furnish additional information. ##

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Codes 812;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some aspects of component reliability

AUTHOR: J. G. Assenheim, Computer Developments Ltd., Kenton, Middlesex, England

SOURCE: British Communications & Electronics, vol. 8, pp. 179-182, March, 1961

PURPOSE: To discuss component failures and their relationship to life tests.

ABSTRACT: Over the past few years the problem of reliability in electronic equipment has been given an increasing amount of attention as the degree of reliability required in service has become steadily higher. A number of papers have been published recently on transistor reliability, and also on the results of reliability testing of other components, some of them conflicting, and confusion can arise due to the very different degrees of reliability which are claimed for similar components. The reason for this is that most of the results quoted apply only to the particular set of circumstances existing when the tests were performed. It is intended to stress here how important it is to quote operating conditions as a factor in component reliability. In this article only component reliability is considered and failures due to such things as bad soldered joints, pieces of loose wire in the circuitry, and clumsy servicing, though important are not included. (Author)

The types of components (and typical failure rate ranges) discussed are transistors (0.04% to 0.4% per 1000 hr.), semiconductor diodes (0.02% to 0.1% per 1000 hr.), capacitors (0.003% to 0.3% per 1000 hr.) and resistors (0.002% to 0.01% per 1000 hr.).

REVIEW: The emphasis on carefully interpreting reliability results is good. The discussion on failure mechanisms may be somewhat out of date for semiconductors, since (as the author says) the field is changing so rapidly. In addition, there are "run-of-the-mill" transistors and there are high reliability (very high cost) transistors; each has different failure behavior.

The article is a survey one and contains little that is new. As such it will be of more interest to those who have not been in this field a long time. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of a cumulative damage concept to fatigue

AUTHOR: R. R. Gatts, Mechanics of Materials Engineer, The General Engineering Laboratory, The General Electric Company, Schenectady, New York

SOURCE: Tranactions of the ASME Journal of Basic Engineering, vol. 83, Series D, pp. 529-534, December, 1961

PURPOSE: To describe and develop a theory of cumulative damage and to derive an equation for a fatigue curve.

ABSTRACT: Damage is defined as the decrease in strength, from one fatigue cycle to the next, of the already damaged material. This strength (S_f) is the single load required to fail the material and is similar to tensile strength (S_e). The endurance limit of the already damaged material is also introduced. Two big assumptions are made: (1) S_e/S_f = constant of the material, and (2) the damage in one cycle is proportional to the energy acquired by the material in going from the stress S_e to the peak value of stress, for that cycle. The further simplifying assumption is made that the stress-strain curve in this region--for increasing stress--is a straight line. From these concepts and assumptions an equation is derived for the S-N diagram (or fatigue curve). This curve has the proper general shape even at the low cycle end. Some dimensionless parameters are introduced and curves are plotted from these. Experimental points from the literature are shown to agree very well in some cases, and fairly well in others. The case of stepped stress amplitudes is also considered and is compared favorably with experiment.

REVIEW: This is another of the many theories of cumulative damage in fatigue and is shown to agree reasonably well with experiment. The concepts of various strengths are somewhat difficult to grasp because the definitions are too short. The discussion is divided into two parts; the first part is not referred to at all in the second. The equations (first part) (1a) and (1b) are not consistent since in (1a) the damage per cycle is assumed proportional to some function of the instantaneous stress amplitude (and implicitly independent of the number of cycles). But equation (1b), a special case of (1a), contains S_e which is obviously a function of n. There are other mathematical technicalities in the second part that interfere with rigor, but the final formula can certainly stand on its own. The assumption that damage is proportional to the total energy acquired by the material after it reaches the stress S_e would seem to be on rather

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

doubtful ground since the major portion of this energy is simply stored elastic energy. Perhaps a better way to bring in the necessary result would be to postulate the equation just preceding (3a). This would avoid the two parts of the second assumption, both of which are rather shaky.

Regardless of the method of derivation, the fatigue equations may well be useful for predicting fatigue damage if the extension to a statistical model is as simple as the author indicates. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Surface reactions during metal fatigue

AUTHOR: (Condensed from ASTM Preprint No. 62 (1962)--see REFERENCE below)

SOURCE: The Journal of Environmental Sciences, vol. 5, August, 1962, pp. 16-17

PURPOSE: To report on some experiments on gas evolution and surface reactions by metal fatigue specimens.

ABSTRACT: Chemical reactions at metal surfaces apparently play a important part in the fatigue process, but visible evidence of these reactions is hard to get. One purpose of this work was to provide such evidence and to determine when the reaction begins. Aluminum alloys were used for most of the experiments, but there were some carbon steel and magnesium alloy specimens. Gas evolution was observed in bending and torsional fatigue, but not in static loading. The evolution was decreased or eliminated if the specimens were kept in a dry box for several days, then fatigued upon removal. Where bubbles occurred under the tape, which was placed on the specimen surface, they came before any cracks could be detected. The gas appears to be atmosphere plus hydrogen. There appeared to be some beneficial effect of the tape on fatigue. This may conflict with other work which showed a detrimental effect by hydrogen and water vapor.

REFERENCE: "Gas evolution from metal surfaces during fatigue stressing," by W. L. Holshouser and J. A. Bennett, ASTM Preprint No. 62 (1962)

REVIEW: The surface properties of materials are becoming more important all the time. This work is very interesting and it is hoped that it will continue. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Vibration testing of solid propellant rocket motors

AUTHORS: C. W. Bellamy and C. F. Sanders, Rocketdyne, A Division of North American Aviation, Inc.

SOURCE: The Journal of Environmental Sciences, vol. 5, August, 1962, pp. 18-20

PURPOSE: To describe some work on the vibration testing of rocket motors, and to indicate some of the problems which are encountered in this field.

ABSTRACT: Solid propellant rocket motors may fail in several ways under the influence of the vibration environment. The fact that a large fraction of the mass of these devices is a viscoelastic material which can behave explosively brings some very special problems to vibration testing. The necessity to protect against hazard and the search for a clear engineering understanding of the vibration phenomena of solid propellant motors have led to a set of techniques which do much to dispel mystery in this field (see Abstract and Review Serial Number 161).

Solid propellant rocket motors may be expected to encounter extremely severe environmental history in use. The environmental reliability of such motors, in the opinion of the authors, can best be determined by earth-bound testing to a set of limits calculated to produce a greater probability of failure in the short term than that in any credible use-situation, rather than by an attempt at simulation. Thus very strenuous test conditions may be specified.

The operation of vibration testing of rocket motors is potentially hazardous and should only be done by remote control. Data concerning the internal behavior of the motor is vital, and, properly selected and used, can serve both the purposes of engineering data and safety. The selection of the number and locations of accelerometers must be made specifically for the type of motor to be tested. The choice of the best locations for thermocouples must depend on the ability to predict maximum stress locations as these will be the hottest spots. It is essential to conduct vibration tests over a wide range of temperature. Five useful tools in the control room are a ratio circuit, an X-Y plotter, a phase angle meter, a multichannel direct-inking temperature recorder, and a dual-beam oscillcscope. The uses of these tools are indicated. (Authors in part)

REVIEW: This paper contains useful information for those concerned with the vibration testing of rocket motors. It serves to clear up some of the mystery referred to in the paper covered by Abstract

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

and Review Serial Number 161. As the authors indicate, however, many problems remain, perhaps the greatest of which is that of obtaining a good estimate of the combined use-environments in which a rocket motor must perform, and of designing proper tests based on that data and the required reliability. This is a fertile field of endeavor for the environmental engineer. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An analysis of cooling methods for reliable operation of components

AUTHOR: Paul S. Birman, Kepco, Incorporated, Flushing, New York

SOURCE: Electronics, vol. 35, June 22, 1962, pp. 56-58

PURPOSE: To show that blower cooling is more reliable than natural convection in a particular power supply.

ABSTRACT: A major problem in the design of high-powered electronic equipment is the dissipation of the heat. In heavy duty transistorized power supplies the problem is especially acute. The choice is usually between forced air cooling and natural convection. The considerations are size, power levels, thermal efficiency, system reliability and the proximity of other equipment. In a 75-watt power supply the forced air cooling is by far the best. The heat dissipators are smaller and the system is more reliable. If the blowers were not used, many more transistors would be required to keep the junction temperatures low enough. In the example here, the failure rate of a blower is about that of one transistor. The choice is between five transistors and a blower or 12 1/2 transistors and no blower. Obviously the first case is better by far. In addition, all other components are cooler which improves their performance and lengthens their life. A table shows the contribution of each type of part to the overall estimated failure rate.

REVIEW: In the example, the figures clearly show the advantages of a well-designed forced air cooling system. If the failure rates of the components had been different or if the exponential failure law is not obeyed, the answer, of course, might have been different--so the results should not be indiscriminately applied. The table headings and descriptions are ambiguous. In a private communication the author has pointed out that the numbers in the table have all been divided by the number of transistors (presumably "5"). One may note that the blower failure rate is not consistent, then, between the example and the table. ##

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Serial Number 428
Codes 711;821;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fatigue sensitivity and reliability of mechanical systems

AUTHOR: A. M. Freudenthal, Columbia University

SOURCE: 16 pp., presented at Automotive Engineering Congress, Detroit, Michigan, January, 1962, Society of Automotive Engineers paper 459A (summarized in SAE Journal, vol. 70, May, 1962, pp. 37-41 under the title "Fatigue sensitivity measures reliability")

PURPOSE: To summarize the failure behavior of structures and to present a model for comparing fatigue life and one for comparing tensile strength.

ABSTRACT: Probabilistic methods are necessary in the design of structures because of the statistical nature of, and scatter involved in, the loading, the material, and the response of the structure. The load spectrum of a structure is not constant amplitude fatigue nor a single load application, but a combination of high and low loads in a complex spectrum. In general, a structure will be weakened by repeated small loads. From time to time there are high loads which may cause the weakened structure to fail, or if not, will contribute to the weakening process. A load spectrum, showing the probability density of a given load could be derived for any structure in a particular use. The fatigue life of a structure depends considerably on its stress concentrations and redundancies. Laboratory tests of constant amplitude fatigue on artificial specimens are not useful for the prediction of the fatigue life of structures. A parameter is derived that is correlated to the probability of structural failure by fatigue as opposed to ultimate load failure. Models of failure are then derived for failure by ultimate load and for failure by fatigue. These models are statistical in nature and expressions for the reliability are derived and analyzed. The models are considered to be about the simplest that fit reality. They are useful largely for comparing the reliabilities of alternate methods or structures.

REVIEW: This is an extensive paper and will be hard reading for those not rather familiar with the subject. The models are not easy to evaluate in many cases and so their application may be difficult. The emphasis on the probabilistic nature of failure is very good.
##

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Serial Number 429
Codes 770;782;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Space laboratories--orbital simulation chambers enhance operational reliability of satellite systems

AUTHORS: F. D. Adarba and R. C. Geiger

SOURCE: Missiles & Space, vol. 7, December, 1961, pp. 24-25

PURPOSE: To describe the High Vacuum Orbital Simulation (HIVOS) Chamber at Lockheed Missiles and Space Division (LMSD).

ABSTRACT: The world's largest High Vacuum Orbital Simulation (HIVOS) Chamber was activated at Lockheed Missiles and Space Division (LMSD) in August, 1961. Capable of obtaining a pressure of 10^{-8} mm Hg, the HIVOS chamber will approximate conditions 350 miles above the earth's surface.

The specific purpose of HIVOS is to enhance the operational reliability of a satellite system and to develop such a system for a minimum orbital life of at least one year. Objectives will be to determine mean-time-to-failure modes of the payload and supporting equipment when subjected to the simulated orbital environment of temperature and altitude. Determination of the degree of operational degradation, thermal compatibility of equipment, and operation effects of equipment in a vacuum will be of primary concern.

One of the foremost problems HIVOS will explore is materials reliability under extreme temperature variance. HIVOS will permit the entire vehicle to be tested as an integrated unit. A temperature range from +500°F to -100°F can be achieved.

The structure and operation of the chamber are briefly described.

REVIEW: This article provides a brief description of the means adopted by one company to simulate some of the environments of outer space.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Valve reliability--proved fundamental design concepts

AUTHOR: William H. Simons

SOURCE: Missiles & Space, vol. 7, December, 1961, pp. 32-33, 44

PURPOSE: To describe a philosophy of design and manufacture of mechanical valves.

ABSTRACT: To say "reliability starts with design" is only partly true; a more complete statement is "reliability starts with design only when proved design concepts are incorporated." If proved concepts are used, a more reliable design will result than if unproved concepts are tried. Some examples of precision valve features are (1) minimum restriction to flow when open, (2) dead-tight seal when closed, and (3) complete flushing of valve when open. A soft-seated design is more reliable because there is resilience in the seal and it wears less. Slight wear or changes will not cause a malfunction. Free floating seals assure that the fluid flow completely flushes the valve and no particles are left in crevices to cause damage. Field service reports are necessary to provide the proved concepts. Especially valuable are the bad reports which show up design or production weaknesses. A part or valve may meet all specifications when it is new; but this is no assurance that it will meet specifications after a million cycles. This is why field-proven concepts of reliable design are so important.

REVIEW: This seems to be more of a product line description than an article describing the reliability of valves in general. While the features which are described here undoubtedly contribute to a good type of valve, other manufacturers of mechanical valves might have different ideas on proved designs for reliability. ##

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Serial Number 431
Codes 771;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An optimal sequential accelerated life test

AUTHORS: S. Bessler*, H. Chernoff, A. W. Marshall**, Stanford University (*Now at General Telephone and Electronics Laboratories, Inc., Palo Alto, California. **Now at Boeing Scientific Research Laboratories, Seattle, Washington.)

SOURCE: Technometrics, vol. 4, pp. 367-379, August, 1962

PURPOSE: To investigate optimal sequential designs for accelerated life tests.

ABSTRACT: This paper investigates optimal sequential designs for accelerated experiments to test whether a device subjected to a standard stress has an expected lifetime exceeding a specified value. It is assumed that the lifetime is exponentially distributed, with expectation a function of the stress and an unknown parameter. This function is assumed known (at least for some range of stresses). At each stage of experimentation, the experimenter chooses a stress level and obtains an observation of lifetime at a cost proportional to the expected lifetime, i.e., proportional to the expected length of time required to obtain the observation. This cost may make it desirable to choose a greater than standard stress and perform an "accelerated test".

Most of the paper is devoted to the case where the reciprocal of the expected lifetime is a quadratic function of stress. At each stage of experimentation, the optimal design (obtained by an application of the combined results of Albert [1] and Bessler [2]) involves randomizing between at most two stress levels. (Authors)

REFERENCES: [1] A. E. Albert, "The sequential design of experiments for infinitely many states of nature," Ann. Math. Stat., Vol. 32 (1961), pp. 774-799

[2] S. Bessler, "Theory and applications of the sequential design of experiments, k-actions and infinitely many experiments. Part I--Theory," Applied Mathematics and Statistics Laboratories, Stanford University, Tech. Reprt. No. 55, prepared under contract N6onr-25140 for Office of Naval Research, March, 1960, pp. 1-50

REVIEW: This paper is a contribution to the mathematical theory of life testing. As such it will be of more interest to the theoretician than to the design engineer. From a practical point of view, the condition that the reciprocal of the expected lifetime be a quadratic function of stress may prove to be a serious restriction.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimal accelerated life designs for estimation

AUTHOR: Herman Chernoff, Stanford University

SOURCE: Technometrics, vol. 4, pp. 381-408, August, 1962

PURPOSE: To develop a technique to obtain optimal accelerated life designs for estimating the parameters of the distribution of the lifetime of a device under a standard environment.

ABSTRACT: The estimation of the probability distribution of the lifetime of a device under a standard environment may require an exorbitant amount of testing time when the lifetime is large. A common approach to this problem is that of subjecting the sample to environments of greater stress than that of the standard environment. On the basis of the results for these accelerated conditions, it is desired to extrapolate to the standard environment. Some assumptions must be made concerning the relationship between the probability distributions of lifetime for different stress levels. Once such assumptions are made, it is possible to pose the problem of selecting the best stress levels to estimate the desired distribution. This is the problem of optimal design.

Doubts about the underlying assumptions would cast serious doubts on the results obtained from accelerated designs. It often pays to modify "optimal" designs to obtain designs which are almost as good under the assumptions and whose "goodness" is not sensitive to deviations from the assumptions.

The applicability of the methods described depends on assuming that the investigator has, before experimenting, a rough idea of what the relevant parameters are. In the absence of this information, some preliminary experimentation may be required.

Five design problems are presented, together with the corresponding optimal designs. The five problems are: (1) Quadratic Failure Rate, (2) Exponential Failure Rate, (3) Quadratic Failure Rate; Limited Time, (4) Quadratic Failure Rate; Limited Time; Replacement, and (5) Failure Rate Linear in the Parameters. The problem of estimating the desired parameters using data from optimal or non-optimal experimental designs is discussed.

The techniques employed on the five problems can be applied to a wide range of variations. Although an exponential distribution of lifetime is assumed in each, this assumption is not essential to the general approach.

REVIEW: This paper is a contribution to the mathematical theory of accelerated life testing. Attention is given to the applicability

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of the results through the medium of numerical examples, together with clearly-presented discussion and figures. Emphasis is appropriately placed on the caution to the user that the validity and usefulness of any acceleration technique depends strongly on the extent to which the model represents the true distribution of lifetime under various environments. ##

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Serial Number 433
Codes 832;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Pneumatic logic--IV: safety and reliability

AUTHOR: E. L. Holbrook, Barker Instrument and Machine Co., Inc.

SOURCE: Control Engineering, vol. 9, pp. 89-92, February, 1962

PURPOSE: To show five examples of safety circuits.

ABSTRACT: Operator error, machinery malfunction, and loss of power all jeopardize the operational reliability of a system. Remote and unattended equipment in particular demands protection from these hazards. In examples ranging from simple to complex, the author combines pneumatic transducers, actuators, and logic elements to control equipment safely and reliably. (Author)

REVIEW: This paper is largely concerned with safety and the response of a system to the malfunction of its parts. (Little if any attention is given to the life of the system per se.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Neuron technology builds reliable circuits from unreliable components

AUTHOR: M. J. Pedelty, Adaptronics, Inc.

SOURCE: Control Engineering, vol. 9, pp. 115-119, May, 1962

PURPOSE: To describe several methods of redundancy for simple computer circuits.

ABSTRACT: The definitions used here appeared in the first article (Control Engineering, vol. 9, April, 1962). Four kinds of errors in a neural net are fluctuations of threshold values or signal strengths and malfunctions at the input or output. Thus a neuron may compute some other function than the intended one. An example is given of triplet networks for the AND and OR (exclusive) functions. Triplet networks may be used for the components of a triplet network and so on. Repeating the replacement three or four times may yield optimum reliability. A majority organ gives an alternative improvement, but the reliability is limited by that organ. An example is given of creating parallel nets whose structure corresponds to that of a many-valued logic. The new part of this is a different connectivity which converts the structure from a Lewis 2^b-valued logic to a 2-valued Boolean logic. This network can require 1/200 the lines required with the von Neumann scheme. Redundant coding of information by the structure is another possibility and an example is given. Errors can also be regarded as the introduction of noise into the network, and treated by information theoretic techniques; this is briefly described. Molecular electronics offers one of the best ways of achieving high redundancy with reasonable size and cost.

REVIEW: This is a summary article for the intermediate reader. The treatment is not elementary enough for the beginner. Reading the first article is recommended if the language is at all unfamiliar. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Residual stresses resemble static stresses

AUTHOR: (Editorial Matter)

SOURCE: SAE Journal, vol. 70, August, 1962, pp. 47-52 (abstracted from SAE Handbook Supplement 198, SAE Information Report "Influence of residual stress on fatigue of steel"--SAE J783)

PURPOSE: To show the effects of residual stresses on fatigue behavior.

ABSTRACT: Investigation of how residual stresses affect the fatigue behavior of harder-than-R_c 25 steels reveals:

1. Residual stresses resemble mechanically imposed static stresses of the same magnitude.
2. Residual stresses are beneficial if compressive, and detrimental if tensile.
3. Residual stresses hardly change when fatigue loading is near the fatigue limit.
4. Residual stresses may relax at stresses above the fatigue limit.
5. Fatigue life at high applied stresses depends little on initial residual stresses.
6. Peak residual stress near the surface is the significant residual stress in bending for both tension and compression. (Author)

REVIEW: This is certainly a valuable piece of work which should assist designers in the area of failure by fatigue. It should be noted that the fatigue tests performed for the study were all of the constant amplitude variety (typical S-N curves). It is possible that some of the results might have been different in a complex fatigue spectrum. Other, similar limitations of the experiments should be kept in mind when applying these results. ##

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Serial Number 436
Codes 711 ;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Atmosphere shortens metal fatigue life; protective films can minimize effects

AUTHOR: (Editorial Matter)

SOURCE: SAE Journal, vol. 70, September, 1962, pp. 60-61 (based on a presentation by W. L. Holshouser and J. A. Bennett, National Bureau of Standards, at Biennial Meeting of Division 20--Mechanical Prestressing of Metals--SAE Iron and Steel Technical Committee)

This paper covers essentially the same material as that of the paper covered by Abstract and Review Serial Number 425. ##

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Serial Number 437
Codes 711;822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weibull plot predicts fatigue life

AUTHOR: Leonard G. Johnson, General Motors Corporation

SOURCE: SAE Journal, vol. 70, September, 1962, pp. 67-68 (condensed from a presentation to the SAE Iron and Steel Technical Committee)

PURPOSE: To show how a Weibull distribution can be used.

ABSTRACT: This is a very brief presentation of the Weibull distribution and its use in life testing. Some equations are shown and the special graph paper is described.

REVIEW: This is so brief that it serves only as a bare introduction. The author has written much more extensively on the subject and other people have, as well. Almost any of these will be more useful than the brief summary shown here. See, for example, the paper covered by Abstract and Review Serial Number 320, as well as the reference cited below.

REFERENCE: "The statistical treatment of fatigue experiments", Leonard G. Johnson. Report from General Motors Corporation, Research Laboratory, GMR-202, April, 1959 ##

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Serial Number 438
Codes 781; 833; 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability at high temperature

AUTHOR: William G. Nelson, Group Engineer, The Boeing Company, Aero-Space Division, Seattle, Washington

SOURCE: Hydraulics & Pneumatics, vol. 14, December, 1961, pp. 97-98

PURPOSE: To discuss the high temperature reliability limitations in hydraulic systems.

ABSTRACT: The trend toward higher flight speeds and reduced weight is reducing the reliability of hydraulic systems. The reliability of hydraulics in long flight duration, manned vehicle applications is not satisfactory. The lack of reliability of the higher temperature systems will limit the upward temperature trend. Systems can be made more reliable by designing reliability into the items. This calls for exacting design reviews and much testing during development. Several comments are made on items which are reliability problems. A table is given of the status of flight hydraulic systems.

REVIEW: The comment on the poor reliability of manned flight hydraulic systems would seem to be directly opposed to the viewpoint expressed in the paper covered by Abstract and Review Serial Number 439. The listing of problem areas is worthwhile and the effort to improve them and to get quantitative reliability data should be encouraged. A more complete paper on this subject can be obtained from the author. ##

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Serial Number 439
Codes 781;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fluid power reliability and performance data

AUTHOR: H. Stern, Thermal Engineering, General Engineering Laboratory, General Electric Co., Schenectady, New York

SOURCE: Hydraulics & Pneumatics, vol. 15, March, 1962, pp. 116-117

PURPOSE: To express some of the problems in specifying hydraulic system reliability.

ABSTRACT: Traditionally hydraulic systems have been efficient and failure-free, more so than electromechanical systems. Thus there has been no need to build up the store of quantitative reliability data that has been generated elsewhere. There is little correlation between laboratory tests and service conditions, although progress is being made in this area. The use of higher pressure, higher temperature systems raises problems that can only be answered by experience with them. At present, a manufacturer has no real method of meeting a guaranteed failure rate specification without either severe overdesign or expensive testing.

REVIEW: This is a short, frank statement of the quantitative reliability problem for hydraulic components. The effort toward finding quantitative lifetime figures on these components should be encouraged. ##

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Serial Number 440
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component reliability in Post Office equipment

AUTHOR: A. A. New, Post Office Research Station (England)

SOURCE: The Post Office Electrical Engineers' Journal, vol. 54, pp. 40-47, April, 1961 (A condensed version was given at the I.E.E. Symposium on Electronic Equipment Reliability, May, 1960)

PURPOSE: To summarize the status of and need for reliable components.

ABSTRACT: The Post Office has always needed long-life, reliable equipment. The demands for higher reliability are stronger today than ever. Failures may be catastrophic or of the drift type; the drift type are sometimes prevented by maintenance action. There is a reason for every failure. The use of statistics wherein randomness of some sort is assumed should not let us forget that fact. If parts are to be improved by redesign or a new start, the failure mechanisms must be known. Failures may be caused by chemical, physical, mechanical, or other processes. Some of these can be accelerated by increasing some stresses such as temperature or voltage; this is frequently done in testing. Care should be taken to see that the failure mechanism is not changed by the additional stress. Some parameters drift with time, but there is no general pattern. The immediate environment of a part is very important in determining its behavior. For many processes, a change in temperature of 10°C produces a change by a factor of 2 to 3 in deterioration rate. Humidity may cause chemical or galvanic corrosion. The voltage on capacitors and the current through resistors are important.

If a large number of parts are considered, their values will have some distribution. This can usually be approximated--to some degree--by a normal distribution, although deviations from this in skewness or bimodality may be very important. The actual number of failures per unit time is governed by the Poisson distribution in many cases. The average failure rate tends to be high at first, then drop, and finally has a hump due to wearout. If many different failure mechanisms are present, the curve may be rather constant.

Tables are given which show some of the Post Office experience.

REVIEW: This article shows some British experience in the reliability field and gives a general introduction to the problems of component reliability. ##

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Serial Number 441
Code 831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The quest for reliable earth-space communications

AUTHOR: Harry T. Hayes, Space Technology Laboratories, Inc., Los Angeles, California

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 23, pp. 481-488, June, 1962

PURPOSE: To discuss some communications systems used in earth-space vehicles.

ABSTRACT: The paper deals with the practical aspects of the evolution of a space communication system from the initial design concept to the performance in orbit. Selected design problems encountered during the design and test phases of several space communication systems are discussed along with the remedial action taken to correct unforeseen deficiencies. The telemetry, tracking and command system used to collect the data from Pioneer I, Explorer VI and Pioneer V are used in the paper as examples of system evolution. The paper is concluded with a brief discussion of current work to improve the efficiency and reliability of space communication systems. (Author)

REVIEW: This paper does not deal at length with the reliability problems per se that were involved in the particular craft that are mentioned, but does discuss the communication systems in moderate detail. It is basically a descriptive report. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The outgassing properties of mica with particular reference to the life performance of thermionic valves

AUTHOR: R. W. Lawson, Post Office Research Station, Dollis Hill, London N.W.2, England

SOURCE: VACUUM, vol. 12, pp. 145-152, May/June, 1962

PURPOSE: To describe the properties of the mica that is used in receiving tubes.

ABSTRACT: The investigation has shown that, compared with other components of a valve, the mica spacers are by far the largest potential source of gas. By using clamps the exfoliation of ruby mica that occurs at temperatures greater than 750°C can be prevented and the mica completely outgassed. The life performance of repeater valves made using such outgassed micas is not significantly different from those using unprocessed micas and hence it can be concluded that mica outgassing due to it being in contact with the cathode core at 730°C must be at a negligibly small level in the normal case.

However, the presence of mica spacers in a valve does place some limitations on the processing of the valve on the pump--the degree of anode degassing being limited by the fact that the mica spacers evolve gas during the R/F treatment. Furthermore the tightness of the cathode core fit in the mica spacer has to be a compromise between mechanical requirements and the avoidance of excessive gas evolution which occurs if the fit is too tight and the cathode temperature is greater than 750°C. For valves assembled and processed under the best conditions permitted by normal practice, probably the greatest influence mica has on valve performance is an indirect one. Valve performance depends on cathode temperature, and for a given heater-cathode system and watts input, the mica-cathode fit is the most important factor in determining cathode temperature. (Author)

REVIEW: This is a good paper on one aspect of tube design. The part devoted to the discussion of life, per se, is rather short and no statistics are given. Studies of this sort are important in that they provide information on failure mechanisms and causes of failure. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Preventive maintenance of large analogue computers

AUTHOR: J. Morrison, British Aircraft Corporation, Warton, Lancs., England

SOURCE: British Communications & Electronics, vol. 9, pp. 414-417, June, 1962

PURPOSE: To describe the maintenance system on a LACE computer.

ABSTRACT: Two schools of thought prevail regarding the application of preventive maintenance to analogue computers. One of these argues that no preventive maintenance is required since this operation itself by repeated insertion and removal of computing equipment may introduce faults.

The second school--that of the author--maintains that without preventive maintenance a gradual degradation in machine performance will set in, producing elusive problem inaccuracies and unrepeatable results.

A rather complete description is given of the maintenance system for the LACE analogue computer.

The maintenance program, at the time of writing, has been running for 30 weeks and statistics obtained have shown an encouraging drop in fault incidence with passing weeks. Operator morale shows a great improvement and very few faults have been reported during machine operation. Further compilation of statistics should enable "mean time to failure" rates of the various computing units to be predicted, with a view to increasing reliability and optimizing the checking periods.

The program has been instrumental in providing a more economical, accurate and reliable computing service and it is considered that these results more than justify the initial outlay required. (Author in part)

REVIEW: This is a descriptive article with some indication of the philosophy involved. The full failure history should be very interesting when it is published. The results for 30 weeks are not in themselves too valuable since mean times between failures of 8,000 - 10,000 hours are not uncommon for analogue computers with preventive maintenance. ##

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Serial Number 444
Codes 711;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dependencies in seal materials and design for environmental extremes

AUTHOR: J. W. Noonan, National Research Council, Canada

SOURCE: 15 pp., presented at National Aeronautic Meeting, New York, New York, April, 1962, Society of Automotive Engineers paper 523G (appears also in Machine Design, vol. 34, August 16, 1962, pp. 186-196)

PURPOSE: To summarize the behavior of seal materials at high and low pressures and temperatures and in the presence of radiation.

ABSTRACT: Vacuum effects: The sublimation of metals is negligible but polymers may lose appreciable weight. A silicone polymer was good up to 600°F; a phenolic polymer, a styrene butadiene copolymer and Kel F were good to 500°F. Not all experiments are directly comparable. Oxidation is the chief problem (for thermal stability) in air and bond stability seems to be the governing factor in vacuum. Little is known about the exact mechanisms of polymer degradation. Another effect is due to the removal of the surface layer of gas. Creep and fatigue are affected--usually beneficially. Some substances such as graphite lose their lubricating properties when the gas layer goes away. Many lubricants will evaporate at low pressures. The measurement of vacuum is, itself, somewhat of a problem at low pressures.

Radiation effects: A table shows the behavior of polymers under gamma radiation. Natural and polyurethane rubbers are the best, PTFE (Teflon) is one of the least resistant polymers. Ultraviolet (uv) degradation seems to require an oxygen atmosphere. The relative behavior of polymers seems to be the same for both uv and gamma radiations.

Temperature extremes: The fatigue behavior of metals seems to be improved at -320°F. Since all the low temperature tests were carried out while immersed in liquid nitrogen, the absence of oxygen may have been important. Below -320°F some metals and alloys become very brittle. Polymers are usually limited to the fluoroethylene types. Two special examples are given. Other data are given on low temperature wear and friction.

REVIEW: This is an introductory summary article and is useful as such; 24 references are listed together with three tables and nine graphs. Several omissions are: (1) A few metals may sublime enough under high vacuum to cause unpleasant coatings where not wanted. (2) The plasticizers for many polymers are especially troublesome in vacuum. (3) Teflon is apparently not affected by gamma radiation in a vacuum. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Proper motor application engineering can reduce costs and improve reliability

AUTHORS: Clarence F. Paulus and David R. Green, Cleveland Electric Illuminating Company, Cleveland, Ohio

SOURCE: 10 pp., presented at the AIEE Empire Tri-District Meeting, Erie, Pennsylvania, May 14-16, 1962, AIEE Transactions Paper No. 62-970 (also Electrical Engineering, vol. 81, pp. 519-522, July, 1962)

PURPOSE: To show how motors should be specified and applied in order to get optimum service life.

ABSTRACT: Motors are essential equipment in a power plant. Their failures may cause a shutdown as injurious to the system as the failure of a main unit. Maximum reliability at minimum cost can be obtained by application engineering of a high order of merit. This includes adequate record keeping; proper knowledge of ambient conditions and operating practices; thorough study of load characteristics, power supply, transferring and starting facilities and adequate specifications which do not impose costly non-standard requirements.

This paper is to a large extent a check-list of what must be done to do a good engineering job in motor application. It does not give all the answers, but it is hoped that if the suggested approach is used most of the problems will be solved in the most economical manner.

The application engineer has a tremendous field in power plant design. One of the most important areas in this field is the application of motors. He can do no less than accept the responsibility for this because he and he alone has the background information, and if he does a thorough job, he can increase the reliability while still holding the cost down to a minimum. (Authors)

REVIEW: This paper is concerned with motors in the range of 100 to 4000 hp. Sample failure reports, specifications and starting warnings are given. There is little of interest here to other fields. ##

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Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Choosing reliable and practical electronic controls

AUTHOR: P. H. Drinker, The Foxboro Company, Foxboro, Massachusetts

SOURCE: ISA Journal, vol. 9, July, 1962, pp. 43-46

PURPOSE: To review the main criteria in the selection of pneumatic and electronic controls.

ABSTRACT: Reliability and practicality are two of the most important considerations in selecting controls. Reliability is a relative term and has several ramifications. Most important, it means that the system (not just a few parts) must be free from critical operating difficulties. It also means that it is fool-proof and easily repaired when it rarely fails. The question of pneumatic vs electronic controls quickly arises. While pneumatic components are as reliable as electronic ones, the pneumatic system may not be--largely because of practical problems often (but not necessarily) associated with the air supply. Electronic instruments have fewer moving parts than air controls and the solid state components are as reliable as the air components. Ambient conditions usually pose no problem with either system and overall, there is little reliability difference between the two systems.

The electronic systems are more practical. There are no mechanical motions and no transmission lags, and they are more easily and simply incorporated into modern data systems. The choice of signal type (voltage or current) and signal level should be made on the basis of compatibility with present equipment, ease of use with auxiliary equipment, and plans for future expansion. The properties of the several types of signals and a check list for the signal level of new equipment are given.

REVIEW: The term reliability is used here in a qualitative and general sense. Some of the arguments for electronic equipment are not necessarily true, although the conclusions may be. Two examples are: "... it can be fairly assumed that to eliminate motion can only improve reliability." and "... there is no reason why solid-state electronic components should not be as reliable as pneumatic ones, providing equal standards of quality are maintained." The first may well be true if other factors are equal, but they are certainly not equal on the two types of controls. Some controls without motion can certainly be less reliable than some with it. The second either defines "equal standards of quality" or is not necessarily true. There are probably many solid-state devices on the market that are less reliable than pneumatic ones.

The transmission lags in an electronic system may be negligible when compared to air, but there may well be phase shifts in the

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

system. Electronic feedback can have good frequency response and thus be effective during transients, although it does not always have it. The beginner who reads this article should be careful about taking the opinions and reasons as unalterable fact. For others, this will be a convenient summary of comparison between pneumatic and various electronic control systems. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evolution toward reliability--how a simple mechanical design is refined

AUTHOR: Stephen G. Woodward

SOURCE: Missiles & Space, vol. 8, May, 1962, pp. 22-24

PURPOSE: To describe three steps in the evolution of an air shroud for a fuel nozzle.

ABSTRACT: The Bendix fuel nozzle for the J-79 engine has, as one part, an air shroud. The part is replaced when it has been damaged somewhat, but not enough to impair its operating function. About 30% of the units in service had thermal damage in the form of slight radial cracking and some warping. The "failure rate" of these parts gradually increases during the service life and then climbs more rapidly. A constant failure rate was assumed and a reliability calculated of exp(-0.3) = 74%. The MTBF was 500 hr. In a commercial version of the engine, the air shroud was welded to the housing nut. The time interval between overhauls was repeatedly extended. The damage on each part was similar to that before, only more severe. The MTBF was calculated to be 3200 hr and since 25% of the parts were failing in the 800 hr service period the reliability is exp(-0.25) = 78%. The material was then changed from AISI 310 to a stellite alloy. The holes were machined by electrical discharge instead of drilling. The service period is now 1200 hr and damage is occurring on less than 10% of the parts in this period. The reliability is then exp(-0.10) = 90.5%. Note that the reliability of the assembly is not affected by the degradation of this part since the part and assembly still function well.

REVIEW: This is an interesting little case history. The reliability calculations, however, are open to criticism. The term "MTBF" (mean time between failures) is probably incorrect; it should be mean time to failure. If 25% of the original units fail, then 75% have survived and 75% is then an estimate of the reliability rather than exp(-0.25). The way the statistics were gathered is not made too clear and thus a check on the calculations is difficult. ##

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Codes 872;882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mathematical model analysis of the general case system

AUTHORS: Benjamin Ellison and Victor Selman, International Electric Corporation, an Associate of ITT, Paramus, New Jersey

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 1-1--1-22, October, 1961

PURPOSE: To present mathematical methods for computing figures of merit for a continuously operating maintainable system with maintenance constraints.

ABSTRACT: A useful figure of merit for systems which must be operated continuously is availability (A), defined as the ratio of the sum of the intervals of time the equipment is capable of operating satisfactorily to the interval of time that its satisfactory operability is desired. Several expressions for A are cited, classified in terms of the criteria (a) whether or not the equipment remains energized during corrective maintenance, and (b) whether or not preventive maintenance is required. A specimen system consisting of five subsystems is given, and formulae are presented for various combinations of redundant units which have both repair and scheduled maintenance parameters.

REVIEW: This paper takes the form, for the most part, of quoting formulae related to the various combinations of redundant units considered. Although some proofs are given in three appendices, the paper does little to enlighten the reader as to the derivation and/or background of most of the formulae cited. The readability and usefulness of the paper to most readers would have been improved if more derivations and background material had been incorporated into the text, and less use had been made of expressions equivalent to "it can be shown that ... ." ##

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Codes 713;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quantitative evaluation of mechanical reliability

AUTHOR: David B. Ehrenpreis, President, David Ehrenpreis, Consulting Engineers, New York, New York

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 2-1--2-15, October, 1961

PURPOSE: To present a reliability technique for the determination of certain physical properties of structural and mechanical members of electronic and electromechanical equipments.

ABSTRACT: Formal documented mechanical reliability calculations have the following advantages over informal techniques.

1. They provide a record of the current thinking of reliability and design personnel.
2. They can be monitored and reviewed by others.
3. They may be revised at a later date in the light of new break-throughs and/or realistic test data.

A quantitative reliability mechanical design checklist should include only questions which necessitate simple numerical calculations which are realistic and can be performed quickly and efficiently. The calculation procedures should be unequivocally stated.

The paper includes outlines of typical formal documented calculations in stress, deflections, and margins of safety for printed circuit cards, drawers, racks, consoles, and compartments.

REVIEW: This paper makes a strong plea for the initiation and use of quantitative mechanical reliability calculations as a decision-making tool in the design of electronic equipment. The points are convincingly made, but the presentation would have been improved had a strong set of examples and/or case histories been included. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A mathematical model for system effectiveness

AUTHOR: Anthony Coppola, Rome Air Development Center

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 3-1--3-11, October, 1961

PURPOSE: To discuss the concept of system effectiveness with emphasis on its application to ground radar systems.

ABSTRACT: Availability may be defined as the ratio of operating time to the sum of operating time and down-time, and may be considered to represent the probability that an equipment will be in operation at any particular instant of time. Electronics systems, however, are designed not merely to operate, but to perform specific missions. In spite of satisfactory operation of an equipment, per se, its performance may be seriously affected by external conditions. A concept which takes these effects into account is that of system effectiveness. In order to define system effectiveness, (E), it is necessary first to define performance, (P), which may be said to be the conditional probability that a system, if operating, is also performing the mission for which it was designed. P is a variable with environment and, dependent on its use, may also be a time-dependent function. The simplest expression for system effectiveness is then E = RP, where R is the reliability of the system. This formula expresses the probability of the system successfully performing its mission for a given period of time. If availability (A) is used instead of R in the formula, E then represents the probability that, at any specified instant of time, the system is performing its mission. In the latter case P must be interpreted as an instantaneous value, instead of as a time function as in the former case.

In order to predict the effectiveness of a system, an engineer requires a knowledge of every detail affecting the performance of the mission. For practical purposes the most significant factors in the environment to be faced must be quantitatively estimated, and the characteristics of the system must be known. The proper mathematical expression to describe the system effectiveness must then be selected. Examples of the combination of probabilities based on the formulas E = RP and E = AP are given. Expansions of the basic formula to account for varying system configurations are discussed. Brief reference is made to the deriving of performance figures and the optimizing of the effectiveness of systems.

REVIEW: The concept of system effectiveness is clearly presented and its

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evaluation by the combination of probabilities is well illustrated. The latter involves only elementary probability concepts. The article provides a good discussion of inherent availability.

From a practical point of view, however, there would seem to be little value in separating operation and performance unless the latter is adequately measurable. Before one can evaluate performance quantitatively, he must be able to measure human performance in terms of failure and error. The fact that such measurement is beyond the current state of technology imposes a severe limitation on the practicality of the method. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Criteria for maintenance, checking and replacement intervals

AUTHOR: R. E. Barlow, General Telephone & Electronics Laboratories Inc., Menlo Park, California

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 4-1--4-12, October, 1961

PURPOSE: To present a preliminary report on the application of some recent results on distributions with a monotone failure rate to problems of replacement.

ABSTRACT: Early work in reliability depended heavily on the constant failure rate assumption, and even today the exponential distribution is commonly used at the system level. However, on the whole, it is being greatly overworked. In reliability work at the part level today, the failure distribution is usually assumed to be a member of a parametric family--e.g., the gamma, the Weibull, or the lognormal. The Weibull distribution is particularly popular at the present time largely because it is tractable and because it has an increasing failure rate for certain parameter values. However, within the usual range of actual observations of time to failure, it is very difficult to distinguish between various parametric families of failure distributions. Therefore it seems desirable to confine attention to a nonparametric class of distributions determined by properties of the failure rate function. Since most materials, structures and devices wear out with time, the class of distributions for which the failure rate is nondecreasing is one of special interest. Ignoring the possibility of infant mortality, this is perhaps the strongest, most natural assumption that can be made. A great deal of information about replacement policies may be obtained with this assumption. For replacement policies, the true role of the exponential distribution appears not as an assumed failure distribution but as a tool for obtaining essentially conservative bounds on the probability of survival, the mean time to failure, the probability of more than n failures, etc.

The properties of distributions with increasing failure rate (IFR distributions) are discussed. It is shown that in a replacement policy based on age, replacement is always beneficial if the failure distribution is of the IFR type. The exponential distribution and the related Poisson process provide conservative estimates of the probability of survival and the probability of n or more failures in (0,t). Moments of the distribution of times to failure are investigated for a periodic replacement policy and a policy of

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block replacement. Optimum replacement intervals and monitoring procedures are discussed. (Author in part)

REVIEW: This paper is largely a mathematical presentation of the implications of distributions with increasing failure rate for replacement policies. Frequent reference is made to relevant work in the literature, and some 14 references are cited.

From the practical point of view, it should be kept in mind that there is some evidence that, over the time of test, the failure rate for certain types of components (e.g., glass capacitors) decreases instead of increasing. It is also worth noting that replacements should be accomplished prior to failure if reliability is to be optimized. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Establishing and implementing system maintainability requirements

AUTHOR: J. W. Campbell, Rome Air Materiel Area, Griffiss Air Force Base, New York

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 5-1--5-21, October, 1961

PURPOSE: To emphasize the need for early and continuous consideration of maintainability characteristics and to outline procedures necessary to assure effective, timely and economical accomplishment of the maintainability objectives as dictated by the system operational requirements.

ABSTRACT: The early consideration of maintainability is essential in the design of electronic equipment and systems. However, the concept of fabricating equipment in a manner to reduce maintenance work load is often lost between the initial design phase and production.

Service Engineering Division in the Directorate of Materiel Management at ROAMA, in accordance with provisions of AFR 66-29, Maintainability Program for Weapon, Support and Command and Control Systems, and various AFLC directives, has the responsibilities of (1) collaborating and coordinating with AFSC on maintainability requirements to be included in all systems, subsystems and component development plans, (2) recommending maintainability requirements for specific systems, subsystems and components for inclusion in specifications, (3) coordinating with AFSC elements on definitive detail specifications for systems, subsystems and components to insure that adequate maintainability requirements are established and incorporated therein, (4) directing maintenance evaluation during the AFLC executive management stage, (5) insuring that maintainability requirements have been carefully evaluated, by maintenance engineering participation, during maintainability evaluations of new systems, subsystems and components, (6) collaborating and participating in tests as prescribed by AFR 80-14 in evaluating maintenance for new systems, subsystems and components, and (7) in coordination with AFSC evaluate, refine or establish maintenance methods, techniques and procedures.

AFR 66-29 is briefly described. An account is given of an attempt to implement an Air Force-industry teamwork program, expected to result in an effective data collection system acceptable to all Air Force commands and industry. This resulted in the report "Industry Report, Study of AFM 66-1 Program, with special attention to AFTO Form 211-4." A brief description of the report is given.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

The need for compliance with the provisions of existing documents, implementation of the procedures and acceptance of and compliance with the responsibilities imposed on all commands concerned is strongly indicated.

Relevant documents and forms are reproduced in two appendices. (Author in part)

REVIEW: This article will be of interest to those concerned with the establishment and implementation of system maintainability requirements. It makes a strong plea for the collaboration, coordination and cooperation of all concerned. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System maintainability evaluation techniques

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

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 6-1--6-24, October, 1961

PURPOSE: To describe four methods for evaluating maintainability.

ABSTRACT: There are many variations in the concepts of maintainability held today by different organizations working in the general field of electronic reliability. The techniques for system maintainability evaluation presented in this paper are based on the ARINC Research Corporation concept of maintainability, as embodied in a set of associated definitions. At the outset of the paper, definitions are given for the following terms: maintainability, operating mode, failing mode, and not operating mode. Several measures of maintenance, viz., time, frequency, efficiency, and probability of fault verification are cited. Of these, time is selected as the most appropriate measure. Categories of time are described.

Maintenance evaluation techniques in various stages of development are presented. The data and these techniques demonstrate that maintainability can indeed be evaluated. There is, however, a real need for new statistical approaches, stronger tools, and more creative research. (Author in part)

REVIEW: This is a carefully-presented and fairly extensive piece of work which should be of value to those who are concerned with the theory or techniques of maintainability evaluation. Data and illustrations of the techniques are presented, and effective use is made of graphs and tables. Typical reporting forms are shown in an appendix. ##

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Code 814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Funding the reliability program

AUTHOR: Clifford M. Ryerson, Vice President, EL-TEK Corporation, Hawthorne, California

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 7-1--7-7, October, 1961

PURPOSE: To review some of the more important aspects of funding for a reliability program.

ABSTRACT: Funding is important to the Reliability Program in two special ways. Firstly, if funding is not adequately considered and provisions made for program expenses, then no amount of wishful thinking can get the best program plan off-the-ground. Secondly, if funding is provided and the appropriate expenses are incurred at the proper times, adequate funding for reliability can save a great deal of money.

The old adage applies that you have to spend money to make money. But it must be spent wisely by spending the right amount at the right times, and on the right things. This requires an integrated effort and a teamwork based on the unified best efforts of everyone concerned. Frequently this calls for a better understanding of objectives and a better knowledge of how each individual fits into the picture. Training and orientation plus special planning and analyses are usually needed for every operational division and organizational level.

Some fundamental aspects of reliability funding are summarized under the headings:

The Total Cost Tradeoff
Internal Cost Balance
The Timing of Expense
Cost Accounting
Value Engineering

(Author in part)

REVIEW: This is a qualitative discussion of some cost aspects of reliability. As such, it may be of value to the novice in the field as a brief introduction to these considerations. It has little that will be new to those experienced in reliability management.
##

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Codes 351;761;816;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Economic justification for reliability improvement on consumer products

AUTHOR: Louis J. Gamache, Motorola, Inc., Franklin Park, Illinois

SOURCE: Proceedings Second Annual New York Conference on Electronic Reliability sponsored by Institute of Radio Engineers, Metropolitan New York Chapter, PGRQC; Long Island Section, IRE; New York Section, IRE; Northern New Jersey Section, IRE; pp. 8-1--8-12, October, 1961

PURPOSE: To discuss certain factors in the economic justification for the improvement of the reliability of electronic products for consumer use.

ABSTRACT: Relatively little has been written on the reliability of consumer products, perhaps largely because of the uncertainty of justification in civilian requirements. However, some equipment manufacturers are talking about reliability, and there is a trend toward longer warranty periods, such as two or even five years. Before going into five-year warranties, the manufacturer will need to do reliability testing not only on components, but also on complete assemblies. It will be necessary to know where the components will be used in order to set up environmental conditions to simulate conditions of end use. The cost of replacement of defective components would in many cases justify the need for prior environmental test data and reliability information.

The specification of the Motorola Golden "M" 600 tubular condenser and the steps taken to improve its reliability are reviewed. The documents used to transmit the necessary information are described. Tests forming part of the lot acceptance program of the vendor are listed.

Tests used to predict early life failures of tubes and to investigate the causes of failures are cited. These include characteristic tests by the curve trace method, "blast" testing under high dissipation conditions, accelerated life tests, and a cycled test. The importance of obtaining acceptable quality merchandise and substantiating test data from vendors is noted.

REVIEW: Much of the current reliability literature is concerned with military or space exploration applications. Inevitably, many of the techniques evolved will be applied in the design and production of consumer products; in fact instances of this no doubt exist already. Certainly when he commits himself to a long warranty period, a manufacturer, for his own protection, must have definite assurance as to the reliability of his product. This paper serves to point up some aspects of thinking and action along these lines in the electronics field. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A specification for electronic equipment for use in heavy industry

AUTHOR: D. Shaw, The United Steel Companies, Ltd., Swinden Laboratories, Rotherham, York, England

SOURCE: The Journal of the British Institution of Radio Engineers, vol. 24, pp. 133-139, August, 1962

PURPOSE: To show what conditions electronic equipment should meet--in terms of life and environment--in heavy industry.

ABSTRACT: Most electronic equipment is intended for either laboratory or domestic use and neither of these calls for too much in the way of reliability. In computers where reliability was mandatory, the environment was, first of all, made as gentle as possible. Next, attention was given to component failure rates in terms of electrical stresses. The use of special circuits to achieve reliability was also recognized. Heavy industry has an environment that is so adverse it is rarely considered by electronics people. These proposed specifications may help eliminate the saying "an electronic equipment may replace two men but it often requires three to maintain it."

Reliability is used here in its general sense of "failure-free" but some figures are necessary. By reliable is meant "90% fault-free for a minimum of 1000 hr and preferably 10,000 hr under industrial conditions." When the equipment does fail, the fault should be easily located and the bad portion, or unit containing that portion, easily replaced. The damaged unit can then be repaired (if possible) at leisure. Handbooks and circuit diagrams must be furnished as part of the equipment. The environments are classified as Severe, Moderate, or Protected, and the properties of each are listed. Equipment tests are specified for each condition.

The general specifications are listed rather completely in the appendices.

REVIEW: Anyone concerned with the use of industrial electronic equipment will not only benefit from reading the article, but will appreciate seeing many of his pet gripes put into print. The author is to be commended for his work in this area.

Difficulties can be expected to arise in practice. Sooner or later--and usually sooner, if grief is to be minimized--the requirements have to be given numbers. Especially in a competitive bidding situation, a vendor cannot give more than the specifications ask for if he hopes to get the order. There must be tests on which

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the acceptance or rejection of the equipment can be based. The experience of the military, who have similar reliability problems, clearly shows how difficult it is to have qualitative reliability specifications. There is little doubt that the more rugged equipment will have a higher first cost, but as the author says, its overall cost should be lower. ##

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Serial Number 457 -1
Codes 822;824;831;
833;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical procedures for circuit-parts selection

AUTHOR: E. E. Brewer, Engineering Standards Laboratories, General Dynamics, Pomona, California

SOURCE: Electromechanical Design, vol. 6, September, 1962, pp. 42-51

PURPOSE: To show how to use statistical analysis during the development stage to see the effects of variations in part-parameters.

ABSTRACT: In order for a circuit to be reliable, it must perform properly after part-parameter variations have been allowed for. These arise because of initial variation and subsequent drift in resistors, capacitors, tubes, transistors, etc. The Monte Carlo method is suitable for analyzing a circuit under these conditions. An example of a resistance network with two inputs and one output is used to illustrate the method. Using this approach the distribution of output values can be calculated--usually with the aid of an electronic computer. It is essential that the behavior of the circuit in terms of that of all parameters be accurately known; it is worthwhile to select a few of the random combinations and build and test them to see if the mathematical model is correct. Temperature and its effects on all parameters are important to check.

If a part is to be operated at other than specification conditions, a correlation analysis can be made between the desired conditions and the nearby specified ones. An example is given, including the least squares data analysis for it. More complex circuits can be handled, but much care and experience is necessary. Blind derating of components may be bad rather than good.

REVIEW: A more detailed analysis of the Monte Carlo method will be found in the article covered by Abstract and Review Serial Number 353. Before any statistical analysis is attempted, an expert in the field should be consulted to make sure that all of the assumptions and restrictions (on which the analysis is based) are fulfilled. For example, in the text example of straight line estimation, the least squares technique is used; the calculation of the spread in values does not correctly take into account the uncertainty in the estimates of the parameters of the line.

It is stated that capacitor voltage derating is pointless if dc leakage is not a problem. Much data has been presented which is in flat contradiction to this statement; voltage is usually considered to have a very important effect on life. The use of parts such as tubes and transistors at other than specification conditions should be approached very cautiously. Transistors are notorious in this regard. They may be "most anywhere" at other than specification limits and this "anywhere" may change from

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batch to batch.

This paper does give an insight into the possibilities of mathematical methods. The beginner, however, should not attempt an analysis by himself--he will need expert help. ##

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Serial Number 458
Codes 710;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How materials behave in space

AUTHORS: L. D. Jaffe and J. B. Rittenhouse, Jet Propulsion Laboratory, California Institute of Technology

SOURCE: Materials in Design Engineering, vol. 56, September, 1962, pp. 97-104

PURPOSE: To describe how materials behave when exposed to vacuum, ions and electrons, electromagnetic radiation, and meteoroids.

ABSTRACT: The common engineering materials behave differently in space than on earth. This problem is complicated by the fact that the space environment varies from place to place. All materials in vacuum will sublime or evaporate to some degree and polymers tend also to decompose. Three tables, covering metals and semiconductors, polymers, and oils, show the removal rates of these materials at different temperatures. Some of the troubles caused by this removal are undesirable condensation on other surfaces which may insulate a conductor or short an insulator, crazing of surfaces, and depletion of thin films. The surfaces of materials tend to become ultra-clean and this generally greatly increases wear and friction (e.g., graphite becomes abrasive). A discussion is given of the wear and lubrication problem.

Materials are damaged by ions, electrons, and other corpuscular radiation. Two tables show the effects on engineering materials such as metals, glasses, and semiconductors. In general, metals and semiconductors are damaged by atomic displacements and organic materials by ionization. Inorganic insulators can be affected by both. Sputtering by ions may also occur. The X rays and intense ultraviolet may cause various kinds of damage ranging from decomposition of plastics to darkening of transparent materials.

While the number and size of meteoroids is uncertain, some estimate of the damage by them is given.

REVIEW: This is a quite complete treatment of some aspects of the space environment. Little mention is made of the combined effects of the several aspects of the environment and little explicit mention is made of the gamma radiation. Not all authors seem to agree on the relative importance of the various components of the environment and the beginner might do well to seek advice from several places. (No references are given in this article.) ##

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Codes 831;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy and switching failure

AUTHOR: H. S. Balaban, ARINC Research Corporation, Washington, D. C.

SOURCE: Electronic Design, vol. 10, September 13, 1962, pp. 72-75

PURPOSE: To show how the reliability of the switch and monitor affects the reliability of a switched redundant system.

ABSTRACT: The often-made assumption that the switching is failure-free in standby redundant circuits is not necessarily justified. Six practical assumptions are made to simplify the analysis. Standby redundancy is assumed with a monitor to decide when to switch. Expressions for the reliability are developed and the usual exponential assumptions are made. The results show that the reliability cannot exceed that of the monitor. Several curves are shown with different values of switch and circuit function reliability. (Several references are given.)

REVIEW: It certainly is true that switching reliability cannot be assumed to be unity and this fact has been discussed in the literature before. The assumptions here are generally realistic although two may not be always satisfied, viz. Number 4: Switching devices do not fail during standby conditions and Number 6: All failure probabilities ... can be described by constant failure rates associated with the exponential distribution. The conclusion that the system reliability cannot exceed the monitor reliability is independent of the failure rate distribution and depends only on the assumed failure modes. The analysis is somewhat pessimistic in that the monitor can fail in one way (not being able to switch) and not affect system performance as long as switching is not required. The analysis allows for no monitor failures.

In using the results of any analysis, including this one, it is most important to keep in mind the restrictions/assumptions made in deriving it. The author has done well to list them explicitly.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Packaging and interconnecting integrated networks

AUTHOR: Edmund G. Shower, Sperry Semiconductor Division of Sperry Rand Corporation, Norwalk, Connecticut

SOURCE: Electronic Industries, vol. 21, September, 1962, pp. 100-103

PURPOSE: To show the interconnection problems associated with packaging wafers of different complexity.

ABSTRACT: Integrated networks on silicon wafers can be produced quite readily by industry. These networks have a very small volume compared to that of their package. When these wafers are put in a package, the external terminals must be connected to the network terminals. The metal interfaces have a potential low reliability as well as being detrimental to high frequency operation. The small wafers (0.12 x 0.12 x 0.005 inch) are produced on a large silicon slice about 0.75 x 0.75 inch with 20 or more circuits on the slice. A possible solution to the speed and reliability problems is to not cut the slice into small wafers (these wafers are packaged separately and then reconnected externally), but to use evaporated film wiring across the oxide coating on the slice. This eliminates 2/3 of the interfaces and shortens the leads. These new leads have small mass and thus are more immune to acceleration damage. The difficulty is that fabrication costs will rise and replacement packages are more expensive and complex. Optimum size will depend on the application.

REVIEW: The approach suggested here is a good one as far as reliability is concerned. Its potential extra cost in terms of replacement of more complex parts may be offset by the higher reliability which leads to fewer spare parts and less maintenance effort. The test equipment, operating at a more gross level, might be smaller, simpler and easier to use; i.e., a fault need be isolated only to a wafer--or group of wafers--not to an individual circuit.

This approach will become even more feasible as system reliability is attained more by circuit design (optimum redundancy) than by component design. Increased standardization of output and input characteristics will also be a help in this regard. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Rugged tubes--what makes them that way?

AUTHOR: E. L. Dana, Westinghouse Electric Corporation, Elmira, New York

SOURCE: Electrical Design News, vol. 7, September, 1962, pp. 96-102

PURPOSE: To describe the construction of rugged electron tubes.

ABSTRACT: Tubes are better suited to many applications than are transistors, and they can be made rugged enough. In general, if a tube can withstand vibration of several G over a frequency range of several hundred cps it can withstand most other mechanical tests. Vibration causes failure when the tube elements move with respect to one another. At resonance, small energy (power) inputs can cause large displacements and result in fatigue failure or contact with other elements. In general, the solution is to make elements stiff and of light weight; this keeps the resonant frequency quite high. Bracing elements by stiff springs against the walls is better than using mica which may loosen. Damping of the structure is not feasible inside the envelope; but it should be applied outside in the tube mounting if it is unavoidable. Careful attention should be given to the tube mounting to see that undue strains are not put on the glass. An example is given of the design of a cathode ray tube.

REVIEW: This is a general paper for those not familiar with the subject and provides introductory information on element design and envelope mounting. Some of the opinions may be open to mild controversy. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Micromodules show durability plus radiation resistance

AUTHOR: (Editorial Matter)

SOURCE: Electronics, vol. 35, September 14, 1962, p. 30

PURPOSE: To give a brief survey of the capabilities of the RCA micromodules.

ABSTRACT: Tests on 6000 components (800 circuits) of the micromodule type have shown a MTTF of 6.5×10^6 hours for the components at a 60% confidence level. All elements were under high stress. No solder connection failures were observed in 250×10^6 connection hours. The circuits can also survive a neutron dose of 5×10^{14} neutrons/cm^2 and an acceleration of 20,000 g. The original concept of the wafers has been extended and now solid circuit packages can be mounted on the wafers. Micromodules are now being applied to Army equipment.

REVIEW: This is a very general article with no references. It does give a rough idea of the status of the micromodule program, but there is little specific information that can be evaluated. The average number of components per circuit (approximately seven) indicates a very simple system. The quoted MTTF does not seem particularly long relative to other experience in this area. ##

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Serial Number 463
Codes 711;775;844;
853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Inspecting fractures: what we can learn from metal failures

AUTHOR: Robert C. Bates, Materials Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania

SOURCE: Metal Progress, vol. 82, October, 1962, pp. 114-117

PURPOSE: To show that the cause of failure can often be determined from a microscopic examination of the fracture surface.

ABSTRACT: Visual or low power inspections of fracture surfaces are quite common and much can be learned from them. Often, the characteristics are not discernible and high magnification is necessary--even the electron microscope in some cases. Different types of fractures were caused and studied in the laboratory to develop a "catalog" for future use.

A cleavage follows the same plane, and will thus change physical direction from grain to grain (since the grains are randomly oriented). The cleavage fracture has the facet appearance and usually fans out to give the "river" pattern.

Intergranular fractures have also a faceted look, but no river pattern.

Fatigue fractures have many fine striations which run perpendicular to the fracture propagation.

Shear fractures have no unique markings--this is their "distinguishing" feature.

Non-metallic inclusions sometimes show up very well because they fracture differently from the metal.

Examples of the above are shown in photographs.

REVIEW: Failure analysis is an important phase of reliability work. Even though this sort of study is best left to "experts," the design and reliability engineers should be familiar with this field. Metallurgical causes are not uncommon in so-called electrical failures. ##

Serial Number 464
Codes 812;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The mathematics of reliability and life testing

AUTHOR: Andre G. Laurent, Wayne State University and Detroit Research Institute

SOURCE: 5 pp., presented at SAE Automotive Engineering Congress, Detroit, Michigan, January 8-12, 1962, Society of Automotive Engineers paper 453B

PURPOSE: To show that the mathematics of reliability is nothing more than the mathematics of probability and statistics.

ABSTRACT: The concept of "random variable" as it applies to a wide class of problems, including many of those encountered in reliability and life testing, is discussed. The terms "population" and "sample" are distinguished. Other topics briefly considered include: the cumulative frequency curve, Bernoulli's theorem, the cumulative probability distribution, the survival function and the probability density. The problem of choosing a suitable mathematical model is discussed, and some examples are given. Some remarks are made about the estimation of parameters and the testing of hypotheses.

REVIEW: This paper discusses the logical background for the theory of reliability and life testing. It does not go into detail on the theory itself. Much the same background, as well as the theory, may be found in a textbook such as "Reliability: Management, Methods, and Mathematics," by David K. Lloyd and Myron Lipow, Prentice-Hall, Inc., 1962. The paper contains a number of misprints; in a private communication the author has pointed out that this is due to the fact that it was not submitted to him for proofreading before final printing. ##

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Serial Number 465
Code 873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Don't make these design errors in air or ground borne vehicular design

AUTHORS: J. W. McDonald and W. H. Barthel, Directorate of Engineering, U. S. Army Transportation Materiel Command

SOURCE: 6 pp., presented at SAE Automotive Engineering Congress, Detroit, Michigan, January 8-12, 1962, Society of Automotive Engineers paper 457D

PURPOSE: To emphasize that reliability and maintainability are of vital importance in military vehicular design.

ABSTRACT: The initial performance of a vehicle is important. Too often in the past, reliability (performance as a function of time) and maintainability have been sacrificed or ignored. The Army is now including contract clauses on these. Buying regulations are being modified to provide stronger incentives for cutting costs and improving the overall performance of the system or vehicle.

The author lists traditional stumbling blocks in design, such as "It's been done this way for 15 years--why change?" He also has many examples and a table showing design deficiencies in Army aircraft. For example, in one type, it may take from 1 1/2 to 5 hours to drain the engine oil. The designer is urged to consider reliability and maintainability as performance parameters that are just as important as the more conventional ones.

REVIEW: This is a "consumer" complaint accompanied by constructive criticism. It emphasizes that the tendency to get high (initial) performance at the expense of reliability and maintainability must be eliminated. It is true in many or most cases, that a lower level of initial performance can be tolerated if it can be continued easily. The high initial performance many times is impossible to maintain for a reasonable length of time. One commentator has said that a big hazard in design is the "genius" who squeezes the last bit of performance from every part; he leaves no room for variability due to time and manufacturing processes. ##

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Serial Number 466
Code 813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Outline of "How practical should a reliability program be?"

AUTHOR: Dorian Shainin, Rath & Strong, Inc.

SOURCE: 2 pp., presented at SAE Automotive Engineering Congress, Detroit, Michigan, January 8-12, 1962, Society of Automotive Engineers paper 464A

PURPOSE: To discuss the practicality of a reliability program for the automotive industry.

ABSTRACT: Reliability is now a popular word. It is taken, by many, to be the mathematical expression of what used to be called dependability. The mathematical analysis of reliability can be quite discouraging when one views the amount of testing required for a given goal. An example is given. The question is--"Is all this testing, etc. worth it?" The answer can easily be no. A practical program will encompass these five points.

1. What constitutes a failure?
2. What should the design engineer do differently?
3. What educational steps are needed; to whom should they be directed, and who best can conduct them?
4. How do we reduce the cost of testing and at the same time increase the knowledge we get from the tests?
5. What changes in methods of setting specifications will make them more realistic and what is the relation of these changes to the serviceability of the product?

REVIEW: This is a somewhat misleading and very general paper. There are some implicit assumptions in the statistics that are used, the most important of which are that the failure of a part causes immediate failure of the system (no redundancy) and that the failure of any one part does not cause failure of another part (independence). For an automobile, there are many important parts for which neither of these is true. The section on testing has the implicit assumption that nothing is known about the life of the parts before testing begins. This is also generally not true. If it were, the automotive industry would have the same problems as the electronics and missile industries have, i.e., a crash program to build new and complex systems with little a priori knowledge of the behavior of the parts.

The automotive industry can benefit from a good mathematical and engineering reliability program. The tools need to be chosen to fit the job at hand and these tools will not necessarily be exactly the same as those used in the electronics/missile industries. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability analyses in complex systems

AUTHOR: John H. Hershey, Bell Telephone Laboratories, Incorporated, White Sands Missile Range, New Mexico

SOURCE: 12 pp., presented at SAE National Automobile Week, Detroit, Michigan, March 12-16, 1962, Society of Automotive Engineers paper 495B

PURPOSE: To show how the constant hazard assumption ("exponential case") can be used to make reliability and other predictions about a system.

ABSTRACT: As presented here, the study of reliability analyses of complex electronic systems opens up intriguing possibilities of their application in the automobile field. The author points out that reliability of a design is determined by the end results desired by the user and that reliability concepts are uniquely based on user satisfaction. The data derived by the reliability engineer are concerned primarily with the time dimension in relation to failure frequency of the equipment being assessed. The measurement and evaluation of these data begin at the model phase and progress through the prototype stage to the production product. The probability of success of a missile during both the pre-launch and flight phases is used as an example to develop an unconditional reliability concept. (Unconditional reliability is the product of availability and mission reliability.) (Author in part)

REVIEW: This is an introductory paper which briefly covers the reliability analyses of a design from the beginning to the final product. The exponential reliability function is assumed for some purposes in the article. Under this assumption equipment hours is the important parameter, not the amount of either equipment or time alone. In practice, the consequences of this assumption are mitigated by specifying the approximate number of equipments that must be tested. The reader is cautioned not to assume that any particular equipment has a constant hazard rate unless he has actually checked it. The comment on environmental testing is somewhat ambiguous; but, in any event, some people feel that combined environments are necessary for good results. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Practical aspects of reliability

AUTHOR: G. A. Raymond, Remington Rand Univac Division, Sperry Rand Corporation

SOURCE: 7 pp., presented at SAE National Automobile Week, Detroit, Michigan, March 12-16, 1962, Society of Automotive Engineers paper 495C (summarized in SAE Journal, vol. 70, August, 1962, p. 83, under the title "Working group attitudes: key to reliability program success")

PURPOSE: To describe procedures that made the Athena a successful computer.

ABSTRACT: Automatic guidance of automobiles on high speed highways will require a high degree of reliability, and is an example of the principle that reliability is a design problem. The Athena guidance computer for the Titan missile had reliability specified as the most important design requirement. This paper discusses the functions of the reliability group and its relationships with other groups. The author also treats the problem of designing reliability into a system and circuits, including factors such as design assistance, design review, parts purchasing, and failure analysis. (Author)

REVIEW: This is a general paper and as such contains no specific design information. The newcomer to the reliability field will find many of the generally accepted ideas discussed. Some of the organizational details are quite different in other companies. The reader should keep in mind that an organization which works well in one company may not be ideal for another; details have to be tailored to meet specific requirements. (The contention that the Athena is the most reliable computer in existence might be debated by other companies.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A general reliability and maintainability program

AUTHOR: R. V. Garvin, General Electric Company

SOURCE: 8 pp., presented at SAE National Aeronautic Meeting, New York, New York, April 3-6, 1962, Society of Automotive Engineers paper 506A

PURPOSE: To discuss the reliability problem from an organizational point of view.

ABSTRACT: An organized plan for managing a reliability and maintainability program is presented, and milestones for a PERT network are identified. This paper discusses the analysis necessary as a preliminary to design, the importance of coordinated techniques between customer and manufacturer, and the testing and reporting of product reliability with respect to product needs.

The scope of any reliability and maintainability program must be a function of the product's needs. Complex systems may justify complex programs and large organizations to implement them particularly when the state of the art is to be advanced. Simpler products, and those which are understood better, are likely to require only the modest effort that matches the needs of the situation. (Author)

REVIEW: As the title states, this is a general article and is introductory in nature; as such, it will be useful for newcomers to the field of reliability. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Time-temperature effect on jet engine thermocouple accuracy and reliability

AUTHOR: Robert B. Clark, Instrument Department, General Electric Corporation

SOURCE: 12 pp., presented at SAE National Aeronautic Meeting, New York, New York, April 3-6, 1962, Society of Automotive Engineers paper 524K

PURPOSE: To find the reliability of several thermocouple and sheath materials in a simulated jet-engine environment.

ABSTRACT: If it is assumed that the conditions of this test program are reasonably similar to the conditions to be found in jet engines, then the following conclusions can be helpful in predicting the accuracy, reliability, and life of jet engine thermocouples.

1. The accuracy and reliability of bare wire GMV Chromel-Alumel thermocouples having temperature gradients along the thermocouple wires is questionable after 22 hr at 2200 F, 50 hr at 1800 F, 530 hr at 1500 F, and 2300 hr at 1200 F because of selective oxidation of the Chromel wire.
2. The current methods of checking the calibration of thermocouples in static air furnaces does not impress a temperature gradient across the thermocouple junction sufficient to indicate possible thermocouple inaccuracies as a result of selective oxidation in the Chromel wire.
3. As a result of oxidation and sulfur attack, the mechanical life of bare wire GMV Chromel-Alumel thermocouples subjected to 1200 F is probably between 2000-3000 hr.
4. Both noble metal thermocouple systems show good stability for extended periods of all four temperature levels and are therefore worthy of further evaluation. Apparently additional work needs to be done with regard to controlling the initial calibration of these thermoelements.
5. Of the materials tested, only Inconel 702 is satisfactory as a thermocouple sheath material at 2200 F.
6. After 400 hr at 2200 F, Inconel 702 shows a visible loss of material.
7. Inconel 702 and Haynes alloy No. 25 have acceptable oxidation resistance at 1800 F, and Inconel "X" has an acceptable oxidation resistance at 1500 F. (Author)

REVIEW: The testing of high-temperature thermocouples is quite complicated if done properly. This appears to be a rather careful piece of work. One question that might arise is whether or not other differences in environment would be correlated with the temperature differences in the stack. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Instrumentation for the development of earthmovers

AUTHOR: Leroy A. Grotto, Development Engineer, International Harvester Company

SOURCE: 10 pp., presented at the 13th Annual Earthmoving Industry Conference, Peoria, Illinois, April 5, 1962, Society of Automotive Engineers paper S337 (summarized in SAE Journal, vol. 70, September, 1962, p. 66, under the title "Testing crankshaft fatigue")

PURPOSE: To describe the instrumentation used to measure stresses on components for earthmovers.

ABSTRACT: While the vehicles used in the earthmoving industry may not be as sophisticated and complicated as those of the missile industry, a great deal of instrumentation is nevertheless required in their development. The major instruments are designed to measure the magnitudes and frequencies of the loads. Strain gages are the work-horse for this purpose. In some cases, over 100 gages may be installed on one component. Automatic data logging is important here. The maximum allowed stress can be restricted by yielding (for a few high loads) or fatigue (many repeated smaller loads). The area between these two is very difficult to judge. Cumulative damage theories are used to convert the odd-shaped stresses to equivalent constant amplitude stresses. Some parts must be operated so as not to fail in fatigue. The relative stresses in the component are determined for simulated loading and then the actual stresses are measured in a few places under operating conditions. Parts are subjected also to standard fatigue tests.

REVIEW: This is a good summary of the design for mechanical reliability in terms of parts failure. There is not enough detail to learn how to perform the tests, but engineers who are reasonably familiar with this type of test will understand what was being done. There is an unwarranted inference in the paper that there is a generally accepted theory of cumulative damage theory in fatigue; there is still much dispute over the best methods and over how accurate the commonly-used ones are. ##

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Serial Number 472
Codes 833;873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A realistic approach to hydraulic system reliability

AUTHOR: B. L. Mettee, Bureau of Weapons, Department of the Navy

SOURCE: 4 pp., presented at the Joint Armed Forces-Industry Meeting, Baltimore Section, April 12, 1962, Society of Automotive Engineers paper S343

PURPOSE: To describe some of the causes of unreliability in hydraulic systems and to suggest corrective measures.

ABSTRACT: The hydraulic systems on some Navy aircraft are rather complex, are subjected to extreme environments, and must be maintained under difficult conditions. Development of components for these systems without regard to the overall, integrated performance is likely to yield poor results. Many adverse operating conditions due to poor performance of other components are omitted from the testing conditions. Some of the tradeoffs that have been made to reduce cost and weight have lowered the reliability. In one aircraft where hydraulic pump reliability was much higher than average, the pump had been derated from 3000 psi to 1500 psi. One might prefer to say that 1500 psi should have been the rating and that other pumps were being "over-rated."

One area where designers have not been realistic is in requiring extremely clean hydraulic systems. It is not possible to maintain "hospital clean" conditions on a carrier and components which require this have faulty design. The testing of a few handmade samples under restricted conditions does not tell how the mass-produced part will perform in service. In the few problem areas where the effort has been made, considerable progress has resulted, but reliability still needs much more effort. An example is given of the "patch" test wherein the high initial wear of poor quality pumps can be detected.

Maintainability is just as important to reliability as is good component design. Hydraulic systems maintenance should not be made difficult or virtually impossible by the design. Components and systems should be designed for fool-proof maintenance. These are all difficult requirements for the designer, but they are necessary for reliable systems.

REVIEW: This is a good article on design problems and the examples are very helpful. One of the biggest problems in reliability is to induce designers to think in terms of designing for long, maintenance-free life; to lay out a system that is easy to maintain properly when service is needed and that is hard to maintain improperly by people who may not know better. Unreliability would be tremendously decreased if engineers just did as well as they know how, right now. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable circuit supplies high peak deflection voltages

AUTHORS: Ralph S. Hartz, Project Engineer, Bendix Semiconductor Division, Holmdel, New Jersey and Richard C. Allen, Senior Engineer, Computer Products, Incorporated, South Belmar, New Jersey

SOURCE: Electronics, vol. 35, October 12, 1962, pp. 54-55

PURPOSE: To present a good design for a cathode ray magnetic deflection circuit.

ABSTRACT: Magnetic deflection for large cathode-ray tubes usually requires high-speed and high-current switching. Short retrace periods introduce a high peak-voltage requirement. This circuit was designed to drive the deflection system of a solution-display device used in analog computers. While it features rapid turn-off of collector current for efficient flyback operation, the peak voltage generated during retrace exceeds 300 volts. High reliability is achieved by output stage redundancy. (Authors)

Instead of two transistors in series for the driving transistors (which would barely be safe), three are used. An RC network is used to divide the voltages equally across the collector-emitter of each transistor.

REVIEW: The redundancy is the use of three instead of two transistors when two will do the job with no safety margin. No actual figures on lifetime are given, so that there is no experimental check on the design. ##

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Serial Number 474
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure analysts curb device faults

AUTHORS: Nelson A. Velez and Charles L. Vogt, Jr., Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: Electronics, vol. 35, October 12, 1962, pp. 68-74

PURPOSE: To give examples of failure modes in several types of components.

ABSTRACT: Failure analysis requires a well-equipped laboratory and inquiring, persevering minds. The analyst must work closely with all other departments. The examples in the paper are summarized here.

Diodes: (a) Aluminum button between spring and crystal had been dislodged and was loose in the envelope. (b) Excessive solder had built up under the crystal and the crystal was cracked. (c) A crack existed between the whisker and the crystal.

Capacitors: (a) Ceramic capacitors showed cracks between the plates. (b) Extraneous solder inside a ceramic capacitor caused shorts.

Transistors: (a) The base lead was melted open and a diode in series with the base was shorted by excessive current. Both were caused by bad circuit testing. (b) Excessive storage time. A diode in the circuit had misaligned whiskers and was presumed to be a poor risk.

Other examples involved a leaky klystron, insulation breakdown in a transformer, broken leads caused by potting compound in a transformer, and fatigue of relay leads. Significant product improvements were obtained as a result of the corrective actions which were taken on the basis of these investigations.

REVIEW: Failure types can be separated into two parts. The first are those which result in a product which is initially bad, i.e., it never did work--or never could pass an inspection test. These do not involve good operation originally which is followed later by failure. The problems are those of traditional quality control. The other type is perhaps more insidious and failure occurs only after some period of service. These types do affect the reliability adversely.

While the "physics" of failure is used to describe the investigative procedures, many of the failures have more to do with engineering and fabrication techniques than with fundamental physics. All of the failures described here would seem to fall into the nonphysics category and most of them have to do with initial quality (as opposed to reliability). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Current noise and reliability in tin oxide resistors

AUTHOR: J. G. Curtis, Corning Glass Works, Bradford, Pennsylvania

SOURCE: Electro-Technology, vol. 69, June, 1962, p. 13

This is a condensation of the paper covered by Abstract and Review Serial Number 263. ##

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Serial Number 476
Codes 770;781;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Overload characteristics of enameled magnet wire

AUTHORS: C. F. Hunt, A. F. Fitzhugh and A. H. Markhardt, Shawinigan Resins Corporation, Springfield, Massachusetts

SOURCE: Electro-Technology, vol. 70, September, 1962, pp. 131-135

PURPOSE: To demonstrate a test method for magnet wire--under overload conditions--that gives better ratings for many applications than do conventional tests.

ABSTRACT: The recent literature has emphasized the need for additional tests to determine all the properties of magnet-wire insulation. Tests have shown, for example, that a class A material may actually behave better than a class F material under some high temperature conditions. A burnout or overload test has been developed and has the following properties: (a) employs a simple twisted pair of wires for the test specimen, (b) establishes realistic failure criteria, (c) provides for thermal shocks, and (d) automatically records the time to failure. Separate currents which are cycled are passed through the two wires, with 120 volts continuously between them. Tables and graphs are shown of the results. The failure mechanisms for different insulations are discussed. The better materials were polyimide and the coatings based on polyvinyl formal.

REVIEW: The paper is quite complete and will be useful to those concerned with insulation specification. Caution should be exercised in using the results of these tests where the test does not adequately simulate the operating conditions. The discussion of failure mechanisms is important. ##

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Serial Number 477
Codes 711;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving reliability of microcircuit connectors

AUTHORS: Jack R. Anderson and John B. Saunders, Stanford Research Institute, Menlo Park, California

SOURCE: Electro-Technology, vol. 70, October, 1962, pp. 74-78

PURPOSE: To describe experiments with thin coatings to reduce friction, wear, and electrical resistance on sliding contacts.

ABSTRACT: The results of a study of surface treatments intended to decrease friction and wear in microcircuit connectors are presented. Special films developed for boundary lubrication of contact metals are evaluated. Comparative test results have been tabulated. The information obtained has general application for electrical connectors and relay contacts used in low-signal-level circuits. (Authors)

The tests were run by moving a metal bar against a stylus and measuring the load, the frictional force, and the electrical resistance. The bar and stylus were made of various materials and the bars were coated with lubricating materials. Octadecylamine hydrochloride on gold was the best combination. Silver iodide films were good although they did not adequately prevent tarnishing of the silver.

REVIEW: The work in this paper is directed toward connector improvement rather than being concerned with connectors themselves. The study is a fundamental one concerning the properties of the surfaces. (Reference is made to monomolecular layers, but no indication is given of how the layer thickness was determined.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Ramifications of PSMR-1, the Darnell report

AUTHOR: Anthony J. Finocchi, Director of Reliability Engineering, ITT Federal Laboratories, Nutley, New Jersey

SOURCE: Electronic Products Magazine, vol. 5, August, 1962, pp. 69-74

PURPOSE: To highlight the areas of the Darnell report that are important to electronics parts producers.

ABSTRACT: The report is summarized and discussed under the 11 headings of the report.

1. Electronic Parts Specifications Management
2. Specification for Reliable Parts
3. Procedure for qualification approval
4. Acceptance inspection
5. Design and procurement documentation
6. Contractual data requirements
7. Military inspection practices
8. Procedures for coordinating specifications
9. Procurement and engineering practice
10. Sources and source listing of technical information
11. Change of sampling plans

The concepts that may cause the most confusion deal with sampling plans. The element of risk cannot be eliminated from the use of mass-produced parts. For large lots, the sample size (in absolute number) tends to stay the same as the lot size changes. The acceptance plans have changed from an emphasis on producer's risk to that on consumer's risk. The EIA has reviewed the report and suggested some changes; these changes are also discussed here.

REVIEW: This is a good summary of the salient points in the Darnell report and it is helpful to have the EIA's position summarized also. The production of parts with guaranteed reliability is bound to be a fairly expensive proposition in our present situation. The EIA's objection to using the consumer's risk rather than the producer's risk is important since it raises a vital point. The quality that can be counted upon in a product is strongly affected by the acceptance sampling plan. Consider the operating characteristic for a typical sampling plan (see figure on next page). P is the producer's risk and is the small probability of rejecting lots of g(ood) quality. P is usually denoted by α and the corresponding quality by AQL (acceptable quality level). C is the consumer's risk and is the small probability of accepting lots of b(ad) quality. C is usually denoted by β and the corresponding quality by LTFD (lot tolerance fraction defective). N is the nominal product quality (e.g., 0.1% defective) and, of course, is not fixed by the sampling plan. This is the quality that the designer specifies. In the past, N has been put

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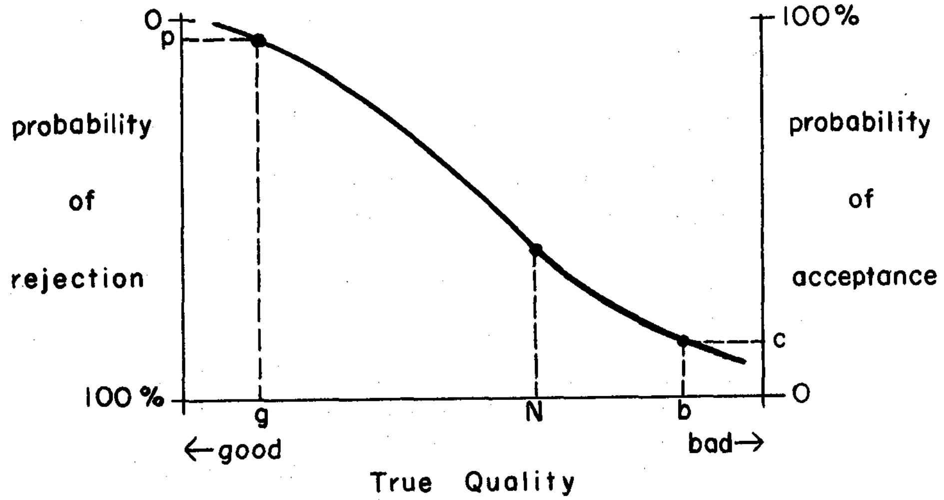

at g where the producer's risk is small. The Darnell report proposes putting it at b where the consumer's risk is small. The EIA objects to b and would like to have N at a point such that the probability of rejection is 60%.

The cause of the problem is the sampling plan and the assumptions behind it. The main restrictive assumption here is that nothing is known a priori about the quality of the lot. In some sampling plans, this is relaxed somewhat by including information from the sampling of previous lots, but basically the assumption remains. For very high quality and any reasonable sampling plan, g and b qualities are very far apart and the costs of producing at g and b are widely different. The producer, on the other hand, usually feels (or at least maintains the public posture) that he can control his process sufficiently to put the quality where he wants it. Under these circumstances, there is bound to be conflict. The producer, generally, wants to have his process average such that most of the lots are accepted. This is why he prefers (and reasonably so) that the nominal quality N be near g. If N is near b, he still must (generally) produce at g, which in this case will be much better (and much more expensive) than N. The designer wants to have N at b so that he can be reasonably sure (according to the sampling plan) that the quality will never be less than N. If N is put nearer to g, he stands a greater chance of getting "below N" (i.e., below specification) material than he would like, if the producer's quality should stray in the wrong direction. If N is not placed at b, the designer may overspecify, just to be sure that the actual accepted quality will be adequate. Perhaps one answer to the dilemma is to allow some of the producer's a priori knowledge of the quality to be used in the sampling plan and thus to sharpen the operating characteristic curve. ##

Serial Number 479
Codes 802;812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability Engineering: Statistical Concepts and Reliability Analysis

AUTHOR: --

SOURCE: A brochure of the material presented in Films MN8770c and MN8770d, 64 pp., The Bureau of Naval Weapons, Department of the Navy, Washington 25, D. C., for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C., price 35 cents

PURPOSE: *To supplement the instruction in Films MN8770c and MN8770d in* developing and demonstrating some of the basic statistical concepts useful in applying reliability engineering techniques to the design, production, use, and maintenance of Naval weapon systems.

ABSTRACT: Some of the statistical concepts useful in reliability work are developed. These concepts include frequency and probability distributions, sample statistics, population parameters, and the normal exponential, binomial, and Poisson distributions.

Some of the applications of statistical techniques in reliability analysis are demonstrated. A relatively simple example is used to show the essential steps of a reliability analysis in which the reliability characteristics of the system were observed, and from the data were established failure patterns or distributions which were analyzed by a combination of statistical and engineering methods. A second example involves the application of simple linear regression, which is discussed in considerable detail. Brief reference is made to multiple linear regression.

REVIEW: This brochure serves as an introduction to a few of the statistical concepts useful in reliability work. The material 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 and 285. ##

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Serial Number 480
Codes 832;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The human element in the maintenance package

AUTHOR: H. J. Page, International Business Machines, General Products Division Development Laboratory, Endicott, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 322-334, January, 1962

PURPOSE: To describe the experiments (and results) used to determine the properties of people which are useful for computer service technicians.

ABSTRACT: An important link in the maintenance package of a data processing system is the performance of maintenance personnel. In the future, a rapidly growing population of increasingly complex electronic systems may well be serviced and maintained by persons with less technical background than presently exists among maintenance personnel. Diagnostic analysis as a significant aspect of maintainability currently represents one of the most complex of man-machine relationships. This study is based upon the proposition that systems down time can be decreased by investigating a number of diagnostic analysis situations encountered by field service personnel in both vacuum tube and solid state data processing systems.

The success of a data processing system is greatly influenced by the performance of field service personnel. Because of the wide variation in the performance of field service personnel, this aspect assumes a role of major importance in the maintenance package. A careful analysis of the task of the diagnostic analysis is needed to identify essential elements for maintenance package evaluation, training planning and evaluation, and selection of recruits. Apparently there exists a core of problems for the diagnostician which are common to many systems which in themselves differ with respect to hardware design or active elements. Successful diagnostic analysis appears to depend more upon an ability to organize relatively simple pieces of information rather than an ability to remember a mass of detail. The task of the diagnostician is concerned more with the logical development of an analysis than with the application of electronic or mechanical principles. Effective selection devices to identify individuals with the potential to become expert diagnosticians can probably be constructed to test for ability to logically synthesize available information rather than measuring the retention of specific facts. (Author)

REVIEW: This seems to be a comprehensive piece of work. The conclusions and summary are given in the abstract above. The design engineer should take cognizance of what people <u>are</u> like (not just what he thinks they <u>should</u> be like) when he designs equipment for maintainability. ##

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Serial Number 481 -1
Code 874

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability prediction and measurement

AUTHORS: R. A. Miles and B. L. Retterer, RCA Service Company, Rome, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 335-342, January, 1962

PURPOSE: To summarize the important achievements of a maintainability study being conducted for Rome Air Development Center.

ABSTRACT: This paper describes the results to date of a maintainability techniques study sponsored by Rome Air Development Center. The basic concepts and experimental procedures leading to the development of the prediction technique are outlined. These concepts involve the basic premise that maintenance time is a function of design, personnel, and support. A number of indices are illustrated. A prediction equation is formulated, and numerical results are quoted for three ground electronic equipments.

The major findings of the research to date are:

1. The principal factors affecting equipment maintenance time are (1) physical design, (2) design dictates-facilities, (3) design dictates-maintenence skills and attitudes required, (4) personnel coordination, (5) attitude-motivation, (6) manuals and instructions, (7) supply conditions, (8) test equipment and tools, and (9) maintenance organization and facilities status.
2. While indices have been set up in terms of time, cost, and capability, those related to time have been found to yield the most meaningful results.
3. A prediction equation has been developed through regression analysis, relating the logarithm of the expected down time requirement to the factors of physical design (A), design dictates-facilities (B), and design dictates-physical, mental, and attitudinal requirements (C).
4. Trade-off between environmental factors and predicted maintenance time is possible where sufficient information is available.

REVIEW: As the authors have indicated, this paper is a summary of the major findings of the subject study. As such, it does not provide the amount of detail that a reader would require in order to fully appreciate what was done. For example, in connection with the regression equation relating log Z to the factors A, B, and C, the latter are referred to as check-list scores. More specific information on these scores and how they were obtained, including at least samples of actual data, would have been helpful. Five references are cited, and some of these may contain more detailed information. (Incidentally, there is apparently a misprint in the

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regression equation in that the minus sign following log Z should no doubt be an equality sign.) ##

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Serial Number 482
Codes 431;821;872;
882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some considerations of scheduled maintenance

AUTHORS: Richard Meyers and Ronald S. Dick, International Electric Corporation (An Associate of International Telephone and Telegraph Corporation) Paramus, New Jersey

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 343-356

PURPOSE: To consider the effects of scheduled maintenance on two basic reliability measurements.

ABSTRACT: This paper is concerned with the effects of scheduled maintenance on the measurement of uptime ratio and the measurement of time interval reliability. The former is defined as the probability that an equipment will be available for use at any time T, while the latter represents the probability that an equipment is operating at the beginning of a time interval and continues to operate for the length of the interval (T).

In the calculations of uptime ratio with scheduled maintenance, the system of interest is composed of a set of similar equipments of which at least n out of a must operate. In the calculations of time interval reliability the condition is phrased to read: no more than n out of a are under repair. In previous work it has been assumed that scheduled maintenance was done t hours following an emergency maintenance action to the equipment. In this formulation there is no fixed clock time at which scheduled maintenance will be performed. Since many scheduled maintenance actions are done at a fixed period of time which is determined beforehand, this paper considers how to do the reliability calculations when at a determined period, we go from a to a-1 equipments and vice-versa. (Authors in part)

REVIEW: This paper presents mathematical methods for calculating uptime ratio and time interval reliability under a scheduled maintenance condition. The underlying distributions in the case of one machine are exponential failure and repair. In the uptime ratio calculations the cumulative binomial distribution is used, whereas in the time interval reliability case the methods of Markov chains are employed. The reader will require a knowledge of these methods in order to follow the presentation. In both cases the assumptions underlying the methods are clearly stated. (Incidentally, there are several plus signs missing in the sums of terms displayed on pages 346 and 347 in the paper.) ##

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Serial Number 483
Codes 844;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Operational reliability of the Athena computer

AUTHOR: G. P. Anderson, Remington Rand UNIVAC, Division of Sperry Rand Corporation, St. Paul, Minnesota

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 357-366, January, 1962

PURPOSE: To describe the failure analyses of both R & D and field operation phases (Phases I and II) of Athena computers.

ABSTRACT: The design engineer must design the system correctly since no subsequent operation can improve the reliability. In the Athena computer there have been no drift failures; this shows that the circuit was designed very carefully. In the R & D phase it was early decided that every failure was important and must be analyzed. The analysis equipment need not be complex, just used well. Table II shows the distribution of failures among the parts for Phase I. The power supply was the worst. This part, along with others, was redesigned. Table IV shows the failures in Phase II. None were in the power supply, but the sealed chassis still caused some failures. Many of these were due to transistors and some failure modes were unfamiliar to the supplier. The computer is operating very well and no missile malfunction has ever been traced to it.

REVIEW: This paper is a rather detailed discussion of the failures found in the computer. The philosophy presented here seems rather good. It is apparent that painstaking attention to both large and "small" matters is essential to high reliability. See also Abstract and Review Serial Number 468. ##

Serial Number 484
Codes 824;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability predictions for multi-mode electronic systems

AUTHOR: John A. Connor, Astro Reliability Corporation, Sherman Oaks, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 367-375, January, 1962

PURPOSE: To explore some useful means whereby system risk parameters can be synthesized from known risks associated with contributing elements.

ABSTRACT: The logic of defining mission success for a classic multi-mode electronic system is discussed. It is contended that an exhaustive definition of success can lose its meaningfulness as a guide to optimum system design or mission application. Rather, a simplified concept is proposed which assumes three fundamental criteria; namely, (1) all system modes must be available for mission success even if deployed sparingly, (2) the probability of mission success is the product of the probabilities for successfully completing all time-sequenced mode periods throughout the mission, and (3) the successful completion of a mode period can be computed from equipment failure rates and the exponential failure law. The theoretical (and practical) constraints incumbent upon the system design and application engineer are discussed in conjunction with a mathematical model development. An interpretation of the model is made to show its inherent applicability to representative electronic systems. Finally, a six-step routine is presented to allow a rational adaptation of the derived "idealized" technique to a general electronic system which may possess various criteria for successful operation beyond its "hard-core" capabilities. (Author)

REVIEW: The routine for analyzing multi-mode systems which is presented in this paper should prove to be useful to designers of such systems. A considerable part of the paper is devoted to discussing the underlying logic and theory. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Correlation of AGREE testing with operational reliability

AUTHORS: Griffith W. Lindsay, Staff Reliability Engineer, DCS/M, ASD, AFSC, WPAFB, Ohio and J. W. Thomas, Vitro Corporation, Silver Springs, Maryland

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 376-381, January, 1962

PURPOSE: To present early results of the correlation study on the ARN-21C TACAN.

ABSTRACT: Previous papers have discussed the manufacture of this receiver and the problems in meeting the AGREE (level H) requirements. This study was for the purpose of deciding the adequacy of the AGREE tests relative to use conditions. The factors that are different between the two are listed. The conclusions of the paper are listed below.

a. The AGREE tests are adequate, when fully exploited, to insure the acceptance only of equipment whose operational reliability is at least as high as the minimum acceptable (with 90% confidence).

b. The AGREE tests do not replace, except in a few areas, the conventional first article or capability tests, which, in turn, give little assurance of reliability without AGREE testing.

c. No amount of AGREE testing under a given specification will give assurance of operational reliability if the specification is not representative of operational conditions.

d. While high inherent reliability as demonstrated by AGREE procedures does not assure high operational reliability, it permits its attainment. Only when spares and spare parts are available, when the equipment in question is properly integrated in the system, when Maintenance Ground Equipment is available, operating and calibrated, when Operating Ground Equipment is in fact operating, and when Technical Orders and other publications are available and are followed, can operational reliability be attained. On the other hand, these factors cannot assure operational reliability if inherent reliability is absent. (Author in part)

REVIEW: This paper, as the author mentions, is incomplete; a further, more complete paper will probably be forthcoming. One interesting point brought out in the study is the multitude of poor maintenance and operating possibilities that can almost completely negate the otherwise good design/manufacture of the equipment. It shows that much more attention could be given to making the system "fool proof." ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Development of new prediction techniques

AUTHORS: Irving Bosinoff, Waltham Laboratories, Sylvania Electronic Systems, A Division of Sylvania Electric Products Incorporated, Waltham, Massachusetts and Jerome Klion, Reliability Techniques Group, Applied Research Laboratory, Rome Air Development Center, Griffiss Air Force Base, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 382-387, January, 1962

PURPOSE: To summarize some of the existing techniques for predicting system performance and to describe some reliability prediction techniques using mathematical simulation methods.

ABSTRACT: As the field of reliability matures a larger number of mathematical tools for predicting electronic system reliability are being developed. This paper is a progress report on some of the more recent of these predictive techniques now undergoing development. Generally classed as "mathematical simulation," or "Monte Carlo" methods, they require a detailed analytic model of the system of which the reliability is to be predicted. Mathematical simulation, as used here, may be taken to mean the synthetic construction and empirical examination of a dynamic reliability model by means of a large computer. In many cases, this is the only feasible means of generating the probability distributions of various appropriate measures of system reliability.

A brief review of current prediction methods is given, including references to the following reports: RCA Technical Report TR-1100 (OTS Publication PB131678), ARINC Research Corporation Publication No. 110-1-136, Martin Denver Report M1-60-54, and NAVSHIPS 93820. The problem of predicting initial performance and degradation failures is described as one of estimating the probability distributions of various system reliability measures, given probability data on the performance of system components. Numerical-valued measures and functional-valued measures of system performance are distinguished. Measures of system reliability are described. The Monte Carlo procedure is discussed. Brief reference is made to multiple regression, to the distinction between absolute and comparative prediction, and to catastrophic failure models.

REVIEW: This paper is a qualitative summary of a report which the authors state will be available via ASTIA later. As a summary, it serves a useful purpose in calling attention to the larger report, and giving some idea as to its content. No doubt details on its availability can be obtained from the authors.

It should be pointed out that the term "new prediction techniques" might be somewhat misleading. Monte Carlo simulation, per se, has been in use for some time, although its application and adaptation to the prediction of system reliability may be a relatively recent development. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: General usage assemblies for Navy electronic equipments

AUTHORS: Thomas E. McDuffie and George C. Neuschaefer, U.S. Naval Material Laboratory, New York Naval Shipyard, Brooklyn 1, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 388-393, January, 1962

PURPOSE: To describe the Navy's program for standard, general usage circuits.

ABSTRACT: From an analysis of about 100 Navy electronic equipments, 24 circuits were found which were recommended for standardization. Of these, 21 were actually built and tested. Table 1 lists the assemblies and Figure 2 shows three different predictions of mean time between failures for each of ten assemblies. The three estimates of life are from laboratory life test data (highest), from parts failure data, and from Naval Material Laboratory Tests (lowest--taken under adverse environmental conditions). Further development of these circuits will be carried out so that 10,000 hours operating life will not be unreasonable for the assembly.

REVIEW: The standardization of these assemblies is an excellent idea. It will be even better if it will be used in practice in the construction of equipment. It may mean that some performance of the system will be sacrificed in some cases, but it should improve the average performance of equipment in service. The Navy is to be commended for this effort and it is to be hoped that the concept will actually be used. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A quad configuration--reliability and design aspects

AUTHORS: Ralph M. Fasano and Alvin G. Lemack, Data Systems Operations, Sylvania Electronic Systems, A Division of Sylvania Electric Products Incorporated

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 394-407, January, 1962

PURPOSE: To discuss in detail the reliability and design aspects of the "quad" circuit.

ABSTRACT: This paper will discuss primarily the reliability and design aspects and limitations of electronic circuits in which a particular type of component redundancy called QUADing is used. For comparison purposes a non-redundant and a QUAD redundant circuit are analyzed to establish the magnitude of the increased reliability, effects on loading, power, terminal supplies, transient aspects, etc. The following statements compare the redundant circuit to the non-redundant.

1. The quading of transistors subjects their parameters to more vigorous and demanding requirements.
2. The redundant configuration can drive but one fourth the load of the non-redundant circuit.
3. The quading approach is inherently a slower one increasing signal propagation time by at least two to one.
4. The redundant design will dissipate up to and possibly more than four times the power if maximum speed is desired.
5. The quading layout normally will demand a greater supply voltage and therefore cause the minimum power ratio to be about 2:1 redundant to non-redundant.
6. Failure of any unit of a QUAD can increase semi-conductor dissipation per unit up to four times. A direct consequence of this is the resultant lowering of ambient operating temperature. (Authors)

REVIEW: This is a reasonably complete discussion of the quad circuit which is receiving a good deal of attention. (See also Abstracts and Reviews Serial Numbers 277 and 396.) The assumptions in any of the derivations must be kept firmly in mind when the theory is applied. Some questions which are occasionally neglected are: 1. Does the analysis include drift failures as well as catastrophic ones? 2. Does the analysis assume that diodes and transistors are perfect switches? 3. Will more circuits be needed because of poorer performance of each one? 4. Will components have the same failure rate in both cases? It is very easy to forget to make a complete analysis of the system before and after quadding. The authors have done rather well in this regard although the possibility of drift failures seems to have been neglected. ##

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844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Forced-air cooling and reliability

AUTHORS: J. L. Keller and S. D. Olicker, Air Armament Division, Sperry Gyroscope Company, Division of Sperry Rand Corporation, Great Neck, L. I., New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 408-415, January, 1962

PURPOSE: To present a method for estimating the improvement in failure rate as a function of forced-air cooling.

ABSTRACT: This analysis assumes the following properties for the module to be cooled:

Every component was essential for module operation, so that component failure and module failure were synonymous

The failure rate of every component was a function of surface temperature alone

Some fraction of the air forced into the module at a specified temperature and weight flow rate passed each component

Turbulent forced-air convection was the primary means of heat transfer between the components and the coolant.

An example is given for a distributed amplifier. The data were experimentally determined.

Within the range where the assumptions are valid, the method meets its objective: a reasonable estimate of the effect of forced-air cooling on reliability can be obtained with a reasonable amount of effort.

Alternate schemes which provide more accuracy at the cost of tedious and involved calculations are not justified. This is particularly true in view of the limited data available relating component failure rate to surface temperature. (Authors in part)

REVIEW: This seems to be a reasonable method to use for assistance in estimating failure-rate improvement. Undoubtedly it is intended to be used along with other techniques for estimating the absolute failure rate. The mathematics are rigorous in that the assumptions are stated and no mistakes are made in the derivations (there are a few minor misprints). The curve for average failure rate vs surface temperature reaches a maximum at about 130°C and then decreases. It is not obvious why the average failure rate should decrease at higher temperatures. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determination and use of failure patterns

AUTHORS: R. L. Horn and G. S. Shoup, The Boeing Company, Military Aircraft Systems Division, Wichita Branch

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 416-424, January, 1962

PURPOSE: To discuss two failure patterns which have evolved from analyses of data on systems of the B-52 airplane.

ABSTRACT: Analyses of data on various systems of the B-52 airplane have indicated the following failure patterns.

1. Failure rate is not constant throughout a mission.
2. Most failures are caused by parts which fail infrequently.

The non-constant failure rates suggest the use of a Weibull distribution for the prediction of reliability. For the systems considered, shape parameters between 0.082 and 0.567 are found to be appropriate. Methods of determining Weibull reliability formulas at the system and part level are presented.

The implications of a non-constant failure rate are seen from an analysis of the causes of high initial failure rate. Reliability can be markedly improved by the incorporation of a few changes in the areas of (1) environmental stresses during take-off, (2) environmental stresses of starting and stabilizing equipment, and (3) maintenance actions. It is also concluded that major gains in reliability can be realized by developing and applying new concepts directed at reducing failures of parts which fail infrequently. (Authors in part)

REVIEW: The data summarized in this paper seem to indicate that the systems considered have failure rates which decrease with time, and that a Weibull distribution is a reasonable choice of model. The degree to which the model selected fits the data depends, of course, on the choice of the shape parameter value, which must be estimated from available data. It should be kept in mind that first estimates may well be subject to revision as more data accumulate. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dependability models for a system of N parallel elements

AUTHORS: J. Finkelstein and R. Schafer, Members of Technical Staff, Hughes Aircraft Company, Ground Systems Group, Fullerton, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 434-441, January, 1962

PURPOSE: To derive and illustrate certain measures of dependability for a system of N parallel elements.

ABSTRACT: Certain types of electronic equipment make use of a number of small identical elements in parallel instead of a single large element. This parallel-element design admits of degraded but still satisfactory states of operation. The model selected to represent the system for dependability calculations must reflect the ability of the system to operate satisfactorily in these degraded states.

Depending upon the usage of the system, various measures of dependability are appropriate. The measures discussed in this paper are defined below.

Availability is the probability that the system will be able to operate within tolerances at a given instant of time after t=0.

Interval Availability is the expected fraction of an interval of length t that the system is able to operate within tolerances, given the state of the system at the start of the interval.

Probability of Survival (or Reliability) is the probability that the system will operate within tolerances for the entire interval of length t.

The system considered consists of N parallel elements, and is such that the system function is satisfactorily performed when at least K of the N elements operate. The possibility of operation in degraded states is a form of redundancy.

The general time-dependent solutions for the above three dependability measures are obtained by solving a set of differential equations by using Laplace transforms. The steady-state solutions are also obtained. An example is given for N=100, K=97 and the time-dependent solutions are given along with the steady-state solutions. Failure times and repair times are assumed to follow the exponential distribution.

REVIEW: This paper consists mainly of the mathematical derivation of the dependability measures, illustrated with a worked example. The results and example should prove useful to systems design engineers in specifying requirements for the equipment designers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Compliance demonstration of a multimode system using a Monte Carlo analysis

AUTHORS: Donald L. Costello and Robert M. Meisel, Surface Armament Division, Alan M. Letow, Air Armament Division, Sperry Gyroscope Company, Division of Sperry Rand Corporation, Great Neck, L.I., New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 446-457, January, 1962

PURPOSE: To discuss the use of the Monte Carlo technique in the demonstration of system reliability.

ABSTRACT: In theory, the demonstration of system reliability is a straightforward procedure. It is necessary merely to take a system, operate it for a statistically sufficient time, count the total failures that have occurred, and assess the results according to an appropriate standard technique. In practice, however, such a procedure is almost never used because (1) the results would not reflect the effects of environmental conditions expected to be encountered in actual operation, (2) it is not feasible from the standpoint of cost, and (3) in many cases only a few systems are produced, and these are required for immediate operational usage. Thus the demonstration of system reliability often depends on an analysis of data collected under actual operating conditions in field usage. The data are usually not in an ideal form for the purpose.

While point estimates of MTBF may be obtained for the modules of which a system is composed, there remains the problem of placing a confidence interval around the MTBF for the system. One method for obtaining a solution to this problem is to employ the Monte Carlo technique. This technique involves generating the distributions of each of the modules on a computer, and from these results obtaining the distribution of system reliability.

The method is described in detail; results on a hypothetical system are given, and density and cumulative functions for system reliability are illustrated.

REVIEW: This is a fairly detailed discussion of the applicability of the Monte Carlo technique to the demonstration of system reliability. There are several misprints in the paper; the informed reader will readily detect them. It would seem that the third and fourth sentences in the "Conclusion" on page 450 should read as follows: "The existence of the X^2 distribution is predicated upon the assumption that the exponential failure law holds. If this is not the case, evaluation of the underlying module distribution (which, unfortunately, is not always easy) is necessary in order to furnish valid inputs into the process." This word of caution is well taken. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: General procedures for establishing and conducting design reviews

AUTHOR: H. K. MacKechnie, Sylvania Electronic Systems, Amherst Laboratories, Buffalo, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 458-472, January, 1962

PURPOSE: To show how and why design reviews are conducted.

ABSTRACT: The purpose of the design review is to analyze the system, and the electronic circuit design including component applications and mechanical design, considering the factors of reliability, cost, and fabrication. The objective is to design a more reliable product requiring few or no factory changes and giving years of trouble-free service. To accomplish this, design reviews are conducted during four stages in the equipment development process:

1. System Concept
2. Circuit Concept
3. Preliminary Design Review
4. Critical (or Final) Design Review.

In addition, after drawings are released, all change notices are processed through the Design Review Team.

While there is some resistance by designers at first, the reviews help them to become better and they then tend to be enthusiastic about them. The design review chairman should report to the project engineer's supervisor to keep the reports objective. A list is given of the committee personnel at the various stages at which reviews are held, the information necessary and the action to be taken. An appendix gives a rather detailed discussion of a specific example. (Author in part)

REVIEW: The main purpose of these reviews is to be sure that nothing, large or small, has been overlooked. The exact system used to accomplish this will vary with the size and needs of the company. One thing they must all have in common, however, is the recognition that people do forget and make mistakes even under the best of circumstances and that on other occasions people can simply be wrong.

This is a detailed paper showing one way in which the problem may be solved. As such it will be of interest to those who are new in the field or who wish to become aware of the experience of others.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability analysis of feedforward logical nets

AUTHOR: José Miró, Systems Research Center, Case Institute of Technology, Cleveland, Ohio

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 473-484, January, 1962

PURPOSE: To discuss the reliability analysis of a broad class of logical systems.

ABSTRACT: The concepts of deterministic and stochastic logical elements are established. The deterministic fundamental cell is defined and a method is given for its analysis. The method is extended to any feedforward logical net, deterministic or stochastic. A deterministic synthesis problem is studied and the results are used to draw conclusions regarding error compensation and more reliable design.

REVIEW: This is a rather specialized paper for those who are concerned with the reliability of logical systems, and are familiar with the Boolean functions used in their analysis. The paper presents an approach to the determination of the output functions, and discusses the computation of the associated output vector probability. Some attention is given to relevant design considerations. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability control of re-order spares

AUTHOR: F. J. Ruther, P.E., Dayton Air Force Depot, Reliability Coordinator

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 485-488, January, 1962

PURPOSE: To give one example of how insisting on long-life parts saves the Air Force money.

ABSTRACT: This paper is written to illustrate three basic points:

1. Reliability saves money.
2. Reliability can be controlled.
3. Reliability, properly used, can permit dynamic standardization.

The cost of a replacement vacuum tube is made up of many costs such as processing the requisition, the material, removing the equipment, and readjusting the repaired equipment. The average logistics cost of the tube is about $15. Manufacturers cooperated in a survey to determine industry practices in life tests. In December, 1960 a contract was awarded on a new reliability basis and the vendor established a 0.65%/1000 hr failure rate for the 6AH6. These specifications can be continually revised for better tubes as manufacturers improve their product. A program is also under way to determine if a correlation exists between life test data and field results. This whole philosophy is in general agreement with the Darnell Report. (Author in part)

REVIEW: All of these steps to improve reliability are most worthwhile. The program described here seems to be a good one and the hope is that it can be expanded. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A simplified method of obtaining highest system reliability

AUTHOR: Masafumi Sasaki, Electrical Engineering Department, Defense Academy, Yokosuka, Kanagawa, Japan

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 489-502, January, 1962

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 paper presents 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 are given in the paper. Constraints on cost, size, and weight are taken into account. Some numerical examples are given.

REVIEW: A major part of this paper is devoted to proofs of some ten theorems related to systems employing redundancy. The statements of the theorems and the proofs are, in general, very difficult to follow. In addition, there are numerous spelling and typographical errors. In short, 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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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Model study of degradation failure and failure level

AUTHOR: H. Shiomi, Electrotechnical Laboratory, Nagata-cho, Tokyo, Japan

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 503-515, January, 1962

PURPOSE: To investigate the dependence of degradation failure on failure definition (critical value of the parameter) and the form of the underlying lifetime distribution.

ABSTRACT: Degradation failure occurs when the value of a specified characteristic falls below a stated failure level (FL). The reliability function R(t) is defined by giving the underlying lifetime probability density function f(t) and specifying FL. This paper is concerned with an investigation of how F(t) = 1 - R(t) changes with f(t) and FL. The investigation is accomplished through the use of plots of F(t) on Weibull charts, with accompanying discussion.

REVIEW: The basic idea of using Weibull plots to investigate the dependence of R(t) on f(t) and FL seems quite reasonable. However, it is difficult to assess the accomplishments of this investigation because of lack of clarity in the presentation. Some non-standard terminology is used, and many points are not clearly expressed. Precise statements of the major conclusions drawn would have been helpful. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Long term component analysis utilizing short term materials and design studies

AUTHOR: W. E. Dunkel, International Business Machines Corporation, General Products Division, Development Laboratory, Endicott, New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 520-523, January, 1962

PURPOSE: To show how tests of short duration can be used to predict the life of electronic components.

ABSTRACT: Short term tests based on material and design studies, as well as a sound knowledge of the effects of manufacturing processes, are good tools to control the lot-to-lot quality of components and, therefore, equipment reliability. The reliability figures based on long term life tests and field experience are obtained after the equipment is mostly outmoded. Much work is done to predict long term effects on several thousand hours of life testing or equipment use. For such an approach, the knowledge of the statistical distribution of the failures with time is absolutely necessary. This knowledge cannot, however, be obtained with the amount of performance data available. Let us assume that one tolerates a constant failure rate of 0.002 per cent per 1,000 hours and the equipment is used for 20,000 hours. At the end of the 20,000 hours 0.04 per cent of the population will have failed if the stated conditions are met. This end point of 0.04 per cent accumulated failures can be reached by a constant, decreasing, or increasing failure rate. The equipment is discarded after the 20,000 hours and the assumption of a constant failure rate, even mathematically incorrect, is sufficient in most cases where short term tests control the lot-to-lot quality. For more sophistication the non-constant failure rate can be split into shorter intervals of constant failure rates, as a non-linear function can be regarded as linear over short periods. The examples chosen are a wire-wound resistor and four different kinds of capacitors. (Author in part)

REVIEW: Most of the tests are just accelerated life tests and are subject to the same hazards as any other accelerated tests. Any report of such tests should include some information or discussion as to the degree of correlation of the results with the results of laboratory and/or field tests. Some tests on the resistors appear to check the quality of the materials used to manufacture them. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The Weibull distribution--with tables

AUTHOR: Alan Plait, The Magnavox Company, Fort Wayne, Indiana (present address: Melpar, Incorporated, Falls Church, Virginia)

SOURCE: Industrial Quality Control, vol. 19, November, 1962, pp. 17-26

PURPOSE: To present some of the basic mathematics related to the Weibull distribution, together with tables of values of the probability density function and the cumulative distribution function.

ABSTRACT: Among the various statistical probability density functions used in reliability studies, the Weibull distribution is assuming increased prominence. It has been applied to a variety of problems, including some in the area of electronic part and equipment reliability.

This article develops some of the properties of the Weibull distribution and presents tables of values of the probability density function and the cumulative distribution function. The use of Weibull probability graph paper is illustrated. The basis for the graph paper is presented.

REVIEW: The presentation of tables of values for the Weibull density and distribution functions is an important contribution, since such tables have not been published previously. The accompanying discussion will be helpful to those who have occasion to work with the Weibull model. Other papers on this model have, of course, appeared in the literature; in addition to those cited as references by the author, two have been covered by Abstracts and Reviews Serial Numbers 320 and 437. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some experimental design problems in attribute life testing

AUTHOR: Sylvain Ehrenfeld, Columbia University

SOURCE: Journal of the American Statistical Association, vol. 57, pp. 668-679, September, 1962

PURPOSE: To investigate some statistical questions of life testing relating to inferences about parameters of survival functions.

ABSTRACT: Many life testing procedures which have been developed involve continuous monitoring of the items under test. In storage deterioration problems, as an example, the failure of items can only be ascertained by means of inspection. Continuous observation, in these cases, is either not possible or not feasible. This paper is concerned with design problems related to the choice of the number and timing of inspections. A general class of survival functions is investigated and optimal procedures, for estimating parameters, derived. The efficiency is compared with continuous monitoring. (Author)

REVIEW: This paper is a contribution to the statistical theory of life testing, with particular reference to storage deterioration problems. It will be of interest mainly to the statistician or mathematician concerned with such problems. Some fifteen references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A method to determine the reliability of telemetry systems reports

AUTHOR: Charles Martinez, U.S. Naval Weapons Laboratory, Dahlgren, Virginia

SOURCE: Journal of the American Statistical Association, vol. 57, pp. 686-689, September, 1962

PURPOSE: To formulate a method with which to determine the probabilities associated with the combinations of actual results and reported results on binomial trials.

ABSTRACT: In order to determine the reliabilities or probabilities of successful outcomes (or failures) from a complex which consists of two independent systems each containing a series of independent trials, the product of two binomial series may be employed. In practical problems, however, some qualifications and constraints are generally imposed which render this approach to the problem awkward and difficult. In this article a complex consisting of a missile system and an integral but independent telemetry system is considered in devising a method to determine these reliabilities. Results indicate that the reliability of telemetry reports is high even when the systems reliabilities are not particularly high. (Author in part)

REVIEW: This paper is concerned with the probabilities associated with combinations of outcomes (successes or failures) on two independent systems, each involving N independent trials. The fact that one system is represented as a weapon system and the other as a telemetry system lends concreteness to the discussion, but is otherwise not essential. For this reason the title may be somewhat misleading.

The discussion involves only elementary probability concepts and the binomial distribution. As the author has indicated, the method could be extended to include more than two systems and other than two successful outcomes, but with larger numbers of systems and/or outcomes the calculations would readily become unwieldy. There are two minor misprints on page 687: p^2 should be p_2 and p_t should be p_3. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Military vs. contract maintenance: a case study

AUTHORS: H. W. Adams and A. S. Morton, Human Factors Department, The MITRE Corporation, Bedford, Massachusetts

SOURCE: 1961 Conference Proceedings, 5th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1961, pp. 1-3

PURPOSE: To describe the analysis of IBM vs. USAF maintenance at one SAGE installation.

ABSTRACT: The computer was located in the Washington Air Defense Sector (WAADS). The technicians assigned to this project were found to be superior to the general ADC technicians on the basis of test scores and grade level; but they were below the IBM personnel on the basis of intelligence tests, technical aptitude, and training grades. The criterion of comparison was the performance of the computer before and after the transition from IBM to ADC maintenance personnel, weighted by performance trends at other sites for the same period. The conclusion was that the ADC did about as well as IBM in maintaining the computer. The unexpected result might be explained by the facts that there were about twice as many ADC technicians as there had been from IBM and the computer is quite reliable anyway.

REVIEW: The reliability of any complex installation is a function of the maintenance adequacy. This report is a good study of one of the factors involved in adequacy. A general inference can be drawn from this study, namely, the easier the equipment is to maintain, the more likely it is that it will be kept in good condition--a point which should be noted by designers. ##

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Serial Number 503
Codes 831;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Power dissipation in microelectronic transmission circuits

AUTHOR: James D. Meindl, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: 1961 Conference Proceedings, 5th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1961, pp. 4-16

This paper is virtually identical to the one covered by Abstract and Review Serial Number 74. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of repairable complex systems--Part A: The similar machine case

AUTHOR: Ronald S. Dick, International Electric Corporation, Paramus, New Jersey

SOURCE: 1961 Conference Proceedings, 5th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1961, pp. 111-150

PURPOSE: To present a mission reliability measure for similar machine type repairable systems using the concepts of maintenance time constraint and restoration time constraint.

ABSTRACT: After resolving and extending the work of Epstein and Hosford [1] by a simpler integral equation approach, this paper gives a general model for exponential repair and failure. The MTBF's for the case of one, two and three similar machines are given using the concept of maintenance time constraint. The reliability function for the one machine case is given with other miscellaneous reliability examples at the end of the paper.

REFERENCE: [1] Epstein, B. and Hosford, J., "The reliability of some two-unit redundant systems," Sixth National Symposium on Reliability and Quality Control, 1960

REVIEW: This is a fairly detailed mathematical presentation, which can be understood by an engineer with a knowledge of mixed difference-differential equations. The underlying assumptions, the background of the problem, and its orientation relative to previous work in the area are clearly indicated. As the title implies, the author expects to publish further work on the problem.

In a private communication the author has indicated that this is the first time to his knowledge that a method based on MTBF has been made available for comparing systems with high failure and repair rates against those with low failure and repair rates. He has also indicated that whereas the constraints on maintenance and restoration times in this paper are fixed times, they will be made variable in further work. The usual models of system reliability may be obtained from the model in this paper by letting the constraints be zero. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: AGREE reliability testing of air to air identification equipments

AUTHORS: J. D. Burr and W. L. Allen, Hughes Aircraft Company, Culver City, California

SOURCE: 1961 Conference Proceedings, 5th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1961, pp. 151-162

PURPOSE: To summarize the progress made on an AGREE testing program for the AAI system.

ABSTRACT: The system reliability was to be proved in accordance with AGREE Task Group 3 recommendations for "Pilot production." The program requires the determination under modified level X conditions of the MTBF and a demonstration that this does not deteriorate during the desired life. The two phases of the program were to determine the MTBF of present production equipments and then to improve the product by proper changes.

Charts and figures show the MTBF figured in different ways; there are also parts failure summaries and a brief description of each failure type.

The majority of the deficiencies experienced in this program were due to variations of uncontrolled component parameters. Until such time that components are developed to withstand these severe environmental conditions on a predictable basis this will continue to be a significant limiting item. (Authors in part)

REVIEW: This is a rather general paper and shows some of the problems in AGREE testing. Many of the failures appear to have no immediate remedy. ##

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Serial Number 506
Codes 813;873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Techniques for achieving operational reliability and maintainability in digital computers

AUTHOR: Thomas B. Lewis, FSD Space Guidance Center, Owego, New York

SOURCE: 1961 Conference Proceedings, 5th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1961, pp. 163-181

PURPOSE: To describe the design of an airborne computer which can easily be maintained in flight.

ABSTRACT: In this paper, the various problems associated with operational reliability and maintainability will be discussed in general and then in regard to a specific digital computer application. Design and programming techniques for the implementation of this plan, including a new built-in method for failure location, will be presented. Their effectiveness, as determined by simulation and actual laboratory tests, will be summarized. Some conclusions which may benefit other applications will also be included.

The importance of considering the problems of operational reliability and computer maintainability at the onset of computer development cannot be overemphasized. Once a computer design is frozen into hardware it is impossible to "legislate" reliability or maintainability.

The various design and programming measures for error detection and minimization of error effects incorporated in the particular application have contributed immeasurably to the operational reliability of the computer and of the system itself. The development of an effective hardware method of failure location permitted rapid and rote computer maintenance with a minimum penalty to the system, and it, in turn, contributed further to increased system reliability by enabling in-flight repair. Ground maintenance was also simplified through the incorporation of such built-in testing capability into the computer itself. (Author in part)

REVIEW: The emphasis on easy fool-proof maintenance is very good. The article is rather comprehensive in discussing the philosophy and detailed approach to the problems, but circuit details are not shown. The machine is yet to be built and final judgment must be reserved until then. Ten references to related work are cited. ##

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Serial Number 507
Codes 524;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductor reliability in switching systems

AUTHOR: W. P. Karas, Telecommunication Engineering, General Dynamics/Electronics (P. O. Box 788, Rochester 3, New York)

SOURCE: 1961 Conference Proceedings, 5th National Convention on Military Electronics, sponsored by Professional Group on Military Electronics, Institute of Radio Engineers, Washington, D. C., June, 1961, pp. 182-190

PURPOSE: To present the results of a program of reliability determination carried out on semiconductors during the development and production of electronic telephone switching systems.

ABSTRACT: During the development and production of electronic telephone switching systems, an extensive reliability program was performed. Part of the program included the reliability determination and assurance of semiconductors. For this purpose, semiconductor parameter data of low- and high-temperature storage and accelerated life tests were recorded on punched cards to enable large-scale statistical analysis programs through automatic computer techniques.

An analysis of variance was performed on data on various types of germanium transistors, and on silicon and germanium diodes, to determine significant variabilities in order to assess with high confidence the reliability of these devices. Results are expressed in terms of variabilities between manufacturers, between lots within manufacturers, the effects of storage and accelerated tests, test times, and interactions between these factors. Effects due to applied stresses are also investigated. (Author in part)

REVIEW: This paper does not provide sufficient detail on the conducting of the tests or the analysis of the data to enable the reader to get a clear picture of precisely what was done. However, the author in a private communication has indicated that for an interested reader the complete report of the analysis of variance and the semiconductor study is available from him. He has also pointed out that the report attempts to show (a) a correlation of test specifications to design specifications which can increase the reliability in the engineering design phase, and (b) the great variability of lot-to-lot and vendor-to-vendor. The complete report should therefore be of value to designers of electronic switching systems. ##

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Serial Number 508
Codes 342;715;782;
833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nuclear blast effects on components and equipment

AUTHORS: Louis L. Kaplan and Richard G. Saelens, U.S. Army Signal R. & D. Laboratories, Fort Monmouth, New Jersey

SOURCE: Electronic Industries, vol. 21, October, 1962, pp. 94-101

PURPOSE: To review requirements for radiation hardening of electronic equipment in relation to military requirements, problems with evaluation of parts, and the state of the art for nuclear resistance.

ABSTRACT: In contrast to the permanent damage observed in electron tubes at steady-state reactors, only transient changes have been recorded during pulse-type exposures. In semiconductors the degree of permanent damage is proportional to the total integrated fast neutron dose. Transient effects in transistor operation are caused by the interaction of gamma radiation with orbital electrons, and ionization resulting from atoms which are displaced by fast neutrons. The permanent damage may anneal out in seconds, minutes, or days. Shunt air leakage paths across resistors is a contributing factor to the transient effects on resistors. More research is needed to determine the significance of cable effects on resistors during experiments. Except for paper dielectric capacitors, transient effects in capacitors were small or negligible.

The Radiation Effects Information Center at Battelle Memorial Institute has been designated as the information collation agency for pulsed radiation effects on electronics. The Department of Defense has prepared MIL-STD 446A for the guidance of military electronic designers.

REVIEW: This is a general article which notes that some of the experimental data on transient effects is not reliable and makes the point that a standard must be established by which all electronic piece parts and systems can be measured. ##

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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: Transients in relay dielectrics

AUTHOR: Kirby B. Austin, Director of Research, Allied Control Company, Inc., New York, New York

SOURCE: Electronic Industries, vol. 21, October, 1962, pp. 102-105

PURPOSE: To show how to avoid testing transients during Hipot testing.

ABSTRACT: Among the failures which occur during a test of the relay dielectric strength are those which are unexpected and due to high transient voltage peaks. These peaks originate within the test set or associated high-voltage switching units. The applicable MIL standards allow for instantaneous application and removal of test voltage under some circumstances. If the make-and-break contacts are in the primary circuit, voltage transients may be expected in the secondary. The problem can be eliminated by switching only when the rms secondary voltage is zero or by switching only at the instant of zero primary current. The latter would require a control similar to a synchronous welding control. Similar considerations would hold for switching in the secondary when the voltage is on. (Several oscillograms are shown of the transient peaks.) Obviously these unexpected voltages may shorten the life of the relay.

REVIEW: The problems of testing a component are well brought out in this article. While those concerned with testing of relays are directly affected by the "anomalies" described here, everyone who makes electrical acceptance checks should be quite sure that unexpected stresses are not being applied during the test. This is a most important and too easily overlooked point. The author should be commended for bringing this case to public attention. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Traveling wave tubes and reliability

AUTHOR: Stanley F. Kaisel, Microwave Electronics Corporation, 4061 Transport Street, Palo Alto, California

SOURCE: Electronic Industries, vol. 21, November, 1962, pp. 102-105

PURPOSE: To show that the traveling wave tube has a long and useful life.

ABSTRACT: Some of the major complaints against the traveling wave tube are short operating and storage life, difficulty of field replacement, and inability to withstand the military environment. The operating life depends on the cathode structure and operating temperature; the problems here are very similar to those with other tubes. Storage life depends on vacuum-tight construction and low outgassing--both can be obtained in production. The operating life can be from 5000 hr to 50,000 hr. The solenoid-focused tubes are difficult to replace and adjust in the field. The magnetically shielded periodic permanent magnet (PPM) focused tube alleviates most of these problems, even in low noise tubes. The operating voltage must be set to within 1% or closer and this can be difficult. One solution is to allow a margin in design so that one can adjust the voltage to about the right place and then trim it by optimizing the overall system performance. Traveling wave tubes are meeting the requirements of MIL-E-5400 class II. Some can withstand 25 g vibration to 3000 cps and 75 g shock. The better high-power tubes are metal-ceramic, but glass still holds the life record for low power tubes.

REVIEW: This is a defense of the traveling wave tube as a good component when it is properly built and applied. (There are no references.) General results from some life tests are given. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Vacuum extends Al fatigue life

AUTHOR: (Editorial Matter)

SOURCE: Research/Development, vol. 13, November, 1962, p. 49

PURPOSE: To report on the preliminary results of a study of fatigue life of aluminum in vacuum.

ABSTRACT: Electropolished 1100-H14 aluminum samples were fatigued in vacuum. The life was increased by a factor of 5 to 8. This research was performed at the National Research Corporation. One explanation of the result may be that the metal cracks do not oxidize in vacuum and thus are not prevented from "growing" back together again when the surfaces again contact each other. The pressures were in the 10^{-9} torr range.

REVIEW: This is an extremely short summary, which serves to bring the study to the attention of those who may be interested. Presumably the full reports will be published later. It should be pointed out that a factor of 6 in fatigue life at a few million cycles (of load application) might be equivalent to only a 10% to 30% increase in fatigue strength. ##

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Serial Number 512
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Environmental testing for Service electronic equipment

AUTHOR: S. C. Schuler, The Royal Radar Establishment, Malvern, Worcs., England

SOURCE: British Communications & Electronics, vol. 9, pp. 670-675, September, 1962

PURPOSE: To outline the environments that Service equipment can encounter and to emphasize adequate laboratory testing and proper design.

ABSTRACT: The importance of environmental testing at the various stages of equipment development is generally recognized and has undoubtedly led to marked improvements in the overall reliability of military electronic equipment in recent years. The underlying purpose of such tests is to check for adequate equipment design and proper selection and use of components and materials.

To achieve greater realism in the simulation of operational environments, more emphasis should be placed on combinations of environments, such as vibration with climatic conditions, when drafting individual testing programmes.

In simulating combination tests it is important to relate such test levels to actual use (e.g. equipment bay temperature and vibration) rather than to the arbitrary conditions included in standard test specifications. The need for more data on the temperatures and vibration environments actually experienced by equipment in flight is emphasized.

The transit and handling environmental levels currently used in testing are somewhat empirical. More research is needed to obtain realistic data on these conditions.

Another important aspect is the approach to component specifications. Much more attention should be given, particularly by equipment contractors, to adequate inspection and evaluation tests on new components before they are incorporated in equipment designs, and to seeing that reliability requirements are reflected in the actual procurement specifications placed with the component manufacturers. (Author)

REVIEW: The discussion of various climates and of induced environments is brief but good. A list of design faults and general corrective measures is included. The adverse comments on soldering might be challenged on the grounds that when soldering is done correctly, the joint is an excellent one. ##

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Serial Number 513
Codes 761;815;833;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The relationship of noise to reliability in servo feedback potentiometers

AUTHOR: John T. Reeves, Senior Electronics Engineer, General Dynamics/ Pomona, Pomona, California

SOURCE: Proceedings, Technical Symposium: Application and Reliability of Precision Potentiometers, sponsored by Precision Potentiometer Manufacturers Association, 27 East Monroe Street, Chicago 3, Illinois, Los Angeles, California, August 20, 1962, pp. 12-52

PURPOSE: To discuss the proper application and specification of servo feedback potentiometers.

ABSTRACT: Designers of systems are prone to disregard hardware limitations when it comes to potentiometers. This can result in inadequate specifications and high reject rates. Some of the acceptance tests have very little to do with potentiometer performance. Two criteria which should be adequate for acceptance testing are set forth in the paper. These criteria pertain directly to performance in feedback systems. They are (1) effective resolution and (2) fault width for amplitudes exceeding a certain value. The two tests are discussed at length and examples of measurements are given.

REVIEW: The adequate specification of acceptance tests is an important phase of design and production. The reliability can then be improved by restricting the important things and letting the others have as loose tolerances as possible. The author also suggests that circuits be designed both electrically and structurally to allow for the inherent nature of a potentiometer. ##

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Serial Number 514
Code 781

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The space radiation environment: Designing for space--1

AUTHORS: E. J. Rohrbach and H. S. Goldstein, Airborne Instruments Laboratory; Deer Park, Long Island, New York

SOURCE: Machine Design, vol. 34, October 25, 1962, pp. 146-150

PURPOSE: To describe the nuclear radiations existing in space.

ABSTRACT: While the newness of the subject leaves exact conclusions open to controversy, a reasonable picture of the environment can be given. The Van Allen belts contain protons and electrons whose distribution varies with altitude. They are now thought to be a continuous zone with different energies and particles having maxima at different places. Cosmic rays are largely protons and alpha particles. They have a rather low flux. The emission of solar flares seems to be largely a Poisson process; two types of these flares can cause damage.

Several tables and figures show some of the results in concise form. There is a brief discussion of the man-made radiation belt.

REVIEW: This article is limited to the material in the title and seems to be adequate though brief. While it is outside the exact scope of the article, it should be mentioned that even though there are no gamma rays in the environment, per se, they are created when many of these particles interact with matter (such as a spacecraft). The sun, of course, emits non-nuclear type radiation such as X rays, ultraviolet, visible and infrared radiation. ##

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Serial Number 515
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation vs materials: Design for space--2

AUTHORS: E. J. Rohrbach and H. S. Goldstein, Airborne Instruments Laboratory, Deer Park, Long Island, New York

SOURCE: Machine Design, vol. 34, November 8, 1962, pp. 148-150

PURPOSE: To give a brief summary of the effects of nuclear radiation on metals and plastics.

ABSTRACT: Materials are damaged in two ways: ionization and displacement of atoms. Organics are largely affected by ionization, metals by atomic displacements. Secondary radiation in the form of gamma rays is generated by the interaction of the high-energy particles (largely electrons) with matter. The structural properties of most metals, in vacuum, are not affected by radiation. Other materials, gases and organics, which are in contact with the metals, can become chemically active and cause corrosion. The presence of air accelerates the damage to some plastics by the radiation. Two tables summarize some of the pertinent data on radiation damage. (The most recent reference listed in the paper is shown below.)

REFERENCE: Jaffe, Leonard D. and Rittenhouse, John B., "Behavior of materials in space environments," Technical Report No. 32-150, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, March, 1962, reprinted from ARS Journal, vol. 32, pp. 320-346, March, 1962 (See Abstract and Review Serial Number 525)

REVIEW: This is a short summary for the beginner in the field. The reference given above is much more complete for those who need more information. The discussion of bremsstrahlung is very brief; it might be added that most of the photons (gamma rays) that are created will have energies appreciably less than that of the impinging electron. There are some other measures of radiation besides the Roentgen and the erg/cm^3 (the erg/cm is a misprint) which are useful in special cases:

1. rem: roentgen equivalent, man
2. rep: roentgen equivalent, physical
3. rad: radiation absorbed dose. ##

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Serial Number 516
Codes 555;840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Probability of success nomogram

AUTHOR: Robert L. Peters, Space Frontiers, Incorporated, New York, New York

SOURCE: Electronic Equipment Engineering, vol. 10, October, 1962, p. 51

PURPOSE: To provide a convenient way of determining probability of success by graphical means.

ABSTRACT: This nomogram provides a simplified method of determining the probability of success given the mean time between failure and the time of mission. Also, it may be used to judge the required mean time between failure when the mission time is specified and a particular probability of success is required. (Author)

The use of the nomogram is explained and an example is given.

REVIEW: A similar nomograph was presented in the paper covered by Abstract and Review Serial Number 93. The need for such a device to solve the simple equation $P = e^{-t/m}$ is questionable, although if one has a large number of solutions to be made quickly it may have some merit. However, for relatively large values of P (say greater than 0.9) the approximation $1 - t/m$ for $e^{-t/m}$, which can be solved mentally, leads to a result almost as accurate as that given by the nomograph. It should also be observed that this device applies only to situations in which a constant hazard rate may be validly assumed. ##

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Serial Number 517
Codes 720;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability screening uses noise levels

AUTHOR: (Editorial Matter)

SOURCE: Industrial Electronic Distribution, vol. 2, October, 1962, p. 7

This is essentially a summary of the material in the paper covered by Abstract and Review Serial Number 263. ##

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Serial Number 518
Codes 731;771;813;
835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving micromodule reliability

AUTHOR: Donald T. Levy, Radio Corporation of America, Semiconductor and Materials Division, Somerville, New Jersey

SOURCE: Industrial Electronic Distribution, vol. 2, October, 1962, p. 24

PURPOSE: To describe some improvements in micromodules.

ABSTRACT: Micromodules which are rejected during acceptance or life testing are fully analyzed to determine the cause of failure. The available techniques include X rays, air-abrading, microphotography, chemical analysis, spectroscopic analysis, physical testing, and chemical disencapsulation. The X-ray technique has been found to be a very useful non-destructive method for examining the structure of a rejected module. Air-abrasion is quite dependable and precise.

After the failure cause has been determined, proper corrective action is taken. Each module is rigorously screened before being accepted for test. Several performance and temperature cycling screening tests are used. The microelements which are submitted by vendors are thoroughly checked and qualified by life tests. Several of the advances are listed in the article. Two tables show life test results for both microelements and micromodules. Two results for 1962 "models" are about 250,000 hours and 460,000 hours MTBF (60% confidence).

REVIEW: A previous paper, covered by Abstract and Review Serial Number 110, was a progress report on this program. The lifetimes of the modules seem to be improving as time goes by. If the results in the table include adequate environmental testing, they are quite encouraging. (The number of significant figures in the MTBF--four or five--is rather misleading; two would probably be quite adequate to appropriately express the accuracy.) ##

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Serial Number 519
Codes 770;801;812;
815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--1 (IED Background Memo)

AUTHOR: G. B. Cohen, Sylvania Electric (Buffalo, New York)

SOURCE: Industrial Electronic Distribution, vol. 2, October, 1962, p. 25

PURPOSE: To introduce some basic reliability concepts.

ABSTRACT: The definitions of reliability and MTBF are given. The "Ball Park" method of calculating MTBF by adding failure rates is explained. Redundancy is briefly discussed.

REVIEW: The main disadvantage of such a brief summary is that it cannot be sufficiently complete. For example: (1) The failure rate discussion assumes a constant failure rate without stating so explicitly. (2) The middle portion of the "bathtub" mortality curve is listed as the random part. It should be emphasized that each failure does have a cause, even though the statistics are such that the behavior can be treated by the mathematics of random processes. (3) The terms "series" and "parallel" are used in a logical sense rather than an electrical sense. (Series resistors which fail by shorting, for instance, would be considered in parallel in the logical sense.) (4) All failures are assumed to be catastrophic and statistically independent.

The article will be useful mainly to increase familiarity with words from the field of reliability. The exact meanings should, however, be obtained from a more comprehensive treatment. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Simulation of the fatigue effects of random stress levels by a minimum number of discrete stress levels

AUTHORS: H. C. Schjelderup and A. E. Galef, National Engineering Science Company, Pasadena, California

SOURCE: Materials Research & Standards, vol. 2, pp. 836-837, October, 1962

PURPOSE: To present a theoretical discussion of simulation for a Rayleigh distribution of stress.

ABSTRACT: Random stresses are difficult to apply in the laboratory. If we knew how, we could find an equivalent single stress to simulate any load spectrum. Miner's theory of cumulative damage is quite simple and reasonably accurate if the S-N curve is known and the stresses fall within a narrow range. If the effects of interaction between highest and lowest stress levels are much greater than between nearby levels, the random stresses can be broken up into several groups and an equivalent stress calculated for each group. The paper does this for a Rayleigh distribution and for different slopes of the S-N curve. In this case the equivalent stress is rather independent of the slope of the curve (within reasonable limits). Two tables show the results of the calculations.

REVIEW: This is a theoretical paper; no attempt is made to compare the results with experience. The mathematics appears reasonable and most of the assumptions are explicitly stated or strongly implied. No mention is made of how the equivalent stresses are to be arranged in the time sequence. One problem that arises in simulation and is not mentioned here is the difficulty of reproducing the same spread in results as well as the same average value. The results are interesting and experiments to test them would be worthwhile. ##

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Serial Number 521
Code 712

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How melting techniques can affect fatigue strength

AUTHOR: R. W. Steur, North American Aviation, Incorporated, Columbus, Ohio.

SOURCE: Metal Progress, vol. 82, November, 1962, pp. 92-93

PURPOSE: To compare the fatigue properties of H11 steel produced by air melting, the Hopkins process, and vacuum processing.

ABSTRACT: Previous research has shown that consumable electrode vacuum-processed material (CEVM) has better transverse ductility and notch toughness than the air-processed steel. To a large extent, the Hopkins process (protective slag cover) was better also. This material compares closely to the vacuum-processed alloy also on the basis of cleanliness, heat-treat response and uniformity. A fatigue study was run on the slag-processed material using test bars in axial stress. The results are presented in a graph. The slag process is between the air process and the vacuum process for notched bars, and for unnotched bars the same is true beyond 3×10^5 cycles.

REVIEW: Since this is a very short paper, much material was undoubtedly left out. The omission of points from the curves and of some notion of the variability of each process is serious. The curves presumably show minimum life; but the term is most ambiguous unless properly qualified. The data should be treated by proper statistical methods, some of which are explained, for example, in ASTM publications put out by Committee E-9 on Fatigue. No mention is made of the stress ratio or other characteristics of the stress cycle. The use of the ratio of fatigue stress to tensile strength on the ordinate is useful, but can be misleading, depending on how the tensile strength was calculated for each. In short, the paper is too brief to enable one to properly judge the adequacy of the conclusions. In a private communication, the author has stated that the data on which the paper was based may be obtained from him and that they were treated by statistical methods. ##

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Serial Number 522
Codes 720;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: More on resistance-welding of electronic components (letter to the editor)

AUTHOR: Ronald J. Conti, Metallurgist, Sippican Corporation, Santa Ana, California (with reply by authors of original article--see Abstract and Review Serial Number 315)

SOURCE: Metal Progress, vol. 82, November, 1962, pp. 114-120

PURPOSE: To discuss the suitability of weld strength as a criterion for weld quality.

ABSTRACT: Tensile strength alone is not economically feasible to use as a criterion for welding conditions. Welds between some materials can degrade with time and/or temperature cycling. Tensile test results can be affected by the testing conditions. The metallurgical nature of the weld can affect its life without appreciably affecting the tensile strength. (Several examples and microphotographs are shown.) The effect of coatings is more important than is inferred in the paper.

Author's reply: Both metallurgical and tensile tests are necessary and are used in conjunction with each other. The joints must have enough strength to withstand handling, but are coated or potted to eliminate mechanical stresses in use. The temperature range of the components is so limited that weld failures due to cycling have been unimportant. The low-melting coatings seem to improve the properties of the weld.

REVIEW: There are broad areas in which the various authors agree. Certainly the use of tensile tests for quick production checks on welds is more convenient than metallurgical examination. In determining the proper weld conditions, both groups agree that both means are important. The effect of coatings seems to be still in controversy; the exact conditions and requirements may be different in the two cases and thus could give rise to apparent discrepancies.

It is encouraging to see this subject treated in the metallurgical as well as the electronic literature. ##

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Serial Number 523
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838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Progress and pitfalls in microelectronics

AUTHOR: J. J. Suran, Electronics Laboratory, General Electric Company, Syracuse, New York

SOURCE: Electronics, vol. 35, October 19, 1962, pp. 45-49

PURPOSE: To give an up-to-date summary of the status of microelectronics.

ABSTRACT: The technologies which are applicable to microelectronics include semiconductors, dielectrics, magnetics, superconductors, thermionics, metallic films, and optoelectronics. For optimum results, combinations of these will have to be used. A table shows how four of the technologies fulfill nine device functions. The type of circuit used to perform a certain function makes a big difference in the complexity of the micro device.

Reliability is a main consideration. If tolerances are too loose, more parts may have to be used and catastrophic failures will predominate; if they are too tight, drift failures may occur too easily. In either case, the failure rate will be higher than necessary. An optimum solution is possible. Redundancy is easier in principle than in practice; for example, all the redundant elements should be checked during production. This is difficult because the device functions with some bad parts.

A discussion is given of some of the state-of-the-art limitations on the various technologies. Considerable progress has been made, but no single approach, today, can do the whole job.

REVIEW: This is a general summary article which does not appear to be complete. Omissions are micromodule construction and solid state devices replacing entire circuits. The stated relationship between component tolerances and power dissipation seems plausible but has not been proved. The context of the discussion, that of contemporary practice, should be kept in mind. ##

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Serial Number 524
Codes 713;781;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Composite material seals show promise for extreme environments

AUTHOR: (Based on presentation by R. E. Headrick, Nonmetallic Materials Laboratory, Aeronautical Systems Division, USAF)

SOURCE: SAE Journal, vol. 70, October, 1962, pp. 58-63

PURPOSE: To show that a metal felt, impregnated with a softer metal can have excellent seal properties.

ABSTRACT: Seals made from composite materials appear to function satisfactorily in the extreme environments imposed by supersonic and space travel. Preliminary evaluations show that dynamic seals fabricated from composites can withstand 1200 F at 3000 psi hydraulic pressures with no trouble. Although these results are encouraging, they are not conclusive. Additional data to be received over the next few months will help determine whether commercial production is feasible or not.

The resilient composite materials concept involves a metal fiber skeleton impregnated with a softer pliable material. The metal fiber skeleton provides strength and springlike resilience at high temperatures, and the softer materials provide a compliant impermeable barrier. Visualize a steel wool pad impregnated with rubber. When this composite is placed under stress at a temperature high enough that the rubber loses most of its mechanical properties, the metal fiber skeleton provides the strength and resilience necessary in a seal material. (Author)

Two types of seals tested so far are molybdenum filled with silver and 430 stainless steel filled with tin.

REVIEW: The development of adequate and long-lived dynamic (and static) seals for use at high temperature and high pressure is to be encouraged. This is but one application of the more general field of fiber metallurgy which has become active in the last few years. The large number of diagrams and pictures help to make the presentation quite clear. ##

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Serial Number 525 -1
Codes 710;781;782;
802;833;835;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Behavior of materials in space environments

AUTHORS: Leonard D. Jaffe and John B. Rittenhouse, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

SOURCE: Technical Report No. 32-150, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, March, 1962, reprinted from ARS Journal, vol. 32, pp. 320-346, March, 1962 (presented at the ARS Space Flight Report to the Nation, New York, October 9-15, 1961)

PURPOSE: To synthesize the best current information on the expected behavior of materials in outer space.

ABSTRACT: It may be useful to summarize the effects of space environments on each class of material.

Metals and alloys are generally quite stable in the high vacuum of space at normal operating temperatures. Sublimation of cadmium and zinc may be of some concern, particularly where there is a possibility of the metal plating out in an uncontrolled manner on a cold insulating surface. Sublimation of magnesium and its alloys becomes appreciable above 175°C (350°F). A slight roughening of polished optical surfaces of other metals may occur through selective sublimation. Frictional behavior of contacting metal surfaces in space environment is a problem, with uncertainties resulting from the lack of reliable data on friction in ultrahigh vacuum. The small amount of data available indicates that similar metals will usually seize when in sliding contact in high vacuum. There is a smaller probability that dissimilar metals or alloys will seize.

Metals and alloys are not affected by space sunlight. Particle radiation will also have no effect, except that in shallow surface layers there may be a change in ferromagnetic properties on exposure to Earth's inner radiation belt or to low energy solar protons.

Meteoroids will occasionally perforate metal walls; spalling of fragments off inner surfaces by meteoroid impact on metallic spacecraft structures will be more frequent. These problems are greatest closest to Earth and diminish with increasing distances from Earth. Micrometeoroids can produce a sandblasting effect on polished metallic optical surfaces on low altitude satellites.

Among the semiconductors, selenium, phosphides, and arsenides have high sublimation or decomposition rates in high vacuum at moderate temperatures. Semiconductor devices undergo no permanent damage from sunlight. Earth's inner radiation belt will seriously damage

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semiconductor properties; in the outer belt, only the more sensitive devices will be permanently affected and then only if the sensitive portion is close to an exposed surface. Solar particle emissions may damage exposed surfaces of all semiconductors and will possibly affect sensitive semiconductors even through appreciable shielding. Meteoroids may cause shorting in exposed semiconductor surfaces.

Most inorganic engineering insulators are unaffected by the vacuum of space except at high temperatures. Sunlight in space affects primarily optical properties of insulators, causing darkening. Such pigments as titania and zircon are probably poor in this respect, as are most glasses. Glasses containing ceria may be better; high purity silica certainly is better. Glasses will suffer radiation damage to their optical properties in both of the radiation belts and possibly when subjected to solar particle emissions. Electrical and mechanical properties close to the exposed surface of inorganic insulators may be affected by both radiation belts. Close to Earth, optical surfaces will undergo appreciable surface damage by meteoroid dust.

Because of the complex composition of most oil and grease lubricants, simple estimates of their evaporation rates may not be reliable. Even oils and greases that do not evaporate in vacuum may not lubricate satisfactorily under vacuum; thus, lubrication tests in vacuum are needed. Some petroleum base, some diester, and some silicone oils and greases are satisfactory, but others are not. Oils and greases are unaffected by radiation in space, except in the Van Allen belts. Fatty acids and graphite are of no value for lubrication in space environment, and diamond is a poor vacuum bearing material. Molybdenum disulfide, however, will apparently lubricate in vacuum.

Such polymers as nylon, acrylics, polysulfides, and neoprene show high decomposition rates in vacuum. On the other hand, some commonly used elastomers, such as vinylidene fluoride-hexafluoropropane, chlorotrifluoroethylene, butadiene-styrene, isoprene, and natural rubber, are rather stable in high vacuum. Similarly, such plastics as silicone resins, tetrafluoroethylene, polyethylene, polypropylene, and ethylene terephthalate exhibit good to excellent behavior in high vacuum. Tetrafluoroethylene has excellent lubrication characteristics in high vacuum, but most other polymeric materials are of doubtful value as lubricants in the environment of space.

Optical transmission of polymers will probably be seriously damaged by unfiltered sunlight; the effects on optical absorption and emission are less certain. Electrical and mechanical properties of polymers will probably be unaffected by sunlight, except in a thin outer layer. In general, exposed polymer surfaces will deteriorate rapidly in Earth's radiation belts and perhaps from solar particle emissions. The flexibility, strength, and electrical characteristics of tetrafluoroethylene, nylon, acrylics, polysulfides, butyl rubber, and similar materials will be detrimentally affected in the radiation belts even through heavy shielding. On the other hand, such polymers as styrene, epoxies, filled resins (glass or asbestos reinforced plastics), natural rubber, polyurethane, and butadiene-styrene will probably not be affected beneath the surface. Polymers will suffer occasional perforation by meteoroids; structural laminates will probably also undergo severe spalling of their inner surfaces when struck. Near Earth, roughening by meteoric dust will affect exposed optical surfaces of polymeric materials.

There are many hazards of space whose importance to materials has been over-emphasized in the past. Among the occurrences unlikely to be of engineering importance are sublimation of aluminum alloys and steels, vacuum decomposition of tetrafluoroethylene, polyethylene, and most rubbers, escape of gases through solid container walls, sputtering of atoms off a surface by collision with atoms or ions in space, meteoric erosion away from Earth, and radiation damage by cosmic rays. (Authors)

REVIEW: This is a rather extensive review of the state of knowledge of this subject as of late 1961. Changes in this knowledge are expected to be slow, although additions may occur at a somewhat faster rate than has prevailed. The paper lists 330 references and gives many tables and graphs which will be useful.

In any new field such as this, there are likely to be some areas of difference among the experts. In cases where this may happen, the design engineer will essentially have to choose his own expert and go by his views, at least until further information is available.

The paper covered by Abstract and Review Serial Number 458 is a condensation of the above report. ##

Serial Number 526
Codes 770;831;853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability evaluation of large solid rocket engines during engineering development

AUTHORS: M. Lipow and D. K. Lloyd, Space Technology Laboratories, Inc.

SOURCE: Planetary & Space Science, vol. 7, July, 1961 (Proceedings of the Fourth AFBMD/STL Symposium on Advances in Ballistic Missile and Space Technology), pp. 217-229

PURPOSE: To present a method of evaluating the reliability of large-scale rocket engines during an R and D program.

ABSTRACT: Reliability estimates are obtained even though the configuration of the engine is undergoing change and the objectives of test firings vary. Each engine is apportioned into principal subsystems which are screened for their degree of representation of the final configuration. The intention of each test firing is determined prior to the test and the behavior of the principal subsystem when tested within the engine environment is classified according to pre-specified ground rules as a success, failure or exclusion. These results are then statistically combined to give an estimate of engine reliability. (Authors)

Copies of the forms and criteria for classification together with a chart for the calculation of reliability are given.

REVIEW: This paper is a good example of squeezing information from tests even though conventional thinking might regard the value of such tests as slight. The statistical derivations are given in references listed in the paper. ##

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Serial Number 527
Codes 825;843;853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Techniques in the demonstration of reliability attainment

AUTHORS: Edwin D. Karmiol and John S. Youtcheff, Missile and Space Vehicle Department, General Electric Company

SOURCE: Planetary & Space Science, vol. 7, July, 1961 (Proceedings of the Fourth AFBMD/STL Symposium on Advances in Ballistic Missile and Space Technology), pp. 230-241

PURPOSE: To describe reliability program measurement and prediction techniques established for use in the development of complex re-entry vehicle systems.

ABSTRACT: This paper describes the analytical techniques which are being utilized in the demonstration of equipment reliability in a re-entry vehicle system development program. Analytical techniques have been established to provide equipment reliability predictions at periodic intervals as functional and environmental test data are compiled. A mathematical model has been developed which allows for a realistic and sound approach to the problem. The equations allow for the calculation of equipment reliability, at several confidence levels, in both the individual and combined operational environments. These expressions have been programmed on the IBM 704 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 equipment reliability, and offer the design engineer an opportunity for any needed redesign early in the program. (Authors)

REVIEW: This paper describes the approach taken by one company to the problem of reliability demonstration in a system development program. The general principles will be of use to others who may be setting up similar programs, although the details will have to be worked out to meet the specific needs and circumstances. The mathematical equations appearing in the paper are not derived, but two references are cited. ##

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Serial Number 528
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of random failures

AUTHORS: G. P. Anderson and L. E. Peterson, Remington Rand Univac, Division of Sperry Rand Corporation

SOURCE: Planetary & Space Science, vol. 7, July, 1961 (Proceedings of the Fourth AFBMD/STL Symposium on Advances in Ballistic Missile and Space Technology), pp. 242-253

PURPOSE: To show that the analysis of failures which could be regarded as "random" can lead to product improvement and increased reliability.

ABSTRACT: The term "random failure" has been used much in recent literature to justify those few failures of electronic parts which could not readily be explained. The goal seems to have been the elimination of causes of failures until only random failures remain. The inference is that nothing can be done about these.

It is the purpose of this paper to show how analysis of random failures has been used in product improvement at Remington Rand Univac. Described are some of the techniques employed in the analysis of computer sealed chassis and component part failures. The paper also points out that these same techniques can be used in evaluating components proposed for use in reliable equipment where insufficient time is available to conduct life evaluations. (Authors)

REVIEW: In this paper several selected examples are used to point out the dangers of disregarding the "infrequent," "ordinary," or "one of a kind" failure. It is indicated that such failures can often be signals for needed design changes, if their causes are correctly interpreted. Efforts to identify failure mechanisms and discover underlying causes of failures can make an important contribution to reliability improvement. ##

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Serial Number 529
Codes 820;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Matrix analysis of reliability for one-shot redundant systems

AUTHOR: George D. Weinstock, RCA Surface Communications Systems Laboratories, New York, New York

SOURCE: Electro-Technology, vol. 70, November, 1962, pp. 99-103

The text of this paper is virtually the same as that of the paper covered by Abstract and Review Serial Number 229. Two corrections have been made, viz. (1) two assumptions have been added (fourth paragraph) and (2) an equation has been removed from the end because of non-valid approximations.

While the earlier abstract and review apply also to this paper, the following additional comments are felt to be appropriate in the context of the present publication.

1. The use of matrices is an artifice and is not necessary (or even desirable) in the development of the equations. It might be pointed out that the matrices that are used are not unique and that their form is nowhere justified. (The typesetting was also poor in that the [2 -1] matrix, e.g., is shown as [2-1].)

2. The "proof" of proposition I is not a proof of the proposition. All that is proved is that the resulting system need not have an exponential probability distribution of life. (The lemma is poorly worded in that the phrase "... the probability distribution of the life of the resulting system with a constant failure rate is no longer exponential" is either incorrect or ambiguous.)

3. Proposition III is not clear. The phrase "... although they may individually operate in a non-linear fashion, their characteristic probability distributions become linear" is unintelligible; the correct statement can only be surmised from the proof. The statement that "... the error in any approximation (of a convergent power series) is less than the first term of the remainder" is true only in special cases--not in general; fortunately the statement holds true in the case being considered.

4. In proposition IV the statement is made that redundancy requires that "A = B." The two systems certainly need not be identical or have the same reliability function. As a special case, however, this may easily be true. It is also stated that "Figure 5 represents the gamut of all possible system configurations." Obviously, this is not true in general, but is true for the most general case considered in the paper.

5. As indicated above, this paper is virtually the same as one which appeared in January, 1962 by the same author. Neither the author nor the editor mentions this fact. The practice of republishing a paper without mentioning that fact (except where unavoidable) is a waste of the time and effort of many people. ##

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Codes 770;833;844;
851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Current noise in fixed film resistors, Part 2

AUTHOR: P. L. Kirby, Welwyn Electric Limited

SOURCE: Radio & Electronic Components, vol. 3, pp. 729-734, September, 1962

PURPOSE: To discuss the variation of current noise with external parameters and internal variables in cracked-carbon film resistors.

ABSTRACT: The variation of current noise with external parameters such as applied d.c. voltage and frequency, and with internal variables in the construction of cracked-carbon film resistors, is discussed in detail. The average level of current noise is given for several sizes of resistor over a wide range of values and suggestions are made as to how resistors should be tested to ensure an acceptable limit to current noise. The extent to which there is a connection between current noise and the reliability of the resistor during its life on load is illustrated by reference to tests on large numbers of resistors. (Author)

REVIEW: The examples in this paper are rather detailed. The correlations between life and initial current noise are rather one-sided in that while defectives might be eliminated, so also would many good resistors.

(Part 1, appearing in the August issue of the same source, does not deal with reliability.)

(See also Abstract and Review Serial Number 263 for a discussion of noise level in tin oxide film resistors.) ##

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Serial Number 531
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Components in space

AUTHOR: J. A. M. McDonnell, University of Manchester, Nuffield Radio Astronomy Laboratories, Jodrell Bank, England

SOURCE: Radio & Electronic Components, vol. 3, pp. 735-739, September, 1962

PURPOSE: To describe the space environment and its effect on electronic components.

ABSTRACT: The possibilities of using satellites for world-wide communications have been vividly demonstrated by the recent success of Telstar. Such satellites must have an operating lifetime of many years, to justify the launching cost, and the development of suitable units depends very greatly on the availability of components designed with a knowledge of the conditions a component will encounter during its life. This article discusses the nature and effect of the environment and the extent to which the environment can be simulated.

Research into the long-term reliability of components will not only benefit space research--the same basic need has been felt in the development of repeater amplifiers in submarine cables. A recent application, in which reliability may be a matter of life and death, is the electronic "pace-maker" to control the heart. This, no doubt, will not be the only bodily function to be transistorized.

Such widespread demands must surely provide a stimulus which will, if reacted to, reap immediate rewards and be reflected by overall improvements in components for the general market. (Author)

REVIEW: This is a good introductory summary article on the topic. Other papers on the space environment and its effects have been covered by Abstracts and Reviews Serial Numbers 145, 166, 181, 242, 255, 361, 384, 413, 429, 458, 514, 515, and 525. ##

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Serial Number 532
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Equipment reliability for nuclear power plants

AUTHOR: M. M. Yarosh

SOURCE: Nuclear Safety, vol. 3, June, 1962, pp. 28-36

PURPOSE: To discuss the status of and ways of improving the reliability of nuclear power plants.

ABSTRACT: There is a need for highly reliable equipment in nuclear power plants for several reasons, e.g., unattended operation and safety. Some studies have been made of the failures that do occur and a large fraction are in the conventional parts of the plant. The reliability of the plant is determined by all the factors in its construction from specifications to materials and workmanship. The designer is a critical part of the chain. If the lifetime behavior of each part is known, the reliability of the system can be calculated. If it is not known, then approximations and guesses must be used to fill in the gaps.

Good failure data are scarce; field data tend to be erratic in quantity and quality, laboratory data are expensive to get and may not represent field use. A coordinated program to accumulate good information in this area would be most helpful. There are some rules of thumb for evaluating system reliability in terms of complexity, redundancy, maturity of design, etc. These must all be used with caution. The components themselves need to be generally improved to have longer trouble-free lives. Maintenance ease and safety checking are important factors; they are hard to evaluate because they include the behavior of people.

REVIEW: This is a broad coverage of the reliability field. It is not intended to provide depth in any area. Some of the statements, if taken out of the context of this intent may be misleading. Before any statistical models are used, their applicability should be carefully checked. While some failures are called "random" it should be continually remembered that this is a statistical description only; each failure has a physical cause which, in principle, is ascertainable. ##

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Serial Number 533
Codes 782;835;844;
851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thermal design for microminiaturized circuitry

AUTHOR: H. C. Kammerer, International Business Machines Corporation, Federal Systems Division, Kingston, New York (present address: International Business Machines Corporation, Components Division, Poughkeepsie, New York)

SOURCE: Transactions of the ASME, Journal of Engineering for Industry, vol. 84, Series B, February, 1962, pp. 1-7 (Paper No. 61--Av-5)

PURPOSE: To describe a method of thermal analysis for thin-film circuits.

ABSTRACT: Now that a number of techniques exist which permit the fabrication of circuits with a theoretical packing density of 1 million or more circuits per cubic foot, thermal design is an essential initial consideration. In most cases the drive toward microminiaturization is based on the need for a large number of circuits in a small weight and volume. If present circuit designs are taken as the basis for microminiaturization, it can be shown that with most materials being considered the temperature will rapidly rise to the point where circuits will become inoperative.

This paper outlines some of the basic considerations in terms of heat conductivity of materials, maximum safe working temperatures, and circuit power levels as dictated by current devices. A method is described whereby a proposed design configuration can be computer-analyzed in terms of isothermal lines and maximum hot spot temperatures and decisions made on that basis as to which type of cooling is most appropriate. (Author)

REVIEW: This is a good illustration of one method of analyzing the temperature distribution in a thin-film circuit. The example is rather complete. It is not surprising that the author should have decided on a digital computer method of solution when the nature of his company's business is considered. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A technique for transient thermal prediction in microminiaturized circuits

AUTHOR: D. M. Cawthon, Advanced Technology Department, Martin Company, Orlando, Florida

SOURCE: IRE Transactions on Product Engineering and Production, vol. PEP-6, July, 1962, pp. 15-20

PURPOSE: To present a new mathematical heat transfer model which accurately predicts transient local temperatures in three-dimensional geometries.

ABSTRACT: The details for a mathematical model that predicts transient three-dimensional heat transfer within composite structures are presented. As an example of a specific application of this mathematical model a technique is shown for predicting local transient temperatures in microminiaturized circuits. The model accounts for all three modes of heat transfer: conduction, convection, and radiation. The numerical method used for handling three-dimensional conduction heat transfer is a modification of the general conduction equation. Determination of heat transfer by convection and radiation is accomplished by the conventional equations.

REVIEW: There are a number of basic errors in the formulation of the mathematical heat transfer model. These errors are listed below according to the mode of heat transfer.

Conduction: Equation (1) and hence the finite difference equations (2), (3), and (4) are restricted to isotropic, homogeneous materials with constant thermal conductivity, K [1]. Yet the author has proposed to account for heterogeneous material and hence variable K by giving values of K for each node as a function of the particular material of the element. To account for these phenomena properly equation (1) must include terms of the form

$$\frac{1}{\rho C}\frac{\partial T}{\partial X_i}\frac{\partial K}{\partial X_i}$$

and equations (2), (3), and (4) must include the finite difference forms of these terms. As to the assumption of isotropy in equation (1), this is probably not a very good assumption for electronics materials in general since crystalline substances, laminated plastics, and laminated metals are highly anisotropic.

Radiation: Equation (6) is not clear and obviously wrong as written. It should read [2]

$$dQ_R = F\sigma\epsilon\, dA(T^4_{sink} - T^4_{i,j,k}) .$$

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Because of the confusion about equation (6), the procedure used in obtaining equation (7) is also not clear. If dQ_R and dA of equation (6) in the corrected form are replaced by Q_R and A pertaining to a face of an external node, then equation (7) is correct as written except for the subscripts being out of place on $T_{i,j,k}$ and the exponent on T_{sink} being absent.

<u>Convection</u>: Equation (8) is incorrect and should read

$$dQ_{conv} = h\ dA(T_{BL} - T_{i,j,k}) \ .$$

Equation (9) is misprinted and should read

$$Q_{conv} = h\ A(T_{BL} - T_{i,j,k})$$

where Q_{conv} and A pertain to the face of an external node. The exact definition of the boundary layer temperature T_{BL} should be given by the author since only someone familiar with the fine points of heat transfer would know that he is referring to the recovery temperature.

REFERENCES: [1] Eckert, E. and R. M. Drake, Jr., "Heat and Mass Transfer," 2nd ed., McGraw-Hill Book Company, Inc., New York, 1959, p. 31

[2] Eckert, E. and R. M. Drake, Jr., op. cit. p. 397 ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability assurance program for the S-3 satellite series

AUTHOR: James L. Holeman, Electro-Mechanical Research, Inc., College Park, Maryland

SOURCE: Proceedings of the 1962 National Telemetering Conference, Washington, D. C., May, 1962, vol. 1, paper 2-5, 15 pp.

PURPOSE: To describe the philosophy of design and reliability assurance for the S-3 satellite series.

ABSTRACT: Since time and manpower in the space program is limited, it is necessary to design and build reliability into this type of spacecraft with a minimum of long test periods and only a small number of test models. The S-3 Energetic Particle Satellite is designed with a reliability assurance program integrated with the design, development, prelaunch, launch and post launch phases of this mission.

In order to assure a high reliability for each spacecraft in this satellite series, reliability considerations are included in each of the seven phases of development listed below:

Predesign planning
Design assurance
Design review
Fabrication control and testing
Systems integration
Satellite launch
Data evaluation.

Throughout the program there is concern with worst-case analysis, catastrophic failure and environmental resistance. The design review is especially complete. (The paper gives a general discussion of each of the phases. The catastrophic failure analysis is treated in some detail.) The actual time of operation was 2700 hours which corresponds to the 55% survival probability prediction. (Author in part)

REVIEW: This is a rather general paper except for the discussion of catastrophic failure calculation. An implicit assumption in the redundancy calculations is that the failure rate of each component is the same before and after a failure of another component has occurred; this is not true, for example, in the case of two resistors in series. It is also implicitly assumed that the reliabilities of the subassemblies are mutually independent. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The Air Force reliability program "MIL-R-27542"

AUTHOR: Vincent J. Bracha, Major, USAF, Ballistic Systems Division, Air Force Unit Post Office, Los Angeles 45, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 17-23, January, 1962

PURPOSE: To introduce industry to MIL-R-27542 USAF "Reliability Specification."

ABSTRACT: Air Force Regulation 375-5, Reliability Program for Weapon, Support and Command and Control Systems, specifies that all Air Force contracts for systems and major subsystems include a requirement for a comprehensive contractor reliability program.

The purpose of this paper is to discuss what the Air Force considers as a "comprehensive reliability program." It is now contained in MIL-R-27542, Reliability Program Requirements for Aerospace Systems, Subsystems and Equipment. It prescribes the basic requirements for the establishment of an acceptable reliability program by the Air Force contractor to assure the timely attainment of the reliability requirements specified in the contract. (Author)

REVIEW: This paper performs the task set forth admirably well. It is recommended reading for AF contractors and good reference material for others interested in reliability. The details of the paper and specification are compromises among various elements of the AF and Industry; hence the policy will not be in agreement with all concerned, nor is it expected that the Specification will remain unchanged for long. ##

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Serial Number 537
Code 813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability management by objectives and results

AUTHOR: Leslie W. Ball, The Boeing Company, Seattle, Washington

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 156-162, January, 1962

PURPOSE: To aid in describing reliability functions as task descriptions rather than philosophy and to describe the skills required by personnel to perform these tasks.

ABSTRACT: Advances in reliability technology long since have left behind the early type of narrative reliability program plan. Today we have what may be called the "Matrix of Management Decision Type of Program Plan". Also definitization of the reliability profession has evolved from the very loose term "Reliability Engineer" to a series of well defined professional skill groups. These developments of specific task plans and well defined professional skills have paved the way for application of the industrial management principle of management by objectives. At the Boeing Aerospace Division, we have reached a point where every manhour of time spent, either on reliability technology development, or on the application of this technology to projects has a specifically identified objective. These Reliability objectives have been established in such a manner that the principle of self-commitment of each employee to personal objectives is being applied.

The purposes of this paper are:

1. To categorize the objectives of technology development.
2. To categorize the objectives of technology application to projects.
3. To correlate reliability skill groups with these objectives.

(Author)

REVIEW: The plan of action as presented is excellent for large reliability programs in large organizations. In private communications with the author it has been indicated that there are over 500 people in the activity. The principles of describing functions by task statements should be observed by all organizations and the degree of completeness should be in proportion to the size and complexity of the organization. ##

Serial Number 538
Codes 340;815

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: Full design definition is essential to missile reliability

AUTHOR: W. L. Hurd, Jr., Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 177-180, January, 1962

PURPOSE: To describe the functions of a documentations activity as a necessary part of a reliability program to assure a reliability achievement of greater than 60%.

ABSTRACT: The Reliability goals for the POLARIS Missile System and all other ballistic missile systems are high. No ballistic missile system to date has achieved and sustained the desired Reliability for any substantial period of time. The Reliability of all successful intermediate and long range missile systems, whether guided or ballistic, whether American or German, has topped-out at about 60%. There has been a remarkable uniformity in missile programs leveling off at 60% $\pm$ 5% Reliability. The inference seems to be that a program with a good design concept, abundant financing, able people and enthusiasm, can achieve about 60% Reliability. Within the POLARIS Missile System it is our belief that Reliability progress beyond this point is achieved only through painstaking attention to detail. We further believe that we must define and control every aspect of the tactical POLARIS Missile System to the maximum extent possible. To us, it is obvious that we must "define" before we can "control." It is not enough that a design can be understood by another design engineer with a background of education and experience equal to that of the originator of the design. It is essential that the design be completely and unmistakably clear to the technicians, to the inspectors, and to the operating personnel who will build, test, inspect, and use the missile system. (Author)

REVIEW: The need for various types of documents to provide instruction and direction has long been recognized. This article lists them, but falls short in justifying the "essentiality" of the documents listed. It fails to describe the details or give references which would enable a reader to utilize the paper for the use intended. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contracting for reliability

AUTHOR: R. H. Johnson, The Martin Company, Baltimore, Maryland

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 181-184, January, 1962

PURPOSE: To describe the major elements of reliability contractual requirements and to list the military documents which involve reliability, its demonstration, and applicable data.

ABSTRACT: This presentation will cover several problems which can arise when establishing contractual statements and negotiating reliability into a contract. These problems are divided into topics as follows:

1. Establishing exactly what it is that is contracted for.
2. Specifying the various reliability requirements in the proper location.
3. Sequence of events to establish a contractual quantitative reliability value.
4. Determining the proper type of reliability statement for a particular contract.
5. Pricing reliability.

These problems or questions are considered and some of them are answered in this presentation; in other cases, guidelines are given for making an analysis and arriving at a decision. (Author)

REVIEW: The author has presented concisely some of the important items which are required in contractual agreements. Reliability statements presented in chart form are handy guides for specification writers, proposal evaluators, and program managers. Unfortunately the paper is general and not sufficiently specific to be applied to any specific project. However, its usefulness is anticipated in organizations where experience is needed in contractual documentation. ##

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Serial Number 540
Code 812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effective reliability--through education

AUTHOR: P. H. Zorger, The Martin Company, Baltimore, Maryland

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 222-226, January, 1962

PURPOSE: To introduce the Martin philosophy of reliability education and indoctrination.

ABSTRACT: The greatest unmet challenge facing any reliability organization is the "need to educate." It is not so much an education directed towards others; it is, rather, an internal education directed toward those who need it most, the design engineers. Those engaged in the necessary business of developing reliable products would do well to accept as their motto the dictum: "An ounce of prevention IS worth a pound of cure," or "an ounce of prenatal reliability planning is worth a pound of post mortem autopsies." Reliability must become one of the characteristics required of every piece of equipment, not just an accidental characteristic that it would be nice to have to a certain degree "if it doesn't cost too much."

Unfortunately, at present, many reliability organizations have a rather limited vision; they preach a rather myopic credo which would make reliability a sort of glorified failure-reporting activity. Certainly, the source of failure must be pinpointed but, because of the cyclical or chain-reaction nature of mechanical failure, every effort must be made to make certain that the cure is not worse than the ill.

It is often said, and almost universally accepted, that the principal objective of reliability engineering is to bring to the design engineer the necessary information which will allow him to build inherent reliability into his design. What is not so universally recognized is the fact that the present statistical techniques will not allow him to build such a mature design. In fact, these techniques serve only to perpetuate the picture of reliability through post mortems. (Author in part)

REVIEW: The author makes a strong case for reliability indoctrination of engineers as a means of effecting the development of sound designs. In doing this, he plays down the role which the statistical analysis of past failures can play in this development. The impression is given that such analyses have little or no value, whereas they can in fact be an invaluable source of information for use in an indoctrination program. It would be useful to have some case history data comparing designs developed without reliability indoctrination to designs developed with the advantage of reliability education. ##

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Serial Number 541
Code 812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A comprehensive education and training program for design reliability

AUTHOR: F. E. Marsh, The Boeing Company, Seattle, Washington

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 227-233, January, 1962

PURPOSE: To present a discussion of the planning and content of a reliability education and training program for design personnel.

ABSTRACT: A reliability education and training program must provide both the motivation and the skills for doing the job adequately. Emotional appeals, by themselves, do not have lasting effects. All levels of management must actively participate in the program.

In creating a reliability education and motivation program for the design personnel of the Boeing Aero-Space Division, the following basic principles have been recognized: (1) no individual really becomes interested in reliability until he is assigned a reliability task or tasks, (2) he has to understand what this task is, (3) he has to know that his performance will be measured against this task performance, and (4) once an assignment is made, the individual then needs to know how and is motivated to learn. A survey of the needs of design engineers indicated a need for (1) detailed training in the technologies of reliability, and (2) training in the understanding and application of specific contractual requirements. Planning for the training material takes into account (1) basic task definitions, (2) product requirements, and (3) skill requirements. From these the detailed requirements for training media can be extracted.

In the Boeing Aero-Space Division a detailed task list provides the means for defining technology training curricula for application to any product. By combining the basic tasks into skill groupings, the training requirements for the reliability specialist assigned to the tasks may be derived. Motivation and assignment of responsibility is made through directives, procedures, product plans, and individual management direction. Training includes dissemination of policy and procedures, reliability research project documentation, manuals and guides, the provision of technical courses, and product application orientation. (Author in part)

REVIEW: The details of the planned educational program indicate a complete comprehensive effort to motivate and equip design personnel with the tools needed to perform any reliability task. Smaller organizations are cautioned in adopting a plan of this level of complexity since the number of courses and lectures required may use up a good portion of their qualified manpower. This program should be scaled down to fit the applicable organizational needs. ##

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Serial Number 542
Codes 120;720

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability through process capability studies

AUTHOR: George O. Hawley, Sandia Corporation, Albuquerque, New Mexico

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 240-251, January, 1962

PURPOSE: To discuss the contribution of total quality control concepts in producing a reliable product, particularly by the use of process capability studies.

ABSTRACT: This paper will expand the conventional Process Capability Study (PCS) concept to encompass the entire product cycle, emphasizing the importance of the individual characteristic and the necessity for its continuing study to assure that it makes proper contribution to a reliable product. In introducing these thoughts, present day and indicated trends in performance and reliability requirements are presented; their effect on design, manufacture and maintenance is described; and the effect of these in turn on the quality engineer's responsibilities and activities is discussed. Then, after defining certain terms, the broad approach to the Process Capability Study is explained. The importance of the concept to the quality engineer is emphasized as it assists him in coordinating a program for assuring that each characteristic makes its appropriate contribution to product reliability. Finally, detailed steps for implementation of the PCS are outlined, with examples which illustrate some of the more important steps. (Author)

REVIEW: This is a quality control paper which should prove to be of interest to manufacturing personnel. Only two references are cited and other material published on process capability is not mentioned. Juran's Quality Control Handbook and Duncan's Quality Control and Industrial Statistics are two works which should be added. ##

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Serial Number 543
Code 841

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A missile reliability reporting system

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

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 268-271, January, 1962

PURPOSE: To discuss in general terms a data reporting and analysis program for missiles.

ABSTRACT: Considerations of economical maintenance of reliability and of weapon readiness point to a requirement for reporting usage of major assemblies and subassemblies of the missile by serial numbers. The reports are accumulated in a computer whence one can obtain immediately any desired reliability information about any category of components, about the reliability status of missiles currently in a state of readiness, and about the necessity for replacing specific assemblies whose expected reliability has become marginal because of age. Good data collection on the first missiles is important to development and planning for future generations of the missile. (Author)

REVIEW: This paper is an introduction to failure reporting. It attempts to present the salient features rather than a detailed discussion of an existing system. However, its usefulness to an organization in developing its own system would have been improved by the inclusion of forms, instructions, and case history data. The value of a system of data reporting will be obvious to most readers; this paper is suggested as reading for newcomers to this phase of reliability activities. ##

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Serial Number 544
Code 813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aspects of an effective reliability program implemented for an advanced bombing-navigation system

AUTHORS: F. W. Blackburn and A. M. Letow, Air Armament Division, Sperry Gyroscope Company, Division of Sperry Rand Corporation, Great Neck, L. I., New York

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 272-280, January, 1962

PURPOSE: To describe briefly some of the elements of a reliability program applied to an airborne bombing-navigation system.

ABSTRACT: The reliability program discussed in this paper was accomplished on an advanced bombing navigation system presently in its production phase. It is a Doppler-stellar-inertial system which provides a highly accurate, continuous determination of aircraft parameters such as heading, groundspeed, steering, ground track, distance to destination, altitude, attitude, time airspeed, and bombing information.

The equipment is a complex combination of very accurate mechanical, electronic and electromechanical devices which by their very nature would have low reliability. In an effort to improve system reliability without removing some of the equipment complexity and thereby reducing its functional appeal, two techniques were used. Redundant circuits and components were critically placed to operate in the event of a malfunction to the primary equipment. In addition, alternate modes were provided whereby successful completion of a mission could be attained if the primary mode of operation is aborted.

A complex system such as this requires a detailed reliability program, not only to monitor and evaluate system and subsystem reliability performance, but also to conduct necessary investigations on equipment problems and to review corrective action. (Authors)

The elements of the program enumerated are: Data Collection, Processing, and Analysis; Prediction Procedures; Systems Analysis; Problem Determination; Corrective Action; Monitoring; Training; and Reporting.

REVIEW: The article falls short in that it uses terms without definition; it mixes statistical, mathematical, managerial, military, quality control, and data processing terms and procedures. It would be useful only to enlightened readers involved in managerial, program direction, purchasing, or marketing activities. ##

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Serial Number 545
Codes 310;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability emphasis on production contracts

AUTHOR: James A. Marshik, Minneapolis-Honeywell Regulator Company, Aeronautical Division, Minneapolis, Minnesota

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 305-309, January, 1962

PURPOSE: To describe the reliability portions of a production contract and the contribution of these activities to the reliability of a product.

ABSTRACT: In discussions of reliability, the reliability cycle of a product is frequently divided into three basic phases. The first is the design and development phase during which the "inherent" reliability is designed into the product. The second phase involves the production of the product. During this second phase, the "inherent" reliability is normally maintained through adequate processes and through Quality Control. The third phase is directed to the usage of the product. Ideally, the product will be used in the manner for which it is designed, and the effectiveness of the first two phases in obtaining reliability will be evident during usage.

This paper deals with the production phase as an important element of reliability control. Design and field information usually receive strong consideration, and rightly so; but frequently insufficient reliability attention is directed at the production line. It is not implied that the production line should be converted into a reliability lab; rather it is pointed out that production information forms a vital link in an over-all reliability program, and the information requires relatively little effort to obtain. The available reliability information is particularly valuable on products which accumulate substantial running time prior to shipment.

The paper is directed at the concepts of control rather than at actual product evaluation. (Author)

REVIEW: This paper is primarily for Quality Assurance personnel in describing the control needed to produce a reliable product. Unfortunately the paper offers little detail on how it is done. It is another paper of platitudes, concentrating on philosophy, concepts and coordination. It offers no references for further reading. ##

Serial Number 546
Codes 341;841

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Integrated record system for manufacturing, inspection, and test of complex weapon systems

AUTHOR: D. R. Elliott, The Boeing Company, Seattle, Washington

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 425-430, January, 1962

PURPOSE: To describe the concepts involved in the development of an integrated data-recording system.

ABSTRACT: This paper describes in general terms the application of an integrated data-recording system used by the Boeing Aero-Space Division on the Minuteman Program. The following forms are discussed: Manufacturing and Inspection Record, Event Record, Event Record Log, Failure Report, and Failure Analysis Report. The use of the records system is described, and sample forms are shown.

REVIEW: This is a description of a system developed by one company for handling the recording and communication of data on a complex weapon system. The effective functioning of such a program is clearly important to the development and production of reliable systems, and therefore makes at least an indirect contribution to the improvement of reliability. It should be kept in mind, however, that a system which works well in one organization may require a considerable amount of modification before being applied in another organization. ##

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Serial Number 547
Codes 817;831;881

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Operational research--a prelude to reliability

AUTHOR: Major Hollie A. Wilkes, ESD, Air Force Systems Command, Bedford, Massachusetts

SOURCE: Proceedings Eighth National Symposium on Reliability and Quality Control, Washington, D. C., pp. 516-519, January, 1962

PURPOSE: To establish the elements which are considered in an availability apportionment study or a trade-off study.

ABSTRACT: The problem of providing adequate background information prior to establishing firm reliability requirements for large electronic systems is relatively common. It is suggested that an operational analysis to determine specific functional and accuracy requirements, system availability needs, capacity requirements, environmental and maintenance determinations will provide the elemental background information. A distinction is made between equipment and system environment reliability. It is necessary to establish input-output specifications of cooperative subsystems prior to beginning detailed component design. If initial cost, lifetime maintenance cost, and the effects upon operational performance of varying degrees of reliability are plotted as a function of reliability index, a firm guide for trade-offs is established. (Author)

REVIEW: The title is misleading since the operational research aspect of the paper consists of the usual platitudes as to what should be considered, but not enough of the finite answers are indicated. The information is neither new nor unique yet the paper is very well written and makes an excellent checklist for the reliability manager responsible for trade-offs and system evaluations. ##

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Serial Number 548 -1
Code 782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability limitations on electronics for nuclear propulsion and space power systems

AUTHOR: Frank Larin, Research Laboratories Division, The Bendix Corporation, Southfield, Michigan

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 238-242

PURPOSE: To focus attention on the need for better environmental design data for electronic components in high temperature, radiation, and vibration fields.

ABSTRACT: One of the problems facing the designer of electronics for nuclear vehicles is lack of information on the environments in which his circuits must operate. While vehicle designers may plan to modify the environments to meet their estimates of the limits of the electronics, the best answer will probably come from a study of what can be done reliably rather than what is needed.

Much of the environmental data is inapplicable because of the conditions under which it is obtained. Although it has been indicated that transistor circuits may be used in radiation levels from 10^{12} to 10^{15} nvt, these are levels at which the device fails rather than the level where the probability of a circuit failure is minutely small. Probably the most serious deficiency has been the lack of data taken in combined environments of radiation, temperature and vibration. Many of the components which still met electrical specifications at the end of the test crumbled when removed from the reactor. Although much of our attention in the past has been directed toward the effect of radiation, in the future the primary interest will shift more toward temperature as the limiting variable.

If a limited number of environmental design goals could be established, the vehicle designers would know what environments they would have to provide and the component manufacturer would know what environmental conditions he would have to meet. The fewer design goals to be met, the greater the effort that could be put into meeting the remaining goals.

REVIEW: This is a fairly critical appraisal both of actual reliability of a range of electronic components and of the general effort so far in developing reliability data. A strong plea is made for establishing reasonable goals and coordinating investigation to contribute to those goals.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

The author in a private communication would add an updated comment stating that: "For nuclear space applications, the performance and reliability requirements are essentially the same as for the nonradiation (space) applications but the problem is greatly aggravated by the more severe environments, particularly temperature and radiation.

... In order to design to specific reliability requirements, it will be necessary to obtain test data from which predictions can be made on the probability of component failure as a function of nuclear radiation exposure." ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation effects to flight control systems

AUTHORS: 1/Lt. V. G. Smalley and Paul Polishuk, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 260-279

PURPOSE: To discuss the results of tests on components and subsystems of flight control systems carried on in high temperature and nuclear environments.

ABSTRACT: Steady-state reactor tests rather than pulse radiation or space radiation are described in some detail. Examples are chosen from each of several design techniques: Weak link concept using modified off-the-shelf components, Basic redesign, Increased component tolerances and use of feedback, and Use of low voltages and high signal strengths.

It was desired to subject the subsystems to multiple environmental conditions--radiation, temperature, vibration, humidity, vacuum, etc. However, none of the reactor facilities outside of the Ground Test Reactor (GTR) was able to provide additional environmental conditions except temperature in the volume required. Weak link design using modified off-the-shelf items was successful only under limited radiation and other combined environmental conditions, partly because of an inability to learn or determine the exact make-up of the component materials. The other approaches were generally successful in producing acceptable systems.

A fairly extensive bibliography of test reports and some five tables listing facilities, capabilities, and test results are included in the paper. One of the more telling conclusions is that there is a need to have the manufacturers be intimately familiar with the constituents and/or capabilities of their components and be willing to divulge this information for better design of radiation-resistant control systems.

REVIEW: This is a very good review article outlining work which has been done, methods used, and limitations in materials, test facilities, and results. Although the authors state that it is within the state of the art to design flight control systems for certain nuclear environments, it is apparent from both the article and some of the results that these are rather limited environments. In a private communication, the second author has pointed out that a great deal more testing in combined environments and development is required before reliable components and systems can be built to operate in the radiation environment. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reactor irradiation of semiconductor devices

AUTHOR: Lyndon Taylor, Components Division, Research and Engineering Department, Texas Instruments Incorporated, Dallas, Texas

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 280-295

PURPOSE: To report on an experiment to determine specific radiation effects on production devices of representative device types as the first phase of a program to develop radiation-resistant devices.

ABSTRACT: Two diode types and eleven transistor types representative of current production were irradiated to a total dose of about 10^{14} fast neutrons/cm^2 and 10^8 ergs/gm(C) of gamma rays in a swimming pool reactor.

It is assumed that the most sensitive parameter is minority carrier life, τ, which is given by the relation:

$$\frac{1}{\tau} = \frac{1}{\tau_o} + \frac{\phi}{K}$$

where τ_o is the initial lifetime, ϕ is the integrated flux, and K is the radiation damage constant of the material. A further consideration of transistor characteristics leads to an approximate expression for the forward common emitter current transfer ratio, h_{fe}:

$$\frac{1}{h_{fe}(\phi)} = \frac{1}{h_{fe}(0)} + \frac{W^2\phi}{2DK}$$

where $h_{fe}(0)$ is the initial value, W is the base width, and D is the minority carrier diffusion constant for the base region.

As was expected, the base width did play a dominant role in the degradation of characteristics, the thinner based, high frequency transistors being less affected than the thicker-base devices. An empirical relation relating the gain-bandwidth product, f_T, to the flux required to reduce h_{fe} to 70% of initial value is obtained as

$$\phi_{max} \simeq (f_T)^n ,$$

where n equals 1.1 for silicon and 0.65 for germanium.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Particular attention is paid to the neutron energy distribution with data included in the appendix. The fission spectrum is normalized to the $Al^{27}(n,p)Mg^{27}$ threshold reaction rather than the S^{32} reaction, as it appears to be more nearly constant through various distances of water.

A number of tables are presented including one listing values of radiation damage constants, K, for each of the transistors.

REVIEW: This is a very good paper, though of somewhat limited extent in that only steady-state irradiation is considered and the temperature range is limited. The effect of annealing out of radiation-induced damage is not treated extensively except that an additional set of data points taken one hour after removal from the nuclear flux is given. No other environmental factors (vibration, pressure, etc.) were considered. The data are marred by some experimental problems. However, a serious attempt is made to investigate the basic problem and a model is set up against which experimental data can be compared. ##

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Serial Number 551
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effects of nuclear radiation on high temperature thermistors

AUTHOR: W. R. Owens, Nuclear Aerospace Research Facility, General Dynamics/ Fort Worth, Fort Worth, Texas

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 296-298

PURPOSE: To report the effect of nuclear radiation on a new type of high temperature thermistor.

ABSTRACT: High temperature thermistors, 100°C to 600°C were tested before, during, and after irradiation in the Ground Test Reactor (GTR). The radiation environment was held constant at 2.2×10^{10} n_f/cm^2 (energy greater than 2.9 Mev.), and 4.2×10^8 ergs/gm(C) hr of gamma for a period of 91 hours. Resistance as a function of temperature was measured for low, medium and high resistance thermistors. No permanent damage was observed, but transient effects were severe at high resistance values.

Ionization of the air around the test jig under irradiation was determined to be a contributing factor to the transient effect, but this was important only at the higher ranges of resistance values. Investigation of radiation heating effects and of the effect of heating on radiation effect were investigated but found to be of no importance.

REVIEW: This is an interesting but minor paper on radiation effects on electronic components. A reasonable attempt appears to have been made to investigate the possible mechanisms for obtaining the results observed, so as to define the actual effect on the component itself. ##

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Serial Number 552
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation effects considerations on materials in cryogenic systems of nuclear rockets

AUTHOR: Jean W. Gordon, General Dynamics/Fort Worth, Fort Worth, Texas

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 299-302

PURPOSE: To discuss the effects of nuclear radiation on materials exposed to a cryogenic environment.

ABSTRACT: For purposes of environmental analysis, a fission reactor as a heat source with a combination coolant-propellant is considered in which the propellant is liquid hydrogen and the radiation levels will be in the order of 10^{15} to 10^{17} n/cm^2 integrated dose and from 10^9 to 10^{11} ergs/gm(C) for gamma dose.

Samples of four structural alloys including smooth, notched, and weld joint coupons were irradiated at 3 megawatts at -423°F for 100 hours for a total integrated neutron flux of about 2 x 10^{17} fast neutrons (E greater than 0.33 Mev). Both organic and inorganic thermal insulation materials and a corresponding range of lubricants, sealing and electrical insulation materials were irradiated. It was found that the inorganics were damaged primarily by neutrons while organics were sensitive to both neutrons and gamma radiation.

The results may be summarized as follows: Cryogenic irradiation of structural materials may induce changes in tensile strength which must be considered in nuclear rocket design; satisfactory thermal insulation is available but adhesive attachment may be restricted by radiation damage; lubrication should be satisfied by gas or liquid hydrogen or by dry film lubricants; metallic or inorganic sealing devices may be necessary and inorganic rather than organic electrical insulation may be more satisfactory for the anticipated radiation levels.

REVIEW: The combination of other physical environments with nuclear irradiation would seem to be a profitable line of investigation, as has been shown in this paper. The question does arise as to what the results might have been if the tests themselves had been carried out under these same cryogenic conditions.

The physical tests for damage appear to have been carried out at room temperature conditions. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nuclear-radiation-resistant circuitry design and test

AUTHOR: James R. Perkins, Vought Electronics, Dallas, Texas

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 310-315

PURPOSE: To discuss "radiation hardening design" through selection of off-the-shelf components.

ABSTRACT: Nuclear radiation alters the properties of materials and components by several types of disorders. Among these are vacancies, interstitial atoms, thermal spikes, and ionization effects. Several general trends in electrical characteristics are observable as a result of these disorders. For example, carbon resistors may change in value by about 10%, capacitors change values and increase dissipation factor while transformers may suffer from deformation due to the change in structure of the insulating compound.

Radiation hardening can be approached through selection of reliable equipment, evaluating each component in terms of the environment and eliminating weak-link components through substitution of more tolerant units, and, where necessary, redesign to compensate for the effect of radiation.

Five units were designed using this approach: valve driver amplifier, motor driver amplifier, demodulator, synchronizer amplifier, and power supply. Radiation tolerance was improved from about 10^{14} fast neutrons/cm^2 to about 10^{17} neutrons/cm^2. Twenty of twenty-four circuits tested were operating properly at the end of the 100-hour test. The integrated neutron flux was 5×10^{16} nvt.

The most valuable aspect disclosed by the test was the advantages gained in using "balanced circuitry" techniques. Balanced circuitry has a dual meaning: the first being the same as balanced bridge circuit arrangements and the second referring to the circuitry location as referenced to the nuclear reactor.

REVIEW: This is a good but somewhat uneven paper. Although the discussion is nominally about modification of electronic assemblies, the most specific results given were the readings of the various dosimetry packets attached to the test tray. The implication of some of the terminology appears to be at variance with usual practice. ##

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Serial Number 554
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nuclear environmental effects on space guidance and control systems

AUTHOR: W. L. Fink, General Dynamics/Fort Worth, Fort Worth, Texas

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 316-319

PURPOSE: To discuss the sources and intensities of various radiations which might be encountered in a space mission from ground test through a six-month period in a Van Allen belt.

ABSTRACT: The nuclear environment of a guidance and control system will depend on the stage of the mission, and will include additional intensity from ground scatter and primary radiation and secondary emissions from capture processes in the air during atmospheric operations.

In addition to the indigenous radiations, there is a high vacuum condition associated with space. This condition causes sublimation and vaporization of many materials at moderate temperatures. Under the influence of this high vacuum, nuclear reactions that normally initiate only minor changes in a material could induce severe damage.

Two critical items in the guidance and control package are the astro-tracker using a photomultiplier tube and transistors. The photo cell of the astro-tracker experiences an increase in dark current as a function of dose-rate. However, if it is inoperative during powered flight it would be insensitive to reactor dose rates and Van Allen radiation would be the controlling factor. The transistors can be protected by burying them within the structure of the vehicle and maintaining a minimum amount of fuel in the tanks for shielding from the reactor.

REVIEW: This paper has as one of its chief values the summary tables of radiation magnitudes and resistance of materials and systems to various radiation fluxes. These include neutrons, gammas, and electrons along with critical dose rates for the photo cells. It also points out that radiation fluxes may change drastically from one point in a flight to another, imposing a variety of damage criteria. ##

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Serial Number 555
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The design and test results of some high gain radiation-resistant magnetic amplifiers, magnetic voltage references, and components

AUTHOR: Joseph Montner, The Marquardt Corporation, Van Nuys, California

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, January, 1962 (Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961), pp. 326-337

PURPOSE: To develop design techniques for minimizing the effects of nuclear radiation on magnetic amplifiers, particularly on the diodes.

ABSTRACT: A number of computing and control-type magnetic amplifiers, operating from 4800 and 400 cps power sources, were designed to withstand radiation levels in excess of 10^{15} nvt (fast neutrons). Much of the essence of the design of these magnetic amplifiers was to minimize the effects of diode characteristic changes on the amplifiers. As the first order of design business, two diode types were chosen. One was the "shelf" type IN538 diffused junction silicon diode (Motorola) and the other was a semi-experimental, thin based, diffused junction silicon diode, the ZJ225 made by the General Electric Company.

Design equations were developed to illustrate the effects of diode leakage on the magnetic amplifier gain. Stability could be increased by increasing feedback (lower power gain), increasing core size, or by increasing the frequency of the operating flux density.

The diodes were shunted with a relatively low value of resistance to stabilize the amplifier against the anticipated degrading in diode inverse characteristics. This is a form of negative feedback. The results show that the combination of radiation-resistant rectifiers together with the experimental design techniques can provide reliable radiation-resistant computing and control circuitry for fast neutron levels approaching 10^{16} nvt.

REVIEW: This is a fairly serious attempt to quantitatively determine the influence of design factors on the stability of magnetic amplifiers and with these in hand to make due allowance for the degradation of certain components as a result of nuclear radiation. Unfortunately information on the actual translation into design is very meager. The test results make the claimed reliability and stability appear rather optimistic. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Components and application techniques for electronic circuitry operating in nuclear environments

AUTHORS: L. T. Bowles, J. R. Crittenden, and E. L. Davis, General Electric Company, Owensboro, Kentucky

SOURCE: IRE Transactions on Nuclear Science, vol. NS-9, August, 1962, pp. 5-8 (presented at International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada, October, 1961)

PURPOSE: To summarize some of the available information on radiation tolerance of electronic components.

ABSTRACT: Designers of electronic circuitry for today's most advanced military and space projects must consider the effects of three types of nuclear radiation on their designs: the integrated dose effect of steady-state exposure to reactor-type environment which may cause permanent damage to circuit and mechanical components, the pulse of radiation which accompanies a nuclear explosion causing temporary circuit malfunction, and natural space radiation.

It is the purpose of this paper to summarize some of the known factors which should influence the selection of electronic components for an equipment which will be least affected by radiation. (Authors)

REVIEW: This paper summarizes the available information in rather general terms. Some consideration is given to both transient effects and circuit stabilization techniques for minimizing them. A plug is given for a commercial approach designated as the Thermionic Integrated Micro Module (TIMM) concept. There is no bibliography, but the author has indicated in a private communication that some details on results are available in the final report on Contract Number AF 33(616)8096. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Not spending reliability money wisely

AUTHOR: (Editorial summary of NEC Reliability Session on "Are we spending our money wisely")

SOURCE: Industrial Electronic Distribution, vol. 2, November, 1962, p. 5

PURPOSE: To summarize a panel discussion.

ABSTRACT: The reliability of military equipment is not now satisfactory and compares poorly with that of some consumer goods. The cost of the reliability effort is hard to determine and the main problems have not been solved. Military procurement procedures do not encourage a manufacturer to try for high reliability. Any studies made of field reliability should have a constructive purpose for future designs. There was much disagreement about the role of the reliability engineer.

REVIEW: (There is no report on this session with which to compare the summary.) Even though the attitude of the participants appears to be negative, improvements are being made. The DOD is trying to write contracts with better reliability specifications and incentives, and industry is trying to make its reliability efforts more efficient. Any effort as large, as fast, and as new as the reliability effort on complex equipment is bound to be bogged down somewhat by human frailty. There seemed to be no DOD representation on the panel, and it is worth noting that DOD spokesmen tend to have a somewhat different idea as to where many of the reliability troubles lie. ##

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Codes 770;801;812;
815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability II (IED Background Memo)

AUTHOR: G. B. Cohen, Sylvania Electric (Buffalo, New York)

SOURCE: Industrial Electronic Distribution, vol. 2, November, 1962, p. 19

PURPOSE: To present the constant hazard rate formula for reliability and to discuss a few rules and objectives for testing.

ABSTRACT: If the reliability is R, the mission time is t, and the MTBF is T, then

$$R = e^{-t/T}$$

Several examples are given of the calculations. The ratio of t/T should be small for high reliability.

At least two and preferably up to five samples should be tested. The test length should be at least three times the contract MTBF. Four factors which should be checked are ambient temperature, vibration, off-on cycling, and high/low input voltages.

REVIEW: See Abstract and Review Serial Number 519 for Part 1 of this series. The comment about Part 1, i.e., that it was too brief to be effective, also applies to this part. For example, there is nothing in the discussion of the reliability equation to show that it is a special case and is not always applicable. The discussion of the time and number of tests is similarly limited in detail.

This series of articles is useful, so far, mainly as an introduction to the language. The brevity of discussion, especially the lack of explicit statements of assumptions, may actually lead to misinformation in some cases. It would perhaps be better to cover less ground per article and do it more thoroughly. ##

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Serial Number 559
Codes 817;830;833;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fail-safe logic using multi-aperture ferrite cores

AUTHOR: D. H. Hardy, formerly of Mullard Research Laboratories, Salfords, now with Panax Equipment Ltd., Redhill, Surrey, England

SOURCE: British Communications & Electronics, vol. 9, pp. 180-184, March, 1962

PURPOSE: To show the use of a multi-aperture magnetic core device, the laddic, as a logic device which will fail safe under various types of failure conditions.

ABSTRACT: The need for fail-safe switching systems is discussed, using railroad block signals and nuclear reactor controls as examples wherein this characteristic is required. The laddic is chosen as a reliable and fail-safe device.

The principle of the laddic is explained. The basic device with a hold winding on each of several "rungs" acts as an "and" gate. This is because all hold windings must be energized to produce an output. Additional windings on any rung perform the "or" function. An output can be taken from the last rung, or its negation from the preceding rungs. The inhibit function can also be achieved by pulsing a winding which is in opposition to the drive pulse. Failure to safety is described for failure of hold, drive or set pulse, for short circuits of any of these inputs, and for core breakage.

Laddics can be used in groups, and can also be used to perform majority logic, thus improving reliability. An inhibit circuit is shown which is fail-safe. Both types of delays required in fail-safe logic are illustrated. That is, delay in which an output continues for a short time after the input is removed, and the other in which an output does not appear until a short time after the input has been received. Examples of usage are given.

Inverter circuits using silicon controlled rectifiers are used as output units which are both inexpensive and fail-safe. This is described in some detail.

The paper concludes with two further applications.

REVIEW: This is a very clearly written elementary paper describing fail-safe operation using a particular logic device. The theory of the device is given in a manner which will appeal to the engineer with neither the time nor the inclination to read the source material with its mathematical explanations. No data are given illustrating the performance of a laddic system in actual service. Drawings are adequate and well-executed. ##

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Serial Number 560
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Data handling equipment (OAO) redundant design--its trade-offs and performance analysis

AUTHORS: K. L. Hall, A. B. Harbach, C. H. Herbert, and J. LaCapra, Radiation-Melbourne, Melbourne, Florida

SOURCE: 13 pp., presented at National Symposium on Space Electronics and Telemetry, Miami Beach, Florida, October 2-4, 1962

PURPOSE: To show how quad and other redundancy increased the design reliability of part of the orbiting astronomical observatory (OAO).

ABSTRACT: The use of sufficiently reliable components to achieve the necessary system reliability without redundancy was not feasible. The approach to the problem is illustrated by a non-inverting driver circuit. The steps that were used in converting this into the quad form are given, together with the calculations of reliability. The various trade-offs gave a "reliability" gain of 139:1 over the conventional design at the cost of 5:1 in power consumption, 3:1 in design time and 2:1 in weight and volume.

It can be seen from these discussions that redundant design is a costly approach at best, but "pays-off" in system reliability. The reliability requirements for the OAO data handling equipment dictated a redundant design, but a thorough trade-off and performance analysis for each circuit has made the burden of this approach as easy to bear as possible. (Authors in part)

REVIEW: As the authors mention, the redundancy approach is costly at best, but does pay off in better reliability. The use of quadding makes a circuit much more complex and adds many more components. This method of redundancy is discussed in the papers covered by Abstracts and Reviews Serial Numbers 277, 396, and 488.

It is very important for anyone using this approach to consider all of the assumptions that are made in the analysis and to be sure that the system as a whole is, in fact, more reliable. For example, a common implicit assumption is that the failure rates of "live" components do not change when others have failed; in many cases this may not be realistic. The system may also require more circuits because of lower "efficiency" per circuit and thus the potential reliability increase would be degraded.

The statement, "... reliability gain 139 to 1 ..." is not clear although in Chart 2 (on p. 12 in the paper) the term reliability is associated with an effective MTBF. Definition standardization is desirable and the interchangeable use of two terms which are well and quite differently defined (such as reliability and MTBF) should be vigorously discouraged. ##

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Codes 782;835;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Space electronics equipment--a space receiver

AUTHORS: R. L. Sims and D. W. Hanna, Philco Corporation, Philadelphia, Pennsylvania

SOURCE: 9 pp., presented at National Symposium on Space Electronics and Telemetry, Miami Beach, Florida, October 2-4, 1962

PURPOSE: To describe an approach to the design of a high reliability space receiver.

ABSTRACT: This Space Receiver is an ultra-reliable, FM type operating at S band. Solid-state circuitry and modular construction is used throughout. Some of the more important features of the receiver are:

a. A 96.3-percent probability of a successful mission for one year with a 25-percent duty cycle. A 92.3-percent probability of a successful mission for one year with a 50-percent duty cycle.

b. A noise figure of 12 db for all environmental and life conditions.

c. RF center frequency stability of ± 0.003 percent for all life and environmental conditions.

d. An operating temperature range of $-40^{o}C$ to $+ 80^{o}C$.

e. Weight is 13 lbs. and size is 290 cu. in.

There are three types of redundancy which were used to improve the reliability of the receiver. These are component redundancy, circuit redundancy and functional redundancy. (Authors)

Space radiation was taken into account as a degrading environment. A block diagram of the receiver and several curves and tables are shown.

REVIEW: This is a good article on design; brevity is one of its good points. It will be interesting to compare the predicted reliability with that actually achieved. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System reliability analysis and prediction through the application of a digital computer

AUTHORS: John F. House and John LaCapra, Radiation-Melbourne, Melbourne, Florida

SOURCE: 13 pp., presented at National Symposium on Space Electronics and Telemetry, Miami Beach, Florida, October 2-4, 1962

PURPOSE: To describe how reliability prediction processes were automated on a digital computer.

ABSTRACT: The formulas and procedures used for preparing the data inputs to the computer are given in several figures and charts. There are four passes through the computer:

1. Pass Number 1 - A basic failure rate is selected from the stored empirical failure-rate data for each component part, based upon the component electrical stress and environmental stress. The selected component part failure rate is then modified, if required, for circuit application.
2. Pass Number 2 - The failure-rate for the next higher assembly (unit) is arrived at by summing the component part failure rates. The probability of successful operation for any specified operating time period, under the condition of no allowable failures, is computed based on the exponential probability distribution.
3. Pass Number 3 - The unit probability is computed under any specified definition of success.
4. Pass Number 4 - The unit probabilities are combined, which yields the system, or modal reliability in terms of the probability of successful operation.

The major advantages of using the computer are:

1. Consistency - The prediction is always done in the same manner and sequence.
2. Accuracy - Human errors, unavoidable when hundreds of manual calculations are made, are eliminated.
3. Cost - Excluding the initial programming, the cost for a prediction is less. Less engineers hours are required and the documentation is provided by the computer requiring much less typing hours for a formal customer report.
4. Control - Once the system aspects are loaded into the computer, it can be used to insure that the reliability design goals are being met by re-running a complete prediction with each circuit release. The effects of design changes, relative to reliability, can also be measured in this manner.
5. As a Design Tool - The Design Goal Program can be used to optimize the system design configuration by "backing into" a contractual reliability figure. This assures that a minimum

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

degree of redundancy is employed to achieve the goal. (Authors in part)

REVIEW: The reliability aspects covered in this paper are concerned largely with catastrophic failures. The method of taking into account drift, especially after a catastrophic failure, is not clear. Care should be taken that the failure data actually used correspond to the assumptions about failure in the theory.

Putting the calculations on a computer may save a considerable amount of time and this will be very worthwhile if the programming is not too long, especially for changes in the system. Due to space limitations there is no discussion of the programming methods and whether or not they can be handled by a design engineer. ##

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Serial Number 563
Codes 424;612;824;
831;837;844

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: 13 pp., presented at National Symposium on Space Electronics and Telemetry, Miami Beach, Florida, October 2-4, 1962

PURPOSE: To present a summary of available reliability prediction methods, and to describe a mathematical simulation prediction technique.

ABSTRACT: A review of the current status of reliability prediction techniques is used as a point of departure for a discussion of the subject from the standpoint of the effect on performance of variations in the component parameters. A transfer function for a network or system is defined as the ratio of the response function (representing the output) to the excitation function (representing the input). The transfer function is determined solely by the properties of the system. The application of a Laplace function to circuit analysis is discussed. The mechanics of the process of computer simulation in a circuit analysis problem are demonstrated by means of an example consisting of a grounded grid amplifier.

It is indicated that the use of simulation techniques which consider the variation in parameters of components, the drift rates, and the catastrophic failure rates will result in more precise estimates of the reliability of systems. The obtainable precision is, of course, dependent on the precision of the available input data. As the accuracy of the data improves, the capability of mathematical simulation will also improve.

REVIEW: The "current prediction methods" which are reviewed briefly in this paper are those which are applicable to systems consisting of independent serial subsystems in which the part failure rates are constant. These methods have often been used in situations where they did not apply simply because no better approach was available. There is a need for more realistic mathematical modeling of systems, and this paper represents a step in that direction. The example cited consists of a relatively simple system, and it is readily evident that the application of the transfer function approach to complex systems will not be easy. However, it is an approach worthy of careful attention and serious effort. The case history study presented in this paper, as well as the ten references which are cited, should prove to be quite helpful. In a private communication, the second author has indicated that the "simple" example was used because of limitations on the presentation time and the length of the paper and that other examples will be found in a final report to be issued shortly. ##

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Serial Number 564
Codes 838;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A concept for a modular space-borne computer

AUTHOR: Frank Sanderson, Nortronics, A Division of Northrop Corporation, Palos Verdes Estates, California

SOURCE: 4 pp., presented at National Symposium on Space Electronics and Telemetry, Miami Beach, Florida, October 2-4, 1962

PURPOSE: To describe a spacecraft computer concept designed to tolerate a limited number of part failures before completely losing its operational capability.

ABSTRACT: The most difficult technical challenge in designing a computer for space applications is the achievement of adequate reliability. Failure rates of even the best available electronic component parts in a conventional design are not sufficiently low to provide adequate probability of successful completion of multi-day missions. This paper describes a mechanization which has the capability of tolerating a number of component failures without suffering serious degradation of computer performance. The accomplishment of this necessitates the use of some form of redundancy.

Failure is accommodated by switching out a defective module and time sharing an alternate unit, thus accomplishing a graceful degradation of the system performance. Credulity programming and self-checking techniques are briefly described. Serial arithmetic units and memories are used to reduce the amount of hardware.

REVIEW: This is a brief and rather specialized paper which will be of interest only to those who are concerned with techniques of error-detection and -correction in computers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of fault-location behavior in electronic equipment

AUTHORS: J. W. Rigney, D. H. Schuster, T. L. Runyan, and I. J. Budnoff, Electronics Personnel Research Group, University of Southern California, Los Angeles, California

SOURCE: IRE Transactions on Human Factors in Electronics, vol. HFE-2, pp. 84-87, September, 1961

PURPOSE: To present the results of two analyses of the techniques of maintenance technicians.

ABSTRACT: Two analyses of maintenance technicians' intermediate behavior in trouble-shooting electronic equipment are reported. In the first, 422 records of this behavior were analyzed to describe the characteristics of the process. It was found that technicians frequently accumulated sufficient symptom information from test points to isolate a malfunctioning stage or to identify a faulty component, before they recognized this fact. Typically, either they continued to make redundant or irrelevant checks before entering the correct stage or replacing the correct part, or they never did use the information and thus failed to solve the problem. Also, 71 per cent of the first replacements of components were incorrect. Evidently, searching for symptom information and interpretation of that information occur on two different behavioral levels, which are not necessarily closely coordinated.

The second analysis revealed the differential effects of practice in applying a trouble-shooting strategy for two subsamples of technicians, one experienced and the other inexperienced in the circuitry involved. Subsequent to the practice, the experienced group made a higher proportion of most efficient moves, whereas the inexperienced group made a lower proportion, per problem, of completely irrelevant moves. It was concluded that the former improved primarily in terms of their trouble-shooting techniques and that the latter gained chiefly in their understanding of gross circuit relationships. (Authors)

REVIEW: This paper contains little for the general reader that is not in the authors' summary, above. (There are no conclusions which are of consequence to the design engineer.) ##

Serial Number 566
Codes 870;874

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLES: Why design for maintainability?
Research data on maintainability

AUTHOR: Joseph G. Wohl, Dunlap and Associates, Inc., Stamford, Connecticut

SOURCE: IRE Transactions on Human Factors in Electronics, vol. HFE-2, pp. 87-92, 112-113, September, 1961

These papers together are essentially the same as the paper covered by Abstract and Review Serial Number 111. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing maintainable circuits

AUTHORS: J. M. McKendry, J. F. Corso, and G. Grant, HRB-Singer, Inc., State College, Pennsylvania

SOURCE: IRE Transactions on Human Factors in Electronics, vol. HFE-2, pp. 93-97, September, 1961

PURPOSE: To test empirically a few basic points concerning the design of more maintainable circuits.

ABSTRACT: A study was conducted to answer certain questions basic to the design of more maintainable circuits. The subjects were 210 engineers, all of whom had considerable experience in electronics. Questionnaires, designed to elicit information on the primary factors affecting fault-location time, were devised for 13 representative circuits varying over a wide frequency range. A statistical analysis of the subjects' responses was conducted to determine whether any general conclusions could be drawn from the replies taken as a group.

The interpretation of the findings of the present study suggests two direct applications: 1) test points should be provided to check the more critical circuit parameters, 2) it would be helpful to arrange test points so that they would be as consistent as possible from circuit to circuit. Unfortunately, the present research results show that this is not an easy task.

Another point clearly indicated by the data of the present study is that an oscilloscope seems to be the most effective trouble-shooting test device. Despite the fact that the oscilloscope's trouble-shooting superiority seems well established, data obtained from technician studies show that meters are more widely used. For correcting this problem, it appears that two courses of action are open to the designer: 1) this tendency can be recognized and test points provided for the most efficient use of meters, and/or 2) specific instructions on test procedures can be provided to the technician in order to facilitate greater use of oscilloscopes. (Authors)

REVIEW: The title of this paper tends to give a somewhat misleading impression of its scope, as indicated by the conclusions shown in the abstract above. (It should perhaps be noted that the original paper was submitted in January 1960.) ##

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Serial Number 568 -1
Codes 424;612;824;
831;837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: MANDEX--A worst-case circuit analysis computer program

AUTHORS: H. S. Scheffler, J. J. Duffy, Autonetics, A Division of North American Aviation, Inc., Downey, California, and B. C. Spradlin, Battelle Memorial Institute, Columbus, Ohio

SOURCE: 39 pp., Pub. No. 550-A-20, New 6-62, Autonetics, A Division of North American Aviation, Inc., Downey, California, June, 1962 (presented at the 14th Annual National Aerospace Electronics Conference (NAECON), Dayton, Ohio, May, 1962)

PURPOSE: To explain a worst-case circuit analysis computer program.

ABSTRACT: This paper explains the Modified AND EXpanded (MANDEX) worst-case circuit analysis program which utilizes a digital computer to determine the effects of variation in circuit input and part parameters on circuit performance. In the MANDEX method, the computer calculates the first derivative of all the output variables with respect to the input parameters and, using these derivatives, sets the input parameters to their end-of-life condition so that a worst-case solution for the output variable is obtained. The computer determines whether performance is acceptable at this worst-case condition, and prints circuit information accordingly. This procedure is repeated for all output variables. In addition to determining whether or not a circuit design will meet worst-case criteria, the program provides the designer with information to aid in improving the design.

To perform this analysis, it is necessary that a mathematical model, which may be programmed, be derived from this circuit. The values of the part parameters and their end-of-life limits, the mathematical equations describing the circuit output variables, and failure criteria must also be programmed into the computer.

No attempt has been made to justify the principles of a worst-case analysis, because it is recognized that, statistically speaking, the probability of occurrence of such a condition is extremely small. Opponents of worst-case analysis reiterate this fact many times and overlook the values to be gained by this technique. First, it is simple to comprehend, and it is a simple job to reorient the design engineer to the computer mechanized MANDEX program. Secondly, the MANDEX technique provides the designer with information concerning his design heretofore unobtainable without extensive laboratory work. If a redesign is necessary, this information provides a logical starting place for this work rather than a hit-or-miss procedure. Lastly, the designer whose design has passed this type of analysis is assured that as long as the component parts remain within their tolerance limits, his design will function properly regardless of the drift of these parts. (Authors)

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This paper gives a careful discussion of the method and its limitations--the latter being the more important. As the authors point out, the program is quite useful even though it may not be the most accurate and even though it has some disadvantages. The method should be seriously considered by those engaged in circuit reliability analysis; but like any other tool, the misuse of the results can be bad.

It should perhaps be noted that the topic of this paper and that of the paper covered by Abstract and Review Serial Number 563 are fundamentally the same, although different sets of terms are used in the two. The model in this paper corresponds to the transfer function in the other; the inputs are the same; the outputs appear to be the same, and the worst-case considerations are an offshoot of the programmed analysis. ##

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Serial Number 569 -1
Codes 730;770;800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: the designer's dilemma

AUTHOR: Donald Christiansen, Technical Editor, Hayden Publishing Company, Inc., New York, New York

SOURCE: Electronic Design, vol. 10, November 8, 1962, pp. 62-101

PURPOSE: To summarize the reliability situation from the designer's viewpoint.

ABSTRACT: The article is divided into four main parts: Closing the loop in supplier-user communications, Let's talk the same language, For the designer: new solutions to old problems, The government and reliability.

Adequate reliability information on very high reliability parts is almost impossible for a supplier to provide. The data which are provided can be furnished in several ways, depending on the situation. The need for standardizing on the requirements is becoming more evident as a vendor finds that different customers want different information. In addition to receiving this "after-the-fact" data, many customers want to assure themselves that the producer is using proper methods in his plant. Many producers are willing to cooperate as long as no proprietary information is involved. Failure reporting--feedback from the field--is essential if product quality is to be kept high. In general, either the quality or the quantity of a field report is so poor as to make it valueless. Many groups are working on the problem and the Martin "MARS" is given mention as an example of a simplified, more effective reporting method. Another trend is toward more attention to failure modes and the physics of failure. In this way, parts can be improved without as long and costly testing. Many examples are given in this section plus a short insert on "Jointly written specs are superior."

Quite a few of the more common reliability terms are defined in a one-page spread.

The designer must appreciate the effect that the general environment will have on the performance of his equipment and he should design to minimize the adverse effects. In general, management must have a step-by-step procedure to spell out all the necessary phases in design so that little is left to chance. Many ways are available for estimating the failure rate of equipment, but predicting reliability from a paper design is risky at best, although it must be done. Ratings should be based on the actual stresses and environments to be expected. Examples are given of the forms that are used to ensure consideration by the designer of these factors for every part. Many of these methods will also show what

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

components are the worst offenders. The reliability figure-of-merit (RFM) system is a tool to help the designer move in the right direction on reliability improvement, despite the inherent inaccuracies of early reliability estimates. Initial reliability apportionment figures are usually based on "magic numbers" such as the number of active elements. The planning of the test program is very important to ensure that it can be done on the budget; examples are given. The actual experimental program can be made more efficient by the use of proper statistical designs. The uses of response-surface techniques for optimizing materials and processes, and of a test matrix to improve the efficiency of a testing program and to demonstrate reliability at a high level of complexity are discussed and illustrated. The design review is discussed in a separate section; it is a most important part of the design process and helps to ensure against human frailty.

NASA emphasizes three tasks that must be done thoroughly: analytic assignment of risks, design review, and exposure of prototype and flight hardware to simulated environments. The Navy is using the Reliability Maturity Index (RMI) on the Polaris. It is explained in some detail. It helps to keep track of all actions which affect reliability. The Air Force has ten major criteria for use as guides: concept and approach, organization, programming, quality control, reliability requirement studies, qualification testing, acceptance criteria, failure/deficiency reporting/analysis/correction, relationships with vendors and subcontractors, training. A separate listing is made of the government reliability and support documents. There are several programs for exchange of information between the vendors and the services related to component reliability: Interservice Data Exchange Program (IDEP), Guided Missile Data Exchange Program (GMDEP), and Failure Rate Data Program (FARADA). A brief description is given of each.

REVIEW: This paper covers a lot of territory--mostly by examples of what is being done. In keeping with the title, there are more dilemmas illustrated than there are solutions--unfortunately, this reflects the present status rather accurately. The article should be used to get an overall feeling for the situation rather than as complete information on any one aspect.

Some of the material in the section on definitions of reliability terms could be somewhat misleading to the reader unfamiliar with the terms. The author, in a private communication, has indicated that he used [1] and [2] as authorities for some of his statements. The reader wishing to become familiar with the meanings of the terms would do well to consult the more complete statements in these references. For example, the author states that "mean life (t) is a measure of the probability that a part or equipment will function properly during its period of constant failure rate."

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Mean life is defined in [2] (p. 30) as the arithmetic mean of the operating times between failures. The conditions under which reliability can be characterized simply by mean life are discussed on p. 32 in [2]. As another example the author states that "confidence level or coefficient ... could be the chance that a value of P lies between P = a and P = b." This could be taken to imply that P is a random variable, whereas modern statistical practice is to consider the interval (from a to b in this case) as the random quantity and the parameter (in this case P) as fixed. A good reference on statistical concepts associated with reliability is [3] (see, for example, p. 279 for a discussion of the confidence coefficient). In general, the reader wishing to develop an appreciation for reliability concepts will find it well worth his time and effort to read (and compare) the discussions in [1], [2], and [3], as well as other references. While the definitions in [3] are not presented in a list or itemized, the assumptions and qualifications on which the concepts are based are clearly stated. These assumptions and qualifications are vital to a sound understanding of the concepts; yet they are inevitably not stated in summarized presentations.

REFERENCES: [1] Reliability Training Text, second edition, March, 1960, The Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, New York

[2] Reliability of Military Electronic Equipment, Report by Advisory Group on Reliability of Electronic Equipment, Office of the Assistant Secretary of Defense (Research and Engineering), 4 June, 1957 (AGREE Report)

[3] Reliability: Management, Methods, and Mathematics, D. K. Lloyd and M. Lipow, Prentice-Hall, 1962 ##

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Serial Number 570
Codes 710;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Project Mercury: Rocket reliability

AUTHOR: Joachim P. Kuettner, Chief, Mercury-Redstone Project, National Aeronautics and Space Administration, Washington, D. C.

SOURCE: Spaceflight, vol. 3, pp. 157-158, September, 1961

PURPOSE: To summarize briefly the reliability program for the Project Mercury rocket.

ABSTRACT: The Redstone booster was one of the most reliable U.S. rockets. It was modified for the Mercury mission and its preliminary flights. These changes were all thoroughly tested before flight. The Mercury Redstone carried the first automatic malfunction detection and alert system. Hundreds of tests were performed on components, subsystems, and systems. In addition to these, the completed vehicle for the manned flight was captive-fired on the ground.

REVIEW: This is a very short qualitative summary of the Mercury-Redstone reliability program. It contains little specific data. ##

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Serial Number 571
Codes 712;713;770;
851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fatigue testing of components

AUTHOR: Raymond A. Cellitti, International Harvester Company

SOURCE: 10 pp., presented at National Farm, Construction and Industrial Machinery Meeting, Milwaukee, Wisconsin, September, 1962, Society of Automotive Engineers paper 572D

PURPOSE: To review the equipment and problems associated with the fatigue testing of machinery components.

ABSTRACT: This paper deals with some important points to be considered in planning tests of structures or structural components under simulated laboratory service loading, and discusses the main purposes of such tests. Test methods and equipment are discussed along with the application and reliability of results to be expected. Particular attention is given to types of fatigue testing machines, important factors affecting test results, test procedure and techniques, presentation of results, and the analysis and application of fatigue data. (Author)

There are nine references and numerous figures to illustrate the material.

REVIEW: This is a good introductory or review paper on the subject. The author presents a balanced and up-to-date picture of the situation. The discussion on stress concentrations could, perhaps, have been improved by including a discussion of concentrations (such as exist around holes) which are a part of proper design and of the fatigue notch sensitivity. ##

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Serial Number 572
Codes 712;770;844;
851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Use of cumulative damage in designing to resist fatigue

AUTHOR: J. A. Graham, Deere & Company

SOURCE: 9 pp., presented at National Farm, Construction and Industrial Machinery Meeting, Milwaukee, Wisconsin, September, 1962, Society of Automotive Engineers paper 572F

PURPOSE: To give two examples of computing service life using a particular cumulative-damage theory.

ABSTRACT: Procedures are described for analyzing service load spectra, making use of fatigue data. Two examples are given, one on a welded hitch and the other on a bevel gear. Cumulative fatigue damage concepts are used to predict the service life, the optimum stress for the design load, and the load and number of cycles to apply on an accelerated test as the equivalent of a lifetime of field service.

Methods were shown for predicting the life of machine parts early in the development program, based on service load spectra from representative operating conditions. The analysis was carried further to show how to determine the optimum design stress. This type of information is useful to the designer in evaluating and improving the design of a machine. This analysis should be conducted early in the design and development program. In fact, recognizing weak areas and correcting them early in the development program often makes it possible to complete the desired field durability tests.

A rational approach was also given for determining the load and number of cycles to apply to a machine on accelerated test. The procedure also keeps to a minimum the number of experimental models needed for developing a new machine.

Another benefit of this approach is that it gives a much better understanding of the machines and what contributes to their success or failure to resist the service loads. Future machines will be easier to design with this knowledge. The investment in testing and analysis should be amply repaid by a more dependable machine and reduced overall test time and cost. (Author)

REVIEW: The paper is an exposition of the use of the Corten-Dolan theory of cumulative damage in fatigue; it probably can be understood by most engineers who have had some experience with fatigue problems. In the first example, no mention is made of the scatter in fatigue life data; presumably the calculations deal with a median life.

(There are other theories and discussions of cumulative damage than the ones described here.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Solid-state devices for telemetering

AUTHOR: W. B. Allen, Manager, Product Engineering Department, Hughes Aircraft Company, Culver City, California

SOURCE: Electro-Technology, vol. 70, August, 1962, pp. 115-117

PURPOSE: To show that transistors and varactors can be used in telemetry transmitters for satellites.

ABSTRACT: At 100 to 400 Mc tubes have more power than solid-state devices, but lack reliability and efficiency. At higher frequencies (1.5 to 2.5 Gc) the tube is more efficient but still lacks reliability. The transistor circuits are much harder to design and are somewhat more complex. Failure rate curves, which are shown in the paper, give silicon transistors only about 1/10 the failure rate of tubes. The use of varactors for efficient (74%) frequency doubling means that the silicon transistors can operate at lower frequencies where they work better.

REVIEW: The view that telemetry transmitters using tubes are less reliable than those using solid-state devices for the high power stages will probably be disputed by some. It is important to remember that reliability is defined in terms of a mission life and that output tubes may be more likely to fail by a wear-out mechanism than by a "random" process. Thus for appropriate mission lengths, their reliability might be quite high.

The article does serve a useful purpose by bringing the possibilities of solid-state devices to the attention of designers. ##

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Serial Number 574
Codes 813;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A status report on equipment reliability--a new approach is indicated

AUTHOR: Leo Landrey

SOURCE: Missiles & Space, vol. 7, September, 1961, pp. 20-23

PURPOSE: To make a practical, limited survey of the methods of achieving reliability.

ABSTRACT: The Atlas computers have a mean-time-between-failures of over 250 hours, more than five times the contractual requirement. Both the Atlas and Minuteman systems used brute force (lots of money) methods of achieving their high reliability. One Atlas computer operated "around the clock" for 12,000 operating hours with no critical failures and little maintenance. From this we can conclude that: solid-state circuitry operates better with no shutdowns and can be extremely reliable; maintenance degrades reliability to some degree; diagnostic procedures are best for preventive maintenance. Some good and proven techniques for high reliability are: reliability prediction and apportionment, design review, testing programs, manufacturing process analysis and supervision, and quality control. Areas for improvement are: better, clearer, and more precise specifications; the education of management; and improved system evaluation. Reliability in space, due largely to space/weight limitations and to the adverse environment, presents more difficult problems. The most promising field is that of determining the mechanism of failure in each case and then finding ways to measure and reduce it. This will permit more accurate accelerated testing of components. Molecular electronics does not seem to be the answer at present.

REVIEW: This is a good evaluation of the status of the reliability program. One might disagree with the comment "... the very nature of building something for the government contradicts the basic concepts of the free enterprise system."

The emphasis on the physical mechanisms of failure is good. Accelerated testing can be worthwhile but extrapolation of the results can be dangerous. Even if the physical basis of the extrapolation can be "taken care of" by assuming there is no problem, there are statistical uncertainties involved that are both serious and rarely calculated. ##

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Serial Number 575
Codes 774;833;844;
851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electrolytic capacitors and their reliability

AUTHOR: A. A. New, Post Office Research Station (England)

SOURCE: Post Office Electrical Engineers' Journal, vol. 55, pp. 115-124, July, 1962

PURPOSE: To discuss the reliability of electrolytic capacitors as related to the methods of manufacture.

ABSTRACT: The origin and development of electrolytic capacitors are briefly reviewed. The principles of operation of electrolytic capacitors are discussed, and the various types at present available are described and their properties considered. Failure rates, calculated from accelerated life tests, are given for certain types of capacitors, and recommendations are made for improving the reliability of electrolytic capacitors in service. As a result of the tests made, the following conclusions can be drawn:

(a) Accelerated life tests confirm the popular impression that in general (i.e. without choosing specific types) electrolytic capacitors of the last decade have only a moderate reliability.

(b) Several manufacturers make a good aluminium unit apart from the methods used for making connexion between the electrodes and the external terminals. However, the best of these if used continuously at about 40°C may give 20-year lives with average failure rates of the order of 1/2 per cent per year.

(c) If a uniformly satisfactory connexion could be incorporated in the types referred to in (b), 20-year lives at 40°C with failure rates not higher than 0.1 per cent per year should be possible, which should make them acceptable for telecommunication equipment.

(d) A method that has been shown to give a continuous metallic connexion (interatomic bond) is the cold-welding process. However, any other process that could be proved to produce the same effect would be acceptable.

(e) Nearly all of the tantalum anodes examined were of good quality. The numerous failures of some types of tantalum capacitors were due mainly to poor sealing techniques and manufacturing faults. If satisfactory methods of sealing tantalum capacitors are used and manufacturing faults eliminated, several types of such capacitors would be expected to have the reliability necessary for telecommunication equipment. (Author)

REVIEW: This seems to be a good summary of British experience with electrolytic capacitors. The experience in this country is expected to be about the same, although some of the manufacturers here might claim higher reliability for their units. The paper does give a good illustration of how the knowledge of the mechanism of failure can aid in finding ways to improve the lives of components. ##

Serial Number 576
Codes 841;842;860

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Report on reliability of electric equipment in industrial plants

AUTHOR: W. H. Dickinson, Esso Research and Engineering Company, Madison, New Jersey

SOURCE: Applications and Industry, no. 61, pp. 132-151, July, 1962

PURPOSE: To report the results of a survey on the reliability of electric equipment in industrial plants, and to suggest improvements for future surveys.

ABSTRACT: A knowledge of electric equipment reliability is required in the economic design of power distribution systems. An AIEE sponsored survey was undertaken in 1959 to collect reliability data in industrial plants. Responses were received from 33 companies, covering 85 plants in 5 industries. Survey results on 27 equipment items are shown in 46 tables. For each industry and for all data received, these show average failure rates by cause, and average down time per failure. (Author)

Suggestions are made for including more detailed questions on the survey form so that the results will be more meaningful.

REVIEW: Data of this type are certainly valuable and the AIEE is to be commended for beginning the work on a substantial level. As with all surveys, the accuracy of the replies can be open to some question; the considerations given for future work are in the proper direction to increase the usefulness of the results. ##

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Serial Number 577
Codes 774;833;844;
851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Progressive stress--a new accelerated approach to voltage endurance

AUTHORS: W. T. Starr and H. S. Endicott, General Electric Company, Schenectady, New York

SOURCE: Transactions AIEE, vol. 55, part III (Power Apparatus and Systems), pp. 515-522, August, 1961

PURPOSE: To analyze an accelerated endurance test that uses stresses which increase with time.

ABSTRACT: Accelerated tests are useful in determining the reliability of materials and products. Two assumptions are made in deriving the formula for life: (1) the accumulated damage is proportional to some power of the applied voltage (other things being equal) and (2) failure in any one specimen will occur at some particular value of damage, regardless of the voltages that caused it; the failure damage may vary among specimens. The life under constantly increasing stress can be compared to the life at constant stress. If the proper correlation does not exist, the assumptions are not true and the basic nature of the failures can be better understood by looking at the "anomalies." The two types of tests are compared for the cases of large and small exponent (in the damage equation) and large and small variability in specimen response.

Test results are shown for Mylar and asphalt-mica composite. An appendix reviews the use of progressive stress testing in other fields.

REVIEW: One of the references in the paper is the paper covered by Abstract and Review Serial Number 39, in which a similar analysis is performed (one of the authors is the same). The authors state their case well and, more important, give the limitations of the method. They also point out what can be learned by studying the deviations from the model. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability aspects of an experimental data processing system

AUTHORS: P. Cox and V. J. McMullan, Electronics Division, Automatic Telephone & Electric Company Limited, Liverpool, England

SOURCE: A.T.E. Journal, vol. 18, pp. 107-130, July, 1962

PURPOSE: To give a 13,000-hour progress report on an experimental computer.

ABSTRACT: The findings in this article are based on the performance of a large data handling system employing transistor and printed wiring techniques, during 13,000 hours of operating time. The article divides broadly into three parts. The first describes the equipment and considers factors influencing reliability. The second deals with commissioning, maintenance and operational experience; it includes a description of a system of written logic that supplants conventional drawings, and a reference to fault detection techniques. The third part appraises the fault data obtained, and comments on fault data analysis.

The experience gained during the commissioning and maintenance of the data handling system discussed in this paper has emphasised the very great importance which must be attached to the speedy detection of faults, the achievement of high levels of component reliability being in itself insufficient. In fact, the lack of servicing practice, which results from this very achievement, makes automatic fault alarm and localisation virtually essential for large systems. The use of plug-in units can facilitate localisation and speedy fault rectification by replacement. Reference has been made to the fact that multiple faults are difficult to trace and this further emphasises the need for automatic methods.

With reference to the component failure rates recorded, the observed adverse effects of moisture indicate the importance of the working environment and the desirability of control. Components developed more recently than those used can be expected to show much improved resistance to climatic effects however and such types are used on later equipments.

An appreciable number of 'no fault found' types of failure have been recorded but further evidence is required before an explanation can be advanced for these. These may not be true component intermittent faults at all but phenomena caused by known and positive component faults or obscure logic faults.

The human element is a real factor in the incidence of failures and the reduction of human element type failures requires not only adequately trained maintenance personnel but also intelligent anticipation and elimination of maintenance hazards, as far as possible,

in the design stage.

The ultimate aim of any reliability assessment is to provide some overall reliability characteristic. The mean time between failures due to 'genuine' faults over the last six months of operation is of the order of 39.2 hours (2.1×10^6 components). The failure rate for the last six months' operation is 0.0012 to 0.0013% per 1000 hours depending upon whether or not suspected accidental and suspected secondary failures are excluded or included. The corresponding failure rate range when plug and socket and soldered joints are excluded is 0.0051 to 0.0086% (0.46×10^6 components). Even though these figures do not take into account data for certain components, the actual useful operating periods for the system should be considerably longer due to the provision of parallel facilities. (Authors in part)

REVIEW: This is a rather comprehensive discussion of the reliability aspects of the experimental computer. It is an extension of the report covered by Abstract and Review Serial Number 144. The data on component failures are a valuable addition to the literature; both catastrophic and drift failures are discussed. ##

Serial Number 579
Code 813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: New approaches to reliability at Hughes Semiconductor

AUTHOR: David H. Simon, Feature Writer, solid/state/design

SOURCE: solid/state/design, vol. 3, September, 1962, pp. 52-54

PURPOSE: To summarize part of the Hughes reliability program.

ABSTRACT: A program to improve the reliability of parts was instituted at Hughes Semiconductor. An example of the improvement is a germanium gold-bonded junction diode for the Polaris; its price fell from $1.04 to $0.175 and its MTBF is almost 400,000 hours. A $2 million investment in reliability test equipment backs up the program. (The programs in use and under development are listed by name.) Samples from lots are subjected to environmental and life tests.

There is an internal surveillance program and a parts reliability improvement program. Non-parametric techniques of process control are used; sub-lots which fail these tests are diverted to less demanding applications.

Hughes is quite satisfied with these programs and they plan to continue their growth in this area.

REVIEW: This is a "newsy" type article rather than a technical one. The statement "... a 10:1 reliability improvement ..." was probably intended to mean a 10:1 increase in MTBF, and would have been clearer if stated in terms of MTBF. On the diode for Polaris statistics, it would have been interesting to know the criteria for failure, and also the degree of confidence associated with the MTBF estimate. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability Bulletin No. 2: Reliability Program Guide for the Management of Firms Contracting for Electronic Products with the Armed Services

AUTHORS: Subcommittee on Reliability (M-5.2), Engineering Department, Electronic Industries Association, 11 West 42nd St., New York 36, New York

SOURCE: 91 pp., published by Electronic Industries Association, 11 West 42nd St., New York 36, New York, January, 1962, price $2.50

PURPOSE: To provide management with the means of adequately setting up a new reliability program or checking an existing one.

ABSTRACT: This reliability Guide has been prepared and submitted for use by contractor managements, giving due consideration to the fact that the reliability parameter is only one of many objectives, requirements, and abilities contributing to system effectiveness. The economical attainment of the desired system effectiveness is a management function. Accordingly, the optimum reliability program is one which will satisfy the specified reliability objectives with the best balance among effort, dollars, and reorganization. This Guide embodies the following basic concepts: (1) reliability is design limited, and (2) reliability inherent in design can be maintained throughout manufacture and use only by intensive effort and consideration by every organization involved. (Authors)

The technical part of the guide is divided into four parts corresponding to the four evolutionary phases of a product, viz. Feasibility, Design and Development, Manufacturing, and Use. For each of these phases there are three management factors: Elements, Procedures, and Controls. The first part of each section contains a diagrammatic worksheet relating the procedural and control items to the elements; the second part contains descriptive information to enable the first part (diagram-worksheet) to be completed. A bibliography is included at the end of each section.

REVIEW: This is a comprehensive, but not too long, document that will be valuable to management for the purposes stated. The guide is explicitly pointed toward management, although those engaged in actually doing the work might profit from reading it by widening their view of the overall problems.

In some cases procedures are spelled out; these should be interpreted by people with considerable experience in the field. Three examples are the following.

(1) The summation of failure rates of components is suggested as a means of estimating the system failure rate. Not the least limitation of this method is the finding of suitable charts where

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the definition of failure for each item is spelled out. The use of the term "ball-park" to describe this kind of estimate is quite apt and the connotations of the term should be kept in mind.

(2) Testing to failure (progressive stressing) is recommended over straight life testing. The efficacy of this method presumes that the mode of failure is the same in each case. This is not true for all stresses on all parts.

(3) The blind application of derating to give safety factors can be bad. Adequate data should support the reliability increase for a decrease in stress.

The bibliography is fairly extensive, but here again the references should not be blindly accepted as gospel, but should be read critically. Most of the references dated 1961 and later have been covered by RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS.

In general, the Reliability Program Guide should be highly useful since it is quite realistic and comprehensive. ##

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Serial Number 581
Code 835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Integrated electron devices

AUTHOR: I. A. Lesk, Motorola, Incorporated, Semiconductor Products Division, Phoenix, Arizona

SOURCE: 1962 IRE International Convention Record, Part 3, New York, New York, pp. 49-59, March, 1962

PURPOSE: To summarize the status of integrated electron devices.

ABSTRACT: The design of integrated circuits may be broken down into four steps--conventional component circuitry, compatible component circuitry, hybrid integrated circuits, and single or multiple block integrated circuits. Surface passivation is an extremely important requirement for integrated circuits. Advantages of integrated circuit applications are apparent in such areas as cost, size and shape, speed, weight, power utilization, and thermal matching. The improved reliability potentially obtainable by integrated circuits is a significant factor in their eventual large scale use, but it must be very carefully designed into them, and guaranteeing it requires quantitatively determined process reliability and control comparable to that now demonstrated on high quality conventional components.

Although standard integrated circuits will be available as catalog items, the varying requirements on integrated circuits for different applications, the continually appearing innovations in devices and circuits, and the use of proprietary circuits by equipment manufacturers indicate that a majority of integrated circuits will be special items. (Author)

REVIEW: The emphasis on the problems in guaranteeing or predicting reliability because of uncontrolled and incompletely understood processes is very good. It points out the area where real understanding is essential and where much future work should be concentrated. ##

Serial Number 582 -1
Codes 713;760;770;
780;832;837;
850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Problems of Polaris reliability and methods for their solutions

AUTHOR: Erich Pieruschka, Lockheed Missiles and Space Company, A Division of Lockheed Aircraft Corporation, Sunnyvale, California

SOURCE: Technical Report 5-10-62-24, 41 pp., Lockheed Missiles and Space Division, Lockheed Aircraft Corporation, Sunnyvale, California, August, 1962 (originally prepared for a guest lecture at the Reliability and Statistical Methods in Industry Courses, University of California at Los Angeles, summer, 1962)

PURPOSE: To show how highly reliable missile types are achievable in spite of the impracticability of specifying and measuring the reliability of the parts.

ABSTRACT: This study discusses the problem areas bearing on the reliability of Intermediate Range Ballistic Missiles and Intercontinental Ballistic Missiles, and gives methods of solution in the light of experience gained from Polaris. The discussion is concentrated on the achievement of reliability in structure, mechanical devices, electronics, pyrotechnics, and propulsions; human factors in reliability engineering, manufacture, inspection, and maintenance are also considered.

It is shown that high reliability of missiles cannot be demonstrated by means of conventional acceptance tests. Because of their great cost, only a few missiles are available for flight tests. Therefore, new methods must be found to avoid this dilemma. Six general problems are surveyed in the paper, viz. (1) external environmental stress, (2) maintenance, (3) noninspectable pyrotechnical devices, (4) effect of power turn-on in electronics, (5) high temperature in the propulsion subsystem, and (6) occurrence of human errors during inspection, checkout, and maintenance. Of these, the first three are considered as solved or easily soluble, while the solution of the last three will require additional research. Approaches to the solution in each case are briefly indicated.

A safety margin concept is presented in which the minimum difference between stress and strength is related to the standard deviation of the difference between the two values. Exact probabilities are difficult to obtain because actual distributions in the tail regions are unknown. The measurement and minimization of the deleterious effects of the cycling on and off of electronic devices is discussed. Some studies have shown that this can be a most serious factor in life reduction.

Among the causes of unreliability in propulsion subsystems, high-temperature effects are perhaps most important. High temperatures cause a reduction in strength due both to material behavior and to

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defects in parts. These defects cannot be adequately inspected out. Research is needed in nondestructive inspection techniques and in finding materials more resistant to temperature. Certain design actions and care in manufacturing are also required.

Human factors in manufacture, inspection, and maintenance are briefly discussed. Of all adverse effects, those due to the human element present the most difficult problems in the attainment of highly reliable, one-shot weapons. Adequate inspection helps to alleviate the problem.

Ten references are cited, and some remarks concerning the correct usage of statistics are given in an appendix.

REVIEW: This paper is, in general, informative but not detailed, as befits the original oral presentation. The remarks in the appendix about the use of statistics are very good. If assumptions are made on the basis of little or no evidence, the uncalculated risk should be candidly acknowledged. Equation 6.1, showing how inspection of parts can influence reliability, is not proved, and its validity is not obvious. (There is also a typographical error in this part: "known destructive test" should be "non-destructive test.") ##

Serial Number 583
Codes 552;820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Straight line plotting of reliability functions

AUTHOR: Alan Plait, Reliability Engineering Department, The Magnavox Company, Fort Wayne, Indiana (present address: Melpar, Incorporated, Falls Church, Virginia)

SOURCE: Electronic Design, vol. 10, December 6, 1962, pp. 44-47

PURPOSE: To provide graphs of some reliability functions.

ABSTRACT: The equation $-\ln R = f_r t$ can be plotted as a family of straight lines on log-log paper with axes of t and R, where R is reliability, t is operating time, and f_r is failure rate. The graph is shown in the paper. If equipment has n identical redundant units the system reliability is increased over that of a single unit. The plot of system reliability vs. redundant-part reliability can also be a family of straight lines and is shown in the paper.

REVIEW: In the theoretical derivation of the first failure equation, the result is true only if f_r is a constant. This limitation is quite important, but is omitted from the paper. The quantity f_r is loosely referred to as the failure rate--it is actually the conditional failure rate or hazard function. Down to R = 90%, the (very good) approximation is made that $1 - R = f_r t$.

The second part is a rather labored derivation of the fact that the failure probability of the system (Q_s) is the product of the failure probabilities of its redundant parts (Q_i). Two implicit restrictive assumptions are made in the derivation and should have been stated. They are: (1) the failure probabilities of all the units are independent, and (2) the failure probabilities of operating units are independent of how many units have failed. The graph is a plot of the equation $Q_s = Q^n$ where $Q_i = Q$ for all i, and n is the number of redundant units. The axes are labeled in terms of $R_s = 1 - Q_s$ and $R = 1 - Q$. There is an inference that for values of $R < 0.1$ the $R_s < R$, but this is not so. The above equation is exact for R (or Q) between 0 and 1 and R_s is always larger than R for $n > 1$. Equation 8 incorrectly implies that the graph is approximate. There are at least the following misprints in the paper: Figure 3 should have 0,0 at the origin instead of 9,9 and the symbol for the binomial coefficients is $\binom{n}{r}$ not $(\frac{n}{r})$. Where extensive calculations need be made, the graphs may be handy, although for occasional use a slide rule might be easier to find than the graph. ##

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Serial Number 584
Codes 770;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to measure dynamic characteristics of semiconductors for reliable circuit design

AUTHOR: F. J. Potter, Semiconductor Products Department, General Electric Company, Buffalo, New York

SOURCE: Electronic Equipment Engineering, vol. 10, August, 1962, pp. 38-43 (Part 1); October, 1962, pp. 42-45 (Part 2) (Originally presented at the Conference on Reliability Assurance Techniques for Semiconductor Specifications, Washington, D. C., October, 1961, and published on pp. 162-180 in Semiconductor Reliability, Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962)

PURPOSE: To describe a technique for measuring the dynamic characteristics of diodes and transistors and illustrate some applications to circuit design.

ABSTRACT: Past techniques for specifying semiconductors for switching service have been unsatisfactory because only the V-I characteristics were considered. More recently charge control concepts have been introduced in analysis techniques. A pulse-null method for measuring the dynamic characteristics of switching diodes is described in detail. The characteristics determined by this method are the dynamic-recovery time constant and the dynamic-recovery resistance of the diode. In addition, a circuit for measuring the forward-recovery time of a diode is discussed. The charge components which determine the dynamic behavior of switching transistors are τ_c, C_c, and τ_s. The dynamic unsaturated collector time constant, τ_c, is shown to be the ratio of unsaturated base charges, Q_b, to collector current; the large signal collector capacity, C_c, is found to be a function of the collector depletion-layer charge, Q_c, and V_{ce}; and the saturated dynamic time constant, τ_s, is determined by the excess base charge, Q_s.

In Part 2, some typical values for the described dynamic characteristics of transistors and diodes are given as well as examples of their use in circuit design.

REVIEW: This two-part article is a fairly detailed discussion concerning the methods of measuring the dynamic characteristics of diodes and transistors and should be of interest to anyone concerned with the design of semiconductor switching circuits. ##

Serial Number 585
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: Report No. 62-020, 11 pp., Advanced Development Laboratory, Philco Corporation, Philadelphia, Pennsylvania, June, 1962 (presented at the Chicago Spring Conference of the IRE Professional Group on Broadcast and Television Receivers)

PURPOSE: To explain a failure mode of power transistors and how it can be prevented.

ABSTRACT: It is desirable to use power transistors as switches up to their maximum collector-emitter voltage capability (BV_{cex}). In this type operation, failure phenomena during switch-off have been observed and attributed in the literature to second breakdown, punch through, reach through, pinch off, and various types of energy level effects.

It is recognized that any transistor has a maximum volt-ampere switching loss capability under established environmental conditions. In many cases this loss has not been sufficient to explain transistor failure. This paper discloses a second mechanism of failure as dynamic conditions within the transistor such that the requirement for operation up to BV_{cex} is not maintained; that is, the base-collector leakage current (I_{cx} or i_{cx}) is not permitted to flow. Prevention of failure in this mode is a matter of counteracting the transistor internal dynamic conditions with the proper base drive. (Author)

The criteria for prevention of breakdown are given as (1) proper base-collector leakage current must flow when BV_{ceo} is exceeded, (2) the load line must not intersect the negative resistance region, and (3) the absolute maximum collector-emitter voltage capability must not be exceeded. Number 3 is considered trivial for this type of application, while number 2 must be considered for each type of transistor. Number 1 is considered in detail and it has been found likely that it accounts for the failures observed and reported in the literature in connection with inductively coupled or resonant-load circuits. An example of this failure mechanism and a method for preventing it are illustrated in the case of a deflecting circuit for a 23", 110° picture tube.

REVIEW: This paper presents a very good treatment of a failure mode in high power switching transistors which has previously been recognized but has not been adequately explained. ##

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Serial Number 586 -1
Codes 552;822;824;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Expressing capacitor reliability accurately

AUTHOR: David E. Maguire, Kemet Department, Union Carbide Corporation, Cleveland, Ohio

SOURCE: Electronic Industries, vol. 21, December, 1962, pp. 100-105

PURPOSE: To present the Weibull distribution and to show its application to two sets of tantalum capacitors.

ABSTRACT: The assumption of an exponential distribution may lead to serious errors. The Weibull distribution can completely describe the decreasing, constant, and increasing failure rate periods of the classical description of failure behavior. Formulas are given for the distribution and its various aspects. The use of Weibull paper is shown. In some cases the components will have a mixed behavior and separate Weibull parameters are necessary for the different periods. Two examples are given in which the data are tabulated and then plotted on Weibull paper. Both graphs have two segments each.

REVIEW: The majority of the paper is given to a good, but not extensive, discussion of the Weibull distribution. The three-parameter form is shown, but the location parameter is assumed to be zero in both examples. This is a customary procedure since the location parameter is quite difficult to determine. The discussion of the benefits of the Weibull distribution is somewhat misleading. The main reason that it fits data much better than does the exponential distribution is that the Weibull has an extra parameter. (Both distributions can use a location parameter, but it is rarely done in reliability work.) Note also that it is quite feasible to apply constant failure rate segments to the failure data just as is illustrated for the Weibull distribution; it just takes more segments. Whether or not it actually requires the estimation of more parameters will depend on the data. It should be emphasized that there is nothing magical about the Weibull equation. It is not the "true" one any more than the exponential is the "true" one in some cases. At the present state of knowledge, all that can be said is that both are useful for empirically fitting failure data and that the Weibull, with its extra parameter, will naturally fit better in more cases.

The experimental data that are tabulated are quite interesting since they (inadvertently) show that data must be handled with care. First, the author states that these are (all) the data obtained so far and that the time of each failure was recorded. In Table I, there is only one failure for each time shown. In Table II, however, over half the times are for multiple failures; some times have as many as six failures. The probability of

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multiple failures in an interval of time becomes negligibly small as the time interval is made small. If this is not the case, then the failures are correlated--a distinct violation of the assumptions of the test.

In the graph for data of Table I, it should be noted that one of the segments has only three points in it. For a two-parameter distribution, this leaves only one degree of freedom so that the uncertainty involved is rather great. The accuracy with which all the parameters are stated (three significant figures) implies a precision far beyond the capabilities of both the amount of data and the graphical method. ##

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Serial Number 587
Codes 555;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor switching dissipation nomograph

AUTHOR: John Jacobs, Semiconductor Products Division, Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota

SOURCE: Semiconductor Products, vol. 5, December, 1962, pp. 32-33

PURPOSE: To show how average switching dissipation can be calculated for a special case.

ABSTRACT: The dissipation of a switching transistor can be easily calculated during the "on" and "off" periods, but the calculation is difficult during the transition periods. The following assumptions are made:

1. The load line is resistive
2. The rise and fall times are both linear
3. The rise and fall times are equal
4. The saturated voltage and the leakage current can be neglected.

The switching power, averaged over one cycle and relative to the switched power, is then 1/3 x frequency of operation x switching time. A nomograph is given for solving this equation.

REVIEW: The assumptions are well stated in the article so that there is no difficulty in determining the conditions under which the formula is completely accurate. Since these conditions are all rarely, if ever, reached in practice, the main problem is knowing whether or not this simple model will give sufficiently accurate results. No indication is given of the usefulness of the model under non-assumed conditions.

The usefulness of nomographs of this type, for such a simple equation, is debatable if it is solved only occasionally. It could be more trouble to find the nomograph than a slide rule. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of transistor failure in a nuclear environment

AUTHOR: Frank W. Poblenz, Research Laboratories Division, The Bendix Corporation, Southfield (Detroit), Michigan

SOURCE: IRE Transactions on Nuclear Science, vol. NS-10, January, 1963, pp. 74-79

PURPOSE: To describe a method for predicting transistor reliability as a function of nuclear radiation exposure, through the use of the Weibull distribution.

ABSTRACT: Early work regarding the effects of nuclear radiation on electronic components was concerned mainly with determining the radiation sensitivity of materials and components. Only one experiment is known to have been performed to obtain radiation reliability figures, and this was on three types of capacitors. Data from this experiment showed only failure rates greater than one percent.

What is actually required by the systems designer is the answer to the question, "At what flux level can the device be used for a particular application if less than 0.01 percent probability of failure is specified?" For transistors and many other types of electronic components exposed to a nuclear environment, the mode of failure appears to be a collection of mechanisms which systematically reduce the performance of the component until it has no further useful life and is essentially "worn out."

In the past, the Weibull distribution has been useful in analyzing fatigue or wear-out data. By suitable transformation of the function, straight line graphs are obtained on special coordinate paper by plotting, as abscissa, the logarithm of the life (integrated radiation dose) and as ordinate, the

$$\log_e[-\log_e(1-F)],$$

where F represents the median rank of the component fraction failed. A slope parameter, b, greater than unity is most often associated with component wear-out. Wear-out data plotted for a group of sample devices exhibits linearity on Weibull paper if the Weibull distribution is the correct function to describe the failures. The slopes, however, for various types need not be the same, leading to the possibility that one type may be preferred if relatively large failure rates may be tolerated while another may be required if only very low failure rates are permitted.

Weibull plots for seven types of transistors are given for 70% and 30% of initial beta endpoints. The linearity of the plots gives grounds for extending the curves to very low failure rates

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without the necessity of using enormously large samples.

REVIEW: This paper represents a substantial contribution to the investigation of transistor, and potentially other electronic component, reliability in nuclear environments. If the extension of Weibull plot data to very low failure rates can be substantiated, considerable improvement in prediction of reliability can be obtained at reasonable cost. Unfortunately, the nature and conditions of the test data are not given, although reference is given to papers which are well documented with the implication that similar conditions prevailed. ##

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Serial Number 589
Codes 833;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improved reliability in wideband feedback transistor amplifiers

AUTHOR: E. Davies

SOURCE: The Marconi Review, vol. 25, pp. 4-10, First Quarter, 1962

PURPOSE: To describe an improved wideband transistor amplifier using fewer components.

ABSTRACT: This and a following companion article have as their philosophy that maximum reliability is obtained when a given specification is met by a circuit incorporating the minimum number of components, provided the configuration assures that performance is not affected by component variations due to aging.

An initial attempt to design a broadband transistor amplifier resulted in a seven-transistor circuit which, while it met specifications, could be loosely described as a 1936 design replacing vacuum tubes with transistors. Analysis of the design revealed poor utilization of transistor mutual conductance, and this was substantiated when a three-transistor circuit was designed which would meet the specifications, but which required unduly complicated gain control to meet input impedance specification.

The final design, based on an analysis of feedback gain and impedance equations makes use of two feedback pairs with a fifth transistor to give an inverted phase output. Gain is flat to 0.2 dB to above 10 megacycles, and -1.0 dB at 17 megacycles. The number of components was reduced from 59 to 28.

REVIEW: Reducing the number of components in a circuit does not of itself make a system more reliable, unless the designer makes use of reliable design techniques. Generous amounts of both a-c and d-c feedback plus overload protection feature this work. ##

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Serial Number 590
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The application of unijunction transistors in timing circuits to improve reliability

AUTHOR: E. Davies

SOURCE: The Marconi Review, vol. 25, pp. 11-18, First Quarter, 1962

PURPOSE: To show the application of unijunction transistors in timing circuits with the specific objective of reducing the number of components used to a minimum in order to achieve reliability.

ABSTRACT: The unijunction transistor is an ideal device, provided its maximum frequency of operation--about 0.75 mc/s--is acceptable. The circuits described show how timing errors due to change in triggering potential with variation of ambient temperature can be avoided.

Functions of television field timing pulse separation, frequency division, sawtooth and brightening pulse generation, and time base trigger delay are each developed and integrated into a system with a reduction of components to about one-third of the number normally employed. The inherent triggering action of the unijunction transistor when the emitter reaches a predetermined level is stabilized by returning the emitter circuit to the base 2.

REVIEW: This challenging article demonstrates how ingenious design can sharply reduce the number of components and complexity by thoughtful consideration of function. No figures on actual failure rates are given, but the reliability of these circuits is considered to be good because unijunctions are robust and easily manufactured, and they are used well within their ratings, particularly with respect to dissipation. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Equipment reliability

AUTHORS: O. E. Keall and W. F. Miller

SOURCE: The Marconi Review, vol. 25, pp. 31-34, First Quarter, 1962

PURPOSE: To report on a reliability test run on 600 transistorized radio receivers.

ABSTRACT: A production run of 600 transistorized receivers provided the opportunity to check component reliability. A three-month soak test without temperature control was followed by a ten-week trial with partial temperature control. The receivers were constructed in two sections, an RF section with 94 components and an AF section with 54 components. Components found faulty, or apparently faulty, on factory final test were not included in failures reported.

During the first soak period, a major difficulty was encountered in the coaxial plugs and sockets used in the test set-up. On the other hand the 15-way plug and socket strip connectors on the two receiver boards gave no trouble.

Major component failure was in IF transformers (27), with the fault traceable to assembly procedures. Temperature cycling revealed other failures, notably in resistors and capacitors. Many of the component failures encountered would not have shown up under normal testing on receipt from the manufacturer.

It was felt that the initial soak period could have been halved, particularly with more attention paid to temperature cycling, at a considerable saving in money. It is open to question whether there is any advantage in demanding premium components as the failures have not been much greater than one per thousand.

REVIEW: Many of the points made by the authors are not new, but probably are worth repeating. The testing jigs and procedures must in themselves be reliable; poor manufacturing techniques can contribute materially to failure rates. The statement on demanding premium components is open to more question, however. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability in direct coupled transistor logic

AUTHORS: A. B. Starks-Field and A. M. King

SOURCE: The Marconi Review, vol. 25, pp. 42-46, First Quarter, 1962

PURPOSE: To discuss maintenance of reliability in direct coupled transistor logic through proper choice of operating conditions.

ABSTRACT: Large digital systems require a high standard of reliability in order to carry out their functions in relation to an operational requirement. Since they are composed of a large number of individual elements, the reliability of these must be of an extremely high standard.

This article gives a qualitative discussion of the design factors affecting the reliability of one such element. (Authors)

REVIEW: This paper is rather general and vague and contributes very little, if anything, to new knowledge. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability demands of automatic error-correcting equipment for digital data transmission

AUTHOR: P. R. Keller

SOURCE: The Marconi Review, vol. 25, pp. 47-54, First Quarter, 1962

PURPOSE: To discuss the general principles involved in the design of reliable electronic equipment.

ABSTRACT: In a digital data transmission system an attempt is made to reproduce at a distant point an exact replica of the input data despite errors introduced by the transmission medium. To reduce errors, a seven-unit code may be substituted for the standard five-unit teleprinter code such that each character contains three mark elements and four space elements. Each received character is then examined and if it does not have the correct ratio, an automatic repetition request (ARQ) signal is sent.

An ARQ system may be said to be reliable if no printed errors occur other than those due to transpositions and if no circuit time is lost other than that taken up by the necessary repetition of detected errors. The system therefore should introduce no errors of its own and any faults must be quickly located and cleared.

An early version of ARQ equipment used about 500 cold-cathode and thermionic tubes, together with about 5,000 other components. Failure experience centered around tubes and resistors. The tubes, although a reliable type, were of a batch made after a manufacturing change.

A new design used alloy junction transistors upon which improvements had been made over a period of years and was thus expected to be reliable (limited testing was done). Metal oxide resistors were substituted for the carbon film types. Metalized paper capacitors fully sealed in a metal case were again specified. Flow soldering rather than connections made with soldering irons were used wherever possible. A modified socket was specified for printed circuit edge connectors and contacts were gold-plated. Worst-case design was employed throughout and design was limited to a small number of basic circuits.

The earlier tube equipment achieved a reliability figure of one failure per 3 x 10^6 component-hours of operation. The target for the replacement transistor equipment is one failure per 10^8 component-hours.

REVIEW: This is a good article which points up the problems implicit in

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

improving an already-reliable system by orders of magnitude on a realistic cost basis. It is evident that there is still considerable room for engineering judgment in attaining the optimum design and component selection and then in trading off some reliability for maintainability.

The author in a private communication has pointed out that the theme of the article is that the effective reliability of a complete equipment is a function of system concept, basic components, circuit design and methods of interconnection, and that these separate aspects should not be considered in isolation from each other. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: *Some factors influencing reliability in analogue circuits for precision radar applications*

AUTHORS: L. W. Whitaker and D. H. Chandler

SOURCE: The Marconi Review, vol. 25, pp. 65-71, First Quarter, 1962

PURPOSE: To put forward a new circuit technique to improve the precision and reliability of analogue circuits.

ABSTRACT: In contrast to digital circuits which need only have an output between some fairly broad limits, analogue circuitry requires frequent setting up. Thus included in the concept of reliability of analogue equipment as a whole will be its ability to stay within prescribed limits for a specified period of time. In addition, the number of setting up adjustments should be as small as possible. The maintenance of analogue circuit stability is a more difficult problem with transistors than with vacuum tubes.

A properly balanced estimate needs to be made of the relative importance of catastrophic component failure against the drift of component value with age. The chance of catastrophic failure increases with the number of components, but the use of modified circuits with more components can make the final output more tolerant of component variation.

The standard technique to improve stability is the use of negative feedback, but for the high values of stability required, problems of high frequency stability arise. The solution offered is that of successive approximation, in which the first stage makes only an approximation and is followed by a second stage operating only on the difference between the approximate and the true solution. The form of error in the first stage is relatively unimportant, and neither stage needs a particularly high gain or bandwidth. In actual application having, for example, both coarse and fine inputs, the actual number of components is not materially increased. The coarse signal drives the first stage while the input to the second stage is the sum of the first stage error and the fine signal. Assuming that the first stage has the poorest high frequency response, time delay errors can only approach that introduced by the first stage, and are of no importance except at very short range.

REVIEW: This is an interesting article, but it is written in very general terms. No direct comparisons are made nor are any criteria set up for evaluating the performance of successive approximation systems. The term "dissipation drift" is introduced but is defined in terms of the jargon of a limited field. The effect is important but the term is admittedly inaccurate. The article is rather frustrating and no bibliography is given. ##

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Serial Number 595
Codes 833;837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability through the use of silicon controlled rectifiers

AUTHOR: H. N. C. Ellis-Robinson

SOURCE: The Marconi Review, vol. 25, pp. 72-77 First Quarter, 1962

PURPOSE: To explore the reliability of applications where silicon controlled rectifiers are desirable for reasons of minimum size and weight.

ABSTRACT: It is always difficult to weigh the pros and cons of a new device which offers physical advantages, but where the long term reliability is an unknown factor. Work was begun on a series of low-voltage, high-current power supplies (100 volts, 100 amps) and has progressed through some ten applications to 100% control of 415 volt 3 phase with output in excess of 20 kva. The maximum number of operating hours accumulated is just over 2500. During all of the life testing, no silicon controlled rectifiers (SCR) have been lost under actual proposed conditions of operation.

Rejection rate on new SCR's has been about 3%. Retest at an average life span of 1,000 hours shows 2% outside of original specification and less than 1% outside of application specification. After an average span of 2,000 hours, the number of those outside specification has increased to 3% and the number of rejections has risen to 1%.

One of the main problems is the rapidity with which the SCR responds to overload condition in that it may be permanently damaged or destroyed in a few microseconds unless great care is taken. The most critical consideration is that of peak inverse voltage. The inbuilt margin is small, generally less than 25% while transients in power supplies may be several times normal peak value. Series silicon diodes with high peak inverse voltage rating and the use of "Thyrectors" across transformer windings may be necessary.

On evidence to date, it can be said without hesitation that, in the low voltage high current application, the SCR is superior to any other known device.

REVIEW: This is a good factual paper citing figures on experiences and reviewing reasons for losses of SCR's where this has taken place. Only 3% of the losses are given under the heading of unexplained failures. No specific circuits are given, but reference is made to three papers giving details of the applications. ##

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Serial Number 596 -1
Codes 820;830;840;
850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: 1962

AUTHOR: John M. Carroll, Managing Editor

SOURCE: Electronics, vol. 35, November 30, 1962, pp. 53-76

PURPOSE: To summarize the state of knowledge of electronic reliability.

ABSTRACT: The article is divided into six sections: Mathematics of reliability, Life testing, Designing reliable circuits, Component reliability, Systems design, and Physics of failure.

The concepts of failure distribution and reliability function are explained. A brief description is then given of the exponential, normal (Gaussian) and Weibull distributions. The failure rate is introduced and the three parts of the mortality curve are reviewed. A table lists some of the ways of reporting failure rates.

In the field of life testing the chi-square distribution is used to put confidence limits on the MTBF of an exponential distribution. The Poisson distribution can be used to estimate the probability of a given number of failures occurring in a particular period. Sequential testing is much more efficient than conventional methods for acceptance testing. Most military contracts have provisions for a statistical demonstration of reliability.

The reliability of a circuit can be estimated in various ways. An initial estimate can be made by counting the active elements, noting the environmental severity and looking at a chart (shown in the paper). The next step is to list the components together with their failure rates and then total the latter. The big problem here is to get failure data based on the same criteria of failure as for the components in the circuit. Here drift failures are the biggest problem. Environmental factors and stress derating factors can be applied to data. Much work is being done by industry and the government to improve the failure data. Several charts are shown of existing and desired failure rates for components.

Component manufacturers are required many times to show statistical proof that their product meets reliability specifications. The producer may be disqualified if he fails to pass these tests. Just what constitutes an adequate test is being given much thought since tests can be long and expensive. Failures can be plotted right on a circuit diagram; an excess of points in any one place will show up trouble spots.

System design is more complicated and so is the reliability calculation. Various kinds of redundancy can be used: parallel circuits, majority logic, and time sequencing. Sometimes it is even

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RELIABILITY ABSTRACTS
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possible to allow for servicing while equipment is on-the-air. Quantities relating the total value or effectiveness of a system can be calculated and tradeoffs made between reliability, serviceability, performance, etc.

If it is known why a component fails--on a basic level--an important step has been taken toward improving it. Accelerated testing, properly used, can uncover weaknesses. Some failure modes and theories are briefly described.

There are 41 references and about 12 books/pamphlets listed for further reading.

REVIEW: This is an introductory-summary type paper. Its main use (and intent) is to give the non-specialist in the field a better feeling for the subject. Care should be used in extracting facts from the paper for specific use. This sort of paper is rather difficult to write and errors, misprints, and controversial statements do creep in. Some of these are:

1. The burning out of a transistor which was used far above its rating is considered a failure. It is one that can be rectified, however, and eliminated from future estimates of failure rate. (Design reviews are not mentioned in the paper. They are quite important and one of their purposes is to catch errors like this.)

2. For a normal (Gaussian) distribution the quantity s^2 is a good estimate of σ^2, but s may not estimate σ too well. In the normal distribution the MTBF is not a satisfactory concept. In the formula for s^2, $\overline{m}$ should be the mean life, and n should be the number of equipments.

3. While the term "failure rate" is used to describe the failure data usually presented, the definition given for failure rate is usually the one reserved for the hazard function or conditional failure rate.

4. The formula for the Weibull distribution is wrong. The variable t should be multiplied by α in both places where it appears. The term m should be defined as mean time-to-failure or average life. The notation $(\frac{1}{\beta})!$ has no meaning if $\frac{1}{\beta}$ is not an integer. The preferred notation is $\Gamma(\frac{1}{\beta} + 1)$ and the value of m is $\frac{1}{\alpha}\,\Gamma\,(\frac{1}{\beta} + 1)$.

5. The parameter λ is often used for the failure rate (hazard) when it is a constant. In other cases, its use can (and does) lead to errors because of the association with the constant case.

6. The definition of a confidence interval is actually that for a tolerance interval, although the term is later used properly

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

in the examples.

7. In the life test examples, the exponential distribution is implicitly assumed. Before using these methods in other cases, the applicability of the methods should be checked. There is an error in the first Practical Example. The data listed as 3 and 5 should probably be 103 and 205.

8. When failure rates are added, care should be used so that not too many significant figures are retained in the answer; retaining too many gives a false sense of precision. The original data, at best, are good to only one or two significant figures. In the sample calculation the final failure rate is given as 481.5; it should have been then rounded off to 480 or perhaps to 500.

9. The phrase "in a reliability sense" is used to describe some components in series or parallel. It should be very strongly emphasized that this sense is quite different from being "electrically" or "circuitwise" in series or parallel. The term is being used in the sense of logic; two parts are in series if the failure of either causes failure of the circuit, they are in parallel if the success of either is sufficient for success of the circuit. If resistors were to fail by shorting and two were electrically in parallel, they would be in series in the logic sense. If resistors fail by opening, the terms series and parallel (logic sense) may not apply to the electrically-parallel pair since it is not known, beforehand, whether the circuit will fail or not when one resistor fails.

In this connection, it should be noted that most redundancy formulas assume that the reliability of the "live" components is not changed when some of the redundant ones have failed. In the case of two resistors electrically in parallel, if one fails by opening, the power dissipation in the other will increase and thus its reliability will decrease.

These formulas for the series/parallel (logic) cases may not be true if failure is by drifting or if the failure probabilities are not independent. An example of dependent failure probabilities might occur when the failure is due to a temperature or vibration increase which affects all components in the same way. See Review Serial Number 199.

10. Care should be used in derating components to improve the reliability, since there are some kinds (relays for example) for which a nominal derating will actually reduce the reliability. If actual test curves are used, this difficulty will be avoided.

11. The discussion of Markov chains is so incomplete as to be worth no more than the mention of the name (and the giving of a reference). See REFERENCE.

12. Care should be used in applying simple majority logic; if the majority voting organ is no more reliable than the original

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circuit (and it may not be), there is actually a decrease in reliability.

13. In time sequencing, the formulas assume that the hazard is independent of time, that the switching is failure-free, and that there is no standby degradation. These are rather severe and unlikely restrictions.

14. In the case of on-air repair, it would seem that the repair <u>rate</u> should be much <u>higher</u> than the failure rate; it is the repair <u>time</u> which must be <u>less</u> than the failure time. In any event, the formula is incorrect, since for very large operating times the indicated reliability can be more than unity (a mathematical impossibility). The derivation probably also assumed constant conditional failure and repair rates.

15. The temperature factor (x 2 for 10°C) and voltage factor (x 2.5 for 10 collector volts) for failure rates of power transistors may be accurate for some transistors under some circumstances. In all other cases they are no better than gross approximations and their use may lead to quite erroneous predictions.

16. In a private communication the author has pointed out the following errors in the paper: (a) "... arithmetic errors in the equation for the accept and reject lines on page 62. The slope is an order of magnitude too high and the absolute magnitude of the intercept should be the same in both cases." (b) "On page 64, line 30, 'the test would have to continue for at least 600 hours...'."

As mentioned at the beginning of the review, the paper should be used to get a "feel" for the subject only; specific facts should be looked up elsewhere.

REFERENCE: Kemmerey, et al: "Finite Mathematical Structures" (suggested by author in private communication) ##

Serial Number 597
Codes 802;821;831;
840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A survey of techniques for analysis and prediction of equipment reliability

AUTHORS: H. Elmore Blanton, Raytheon Company, Bedford, Massachusetts and Richard M. Jacobs, Sylvania Electric Products, Inc., Waltham, Massachusetts

SOURCE: Industrial Quality Control, vol. 19, December, 1962, pp. 18-25 (Part 1) and January, 1963, pp. 13-18 (Part 2)

This paper was covered by Abstract and Review Serial Number 191. ##

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Serial Number 598
Code 811

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design reliability creation through management directives

AUTHOR: John W. Griswold, The Boeing Company, Seattle, Washington

SOURCE: Industrial Quality Control, vol. 19, January, 1963, pp. 5-10

This paper is essentially the same as the one covered by Abstract and Review Serial Number 247. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: High-density tantalum-film microcircuits

AUTHOR: T. V. Sikina, Philco Scientific Laboratory, Blue Bell, Pennsylvania

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 24-31

PURPOSE: To show how high-density tantalum-film microcircuits can be produced.

ABSTRACT: This paper describes a flexible microelectronic approach in which thin film tantalum passive components and diffused silicon active devices are used. The electrical performance of these circuits has been given. The discrete components were evaluated to establish their individual capabilities under exacting environmental conditions. A high degree of component reliability, compatibility and flexibility has been demonstrated. Significant progress has been made toward microsystem objectives such as reduced cost, increased operational speed, and low-power dissipation.

A novel masking and etching technique has been developed to eliminate fragile copper or metal masks, which require much preparation. Glass or ceramic substrates up to several inches on a side can be processed inexpensively into a broad range of thin film passive components. These components are suitable for both linear and logical circuit functions. (Author)

REVIEW: A good deal of work was done to collect the data presented and some ingenious techniques were combined to develop the processes described. Since this review is concerned with reliability considerations, it must be noted that the capacitors show an onset of failure at 100 and 250 hours even though most of them lasted for 3000 hours. However, one can be optimistic with the author that hermetic sealing and lower operating temperatures than were used in the life test will lead to improved reliability. Assembled flip-flop circuits, with transistors, are reported to have operated successfully for six months at room and elevated temperatures. This is very encouraging and one hopes that the more extensive life testing will supply more precise data on the reliability of the assemblies. This work, and that of others, indicates that the tantalum film approach to microcircuits is one of the more promising lines of effort towards high-reliability circuit assemblies.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Film circuit panel for space guidance computers

AUTHORS: A. E. Lessor, J. W. Skerritt, R. E. Thun and D. S. Weed, International Business Machines Corporation, Kingston, New York

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 32-36

PURPOSE: To show an example of the use of thin film circuits in a computer.

ABSTRACT: The design and fabrication of a circuit panel containing a representative section of a microminiaturized space guidance computer is discussed. The panel consists of two 2-1/2 by 3-1/2 in. glass slides each of 0.04 in. thickness which are laminated together with an epoxy core for a total thickness of 0.126 in. Such a panel configuration meets all military requirements with regard to shock and vibrational stresses. The passive networks consisting of resistors, insulators and connectors have been deposited by vacuum evaporation onto the outer surfaces of the two glass slides. On each side, these networks represent a regular matrix of 63 basic circuits, interwoven with the interconnection pattern. Transistors and diodes are packaged in small functional blocks which are attached to film lands on the two panel surfaces by a solder reflow process. Two circuit configurations have been used, one logical and the other a driver, to obtain all required electronic functions. (Authors)

REVIEW: There is very little real information in this paper. The authors have carried out an ingenious arrangement for wiring together a large number of functional blocks, and the two units made passed the standard electrical and environmental tests. Nothing is said about the problems of soldering many connections and the effective yield. Nothing is said about life tests other than on their cermet film resistors. These were compared with other film resistors and were shown to be more stable. However, they had been annealed in a reducing atmosphere to obtain the desired resistances, and the other resistors presumably did not get such a stabilizing treatment. The paper will be more useful to the circuit designer as a suggestion for a method of packaging. (In a private communication the first author has stated that the reducing atmosphere is for the protection of the copper lands only; units have been made with gold lands and annealed in air.) ##

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Serial Number 601
Codes 333;835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Preparation and evaluation of thin film circuit functions

AUTHORS: J. J. Bohrer, B. J. Patton, and G. N. Queen, Jr., International Resistance Company, Philadelphia, Pennsylvania

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 37-43

PURPOSE: To show the behavior of resistance films on non-glass substrates.

ABSTRACT: This is a continuation of the work given in [1]. The behavior of a resistance film on rough alumina substrates was studied and the drift of resistance with time and power level was determined. The power versus temperature rise characteristics were also determined. They behaved better than when put on glass, but the reasons for this are not known. Studies were also made of the films on glass-bonded mica substrates and the films "behaved" very well. A small amount of work was done on dielectric films, but the studies are in a very early stage.

Several tables and graphs of the results are given.

REFERENCE: [1] G. N. Queen, Jr. and J. J. Bohrer, Proc. 1960 Electronic Components Conference, pp. 39, May 1960

REVIEW: This is an excellent paper. It covers well the work which was done and shows a good concept of measurements for reliability. It is assumed that the methods of film preparation are covered in the earlier paper cited above. The data are so clear that one wonders why the authors made so little attempt to interpret them. For example, questions which could be asked include "Why is the film temperature solely dependent on power density?", "Why does a 2,000 hour life test at 70°C cause the temperature coefficient to go negative from an initial positive value?", and "What is meant by a 70°C ambient?" (p. 39). The capacitor tests are admittedly incomplete but show how the test should be run. ##

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Serial Number 602
Codes 720;833;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design of a system for deposition of compound thin films by evaporation from separate sources

AUTHORS: D. R. Frankl, A. Hagenlocher, E. D. Haffner, P. H. Keck, and A. Sandor, General Telephone & Electronics Laboratories, Incorporated, Bayside 60, New York and E. Both and H. J. Degenhart, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 44-46

PURPOSE: To describe apparatus for evaporating thin films of a wide variety of chemical compounds useful in microelectronic circuitry.

ABSTRACT: The following major features have been incorporated in the apparatus described in this paper:

a. Two independent evaporation sources, each heated by a high-power electron beam.

b. A two-stage differential pumping system for each gun; these systems provide a controlled pressure of oxygen or other gas in the evaporation chamber without destroying the electron emitters.

c. A temperature-controlled substrate holder.

d. An evaporation-rate monitoring system for each source. (Authors)

The paper is a description of the apparatus. A few preliminary results are shown.

REVIEW: Since the system had not yet been fully tested, there are no conclusions on the advantages to be obtained. The hope of evaporating $BaTiO_3$ without dissociation was shown to be unwarranted.
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Serial Number 603
Codes 720;835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Integrally fabricated resistors and their performance

AUTHORS: M. Beckerman and R. L. Bullard, Components Division, International Business Machines Corporation, Kingston, New York

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 53-56

PURPOSE: To discuss the fabrication and performance of chromium-silicon monoxide cermet film resistors.

ABSTRACT: The resistive mixture is flash evaporated onto a 0.5 micron silicon monoxide overlay on the substrate. The terminal lands are evaporated chromium and gold. An overlay of 1.0 to 1.5 microns of silicon monoxide completes the process. The wafer is exposed to air between each step and annealed in air at the end. A miniature four-terminal resistance-measuring device was built and used for checking the resistance.

The resistors on a single substrate had a variation of less than 8%. The results of various kinds of life tests are shown in the graphs. They were considered satisfactory.

REVIEW: This paper presents an apparently complete procedure for preparing cermet resistors in the range of 280 ohms per square and a discussion of their reliability. The advantage is shown of making the film as the filling in a silicon monoxide sandwich, in that the films are stable enough for most purposes out to 3500 hours on cycled test. They should be tested for steady-state operation on life test. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Properties of tantalum sputtered films

AUTHORS: D. Gerstenberg and E. H. Mayer, Bell Telephone Laboratories, Incorporated, Murray Hill, New Jersey

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 57-61

PURPOSE: To show that sputtered tantalum films can be stable without the need for further protective coatings.

ABSTRACT: The study on which this paper is based was concerned with the development of a technique for depositing tantalum films by cathode sputtering in an argon atmosphere with properties as close to those of the pure bulk material as possible. Reactive gases such as nitrogen, oxygen, and hydrocarbons were then deliberately introduced into the sputtering atmosphere to study their specific effects on the electrical properties and structure of thin tantalum films.

The paper, however, deals exclusively with the structure, resistivity, temperature coefficient, and thermal stability of tantalum films sputtered in a partial nitrogen atmosphere. The improved properties of resistors made from such films with respect to power aging, humidity tests, temperature cycling, and noise measurements are illustrated.

The vacuum equipment was a standard 14-inch bell jar type with a base pressure of 2×10^{-6} torr. The sputtering in argon took place at 15×10^{-3} torr. For reactive sputtering, nitrogen (0.02% impurities) was introduced at partial pressures up to 10^{-3} torr. Curves of specific resistivity and temperature coefficient vs nitrogen pressure are shown. The films could be stabilized by anodizing in 0.02% citric acid at 30 to 75 v. After stabilization, all resistors showed changes of less than 1% after 850 hours at 150°C. The resistors, all in all, are quite promising. (Authors in part)

REVIEW: The primary objective of this paper has been achieved well. That is, it is shown that sputtered tantalum film resistors can be made that are quite stable without the need for protective coatings. Actually, ideal protection is obtained by a heavy oxidation of the sputtered film surfaces by an anodizing process. Also, by adding nitrogen to the argon gas for sputtering, the specific resistivity can be raised by a factor of five and the temperature coefficient of resistance dropped by a factor of over twenty to bring it to a comfortably small value of 60 ppm/deg C. The set of procedures

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

for preparing the films, controlling their properties, and testing for stability are a valuable contribution that should be of interest to many workers in thin-film circuits. The report that the films consist of Ta_2N or TaN, depending on the partial pressure of nitrogen, suggests many more questions that it answers. ##

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Serial Number 605
Codes 711;720;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Sputtered dielectric capacitors

AUTHORS: E. E. Smith and S. G. Ayling, Standard Telephones and Cables Limited, Capacitor Division, Paignton, Devon, England

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 82-89

PURPOSE: To describe the development of a silicon dioxide dielectric for capacitors.

ABSTRACT: A reactive sputtering technique has been developed for the preparation of thin films of metal oxides suitable for use as capacitor dielectrics. The metal oxide system used determines the properties of these films; sputtered titanium oxide gives ceramic characteristics while sputtered silicon dioxide gives substantially the characteristics of bulk silica.

Work has been concentrated on the deposition of silicon dioxide and a capacitor has been developed having characteristics which are, in general, similar to those of mica capacitors. To obtain these characteristics it is necessary to exclude moisture from the dielectric and to form a discrete component. This can conveniently be done by encapsulation in epoxy resin. The capacitance yield and working voltage are determined by the dielectric thickness. For a 1500 pf capacitor for operation at 6 volts d-c, a yield of approximately 0.04μf/sq. in. is obtained. The technique and equipment used during the deposition of the dielectric layer are discussed. Full data are presented on the temperature and frequency characteristics of resin-protected capacitors with a sputtered silicon dioxide dielectric. Initial results on dielectric layers with other reactively sputtered metal oxide systems are presented. (Authors)

REVIEW: A strong point is made for the use of reactive sputtering vs anodizing as a means of preparing layers of metal oxides as dielectric layers for capacitors. A good demonstration is provided that silicon dioxide film can be obtained by sputtering silicon in oxygen. However, the capacitors are moisture-sensitive and require hermetic packaging. Unfortunately no comparison is made with capacitors made with anodized tantalum. The complete fabrication of a multivibrator circuit with capacitors, resistors, and soldered-in transistors shows that a satisfactory job has been done, but it is only one of many such efforts. No life data are reported. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Substrates for deposited-film passive components

AUTHOR: R. J. Settzo, Corning Glass Works, Bradford, Pennsylvania

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 201-204

PURPOSE: To compare the properties of several Corning glasses, Fotoceram, and alumina as materials for use as substrates for thin films.

ABSTRACT: A number of substrate materials currently utilized in the deposition of thin film components have not been designed for this purpose, and they may be seriously deficient in a number of characteristics. Special purpose glasses and some ceramic materials show marked improvement in properties, but no single material possesses all of the properties of an ideal film substrate. The choice of a substrate material involves technical compromise, and a knowledge of circuit requirements is essential in making this choice. A major consideration in film circuit fabrication is the generation and removal of heat. The amount of heat generated can be reduced by utilization of components having tight end of life tolerances, but this choice generally involves an increase in manufacturing cost. Alternatively, a more efficient method of thermal dissipation must be devised, and this generally involves the choice of a ceramic substrate with its attendant surface roughness problem.

The deposition of a number of similar components on a single substrate leads to marked similarities in component performance. It may be possible in some instances to utilize this characteristic in achieving reduced end of life tolerance spread and thus obtain improved performance with no increase in cost. The properties of a given film material are intimately related to its substrate. In many cases, process modifications can be made to improve the performance of a given combination when the problem of materials compatibility is recognized. This recognition is a necessary first step in designing reliable, low cost, deposited circuitry. (Author)

REVIEW: This paper points out that no substrate can be anything more than a compromise in the variety of properties that must be combined. Many of these properties are listed and discussed in general terms. The data shown compare the changes in life of tin-antimony oxide films on alumina, Fotoceram, and a new glass (Corning #1723) specifically produced to match the thermal expansion of the film. It shows clearly that the films are more stable on the matched glass but that after 500 hours, and out to 3,000 hours they are all quite stable. The interpretation of these data is not clear. The alumina and Fotoceram show opposite signs of resistance change even though they both exceed the expansion coefficient of the glass. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of multi-function devices--a progress report

AUTHORS: W. R. Leib and J. A. Davies, General Electric Company

SOURCE: 14 pp., presented at the Fall Radio Meeting, Institute of Radio Engineers and Electronic Industries Association, Toronto, Canada, November 12, 1962

PURPOSE: To make a progress report on the reliability compactron tubes.

ABSTRACT: Compactrons are multi-function tubes--generally containing more functions than the usual type of multi-function tube. The results are presented in several ways: compactron predicted vs observed failure rate, line rejects of prototypes vs compactrons and 90-day warranty failures of prototypes vs compactrons, and failure rate ratios of compactrons to prototypes on life test. The life test ratio showed that compactrons, on the average, have about 50% of the failure rate of their combined prototypes. This varied from type to type and was quite poor on some types during early production. Most of these problems have been overcome. The predicted ratio was 43%, giving fairly good agreement. Five of six compactrons have a lower in-line rejection rate than their prototypes. The sixth had early troubles and has since been improved. The same good results are true for 90-day warranty replacements. The average failure rate, on life test, is about 1%/500 hr at rated voltage and dissipation; actual use failure rates are usually 1/2 to 1/10 of the life test figures, due to derating. A number of detailed tables and graphs are shown.

REVIEW: This is a further progress report on compactrons; the earlier one was covered by Abstract and Review Serial Number 168. The results are encouraging and perhaps future results, completely free from the start-up problems, will be even better.

The further proliferation of tube types, long past the bounds of reason, should be justified in each case by clearly established and significant improvements. It appears that the compactrons may justify themselves in this regard. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--not gadgets

AUTHOR: Major General Dwight E. Beach, Deputy Chief, Research and Development, Department of the Army, Washington, D. C.

SOURCE: Ordnance, vol. 46, pp. 203-205, September-October, 1961

PURPOSE: To make a plea for simple, effective, cheap, and reliable weapons.

ABSTRACT: Sooner or later, all officers will become associated with R & D in some capacity. There is a challenge to develop weapons which are inexpensive, yet effective. To be effective they must be simple, reliable and, usually, of light weight. They must be operable by ordinary soldiers in the field and they must be repairable by the same soldiers. The M3 submachine gun of World War II cost $30 and replaced one costing $200; it was effective and used no critical materials.

During design and development all efforts to chromeplate and sophisticate the weapon must be resisted. The R & D group must always ask "Is this gadget really necessary?"

REVIEW: This article is an effective plea for simplicity and reliability in weapons. The emphasis is a good one and holds true in all products, consumer, industrial and military. The military can probably assist this effort by requiring more reasonable performance specifications in many cases. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability through redundancy in electromechanical devices

AUTHOR: P. F. Bechberger, The Bendix Corporation

SOURCE: Aerospace Engineering, vol. 21, October, 1962, pp. 30-34

PURPOSE: To show how reliability in electromechanical devices can be improved with redundancy using an inertia reaction wheel as an example.

ABSTRACT: The inertia reaction wheel has three main causes of failure: bearings, windings, and case. The non-redundant failure probability in 10^4 hours was 2%. Each bearing was replaced by a concentric, coplanar pair. If both rotate properly and if the cross-coupling of failures is negligible, then the failure probability will be very small (0.0032%). The causes of bearing failure are discussed in relation to the redundancy. The four windings per wheel were replaced by a special set. The causes of winding failure are given in relation to the modification of the windings. Redundancy of the seal is also discussed at some length. The new failure probability was estimated at 0.0043%.

REVIEW: This is a good paper on redundant design. The failure probability figures seem to be derived from industry expectations rather than from tests on these inertia reaction wheels. The estimated weight penalty for this redundancy does not seem to include the expected increase in electronics. The consideration of interaction of the redundant systems is very good--this phase is often overlooked.

If reliability is to be defined as a probability of success, then it is correct to say that the failure probability was reduced by a factor of 100, but it is incorrect to say that the reliability was improved by a factor of 100 (for the case in the paper). ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Water-lubricated hydrodynamic pump bearings provide high reliability

AUTHOR: E. J. Stefanides, Central States Editor, Design News

SOURCE: Design News, vol. 17, December 26, 1962, pp. 32-33

PURPOSE: To describe the bearings in a special pump as a good design idea.

ABSTRACT: Water-lubricated hydrodynamic bearings of carbon-graphite were used to solve the problem of providing reduced friction along with meeting exceptionally high reliability requirements in the canned-motor pumps developed for use in atomic-reactor power stations. The bearing reliability is enhanced by the natural lubricity of carbon-graphite material; this lubricity prevents galling and seizing during start-up or periods of boundary lubrication operation. (Author in part)

REVIEW: This is a rather short article on the design of the bearings. Since reliability is emphasized it might have been helpful to give some numbers, such as the expected life of a single pump and the fraction of pumps which are expected to exceed some specified life. The only figure given is 1/2 million hours of operation, but no mention is made of how many pumps were involved.
##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Simple test anticipates transistor failures in complex equipment

AUTHOR: Roy P. Foerster, Martin Marietta Corporation, Baltimore, Maryland

SOURCE: Electronic Equipment Engineering, vol. 10, November, 1962, pp. 28-29

PURPOSE: To show how circuit design can be modified so that marginal checks can be made.

ABSTRACT: The DC "beta" and collector-base leakage are the two parameters which give the best picture of a transistor's condition. If the bias power supply is made adjustable, and the system is designed for such a test, marginal operating checks can be made. (An example is given.)

REVIEW: This seems to be an example of marginal checking. The system has its proponents and opponents. The designer should be sure that he will, in fact, find what he is after without causing more trouble than he saves. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Microelectronics '62

AUTHORS: (EEE Editors)

SOURCE: Electronic Equipment Engineering, vol. 10, November, 1962 pp. 40-53

PURPOSE: To present a broad picture of the status of microelectronics. (The abstract and review are limited to the several portions dealing directly with reliability.)

ABSTRACT: Microelectronics can be separated into integrated, thin film, and modular circuits. Reliability, cost, and size are important--usually in that order. The modular circuits, typified by the RCA approach, have the most data and are as good as the best conventional circuits. The other two are thought to be reliable with integrated circuits expected to prove it first.

Texas Instruments released a reliability report which showed present failure rates and the hoped-for extrapolated trends. Failure rates are expected to be well below 0.1%/1000 hr before 1963. The integrated circuit process usually used--and seemingly most promising from a reliability viewpoint--lays down a large number of components by a reproducible process. Circuits are built up by the different interconnections; any changes in the basic block pattern are avoided when feasible, since changes introduce new failure modes. The screening tests are for performance only--as compared to parameter checks.

The Army's micromodule process at RCA was designed to yield good reliability information all along. Some of this information is summarized in tables.

REVIEW: This is a good summary article. However, it contains little specific reliability information, except on TI and RCA products. Few references are cited, although many papers on microelectronics have appeared recently. ##

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Codes 822;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Worst-case design of low-level circuitry

AUTHOR: P. M. Ansbro, Philco Corporation, Lansdale, Pennsylvania

SOURCE: Electronic Equipment Engineering, vol. 10, November, 1962, pp. 54-57

PURPOSE: To give an example of worst-case design of transistor-diode circuits.

ABSTRACT: The design procedure is given for a diode-coupled, transistor inverter circuit with multiple fan-in and fan-out. The dc circuit laws are applied several times and appropriate relationships between parts parameters are derived by using simple algebra. The designer must know the characteristics--both maximum and minimum values during the desired life of the circuit. Examples are given of circuit design for a T2504 transistor and several diode types.

REVIEW: Worst-case design has its good and bad points. The best to be said for it is that it is rather straightforward, easy and safe. The worst to be said against it is that it is over-cautious and may require more circuitry to perform a given task; thus while the logic element may be most reliable, the system does not have its maximum reliability. There are adherents to both viewpoints and the design engineer, if he is careful and does not use it blindly, can get much good from the method.

There are a few misprints and omissions that may make the use of the equations a little troublesome. Not all of the equations were checked for accuracy, but the principles used in the paper are quite sound. Since this was an example, it would have been helpful to have more explanation of some of the early equations.

Extreme care should be taken in substituting values in the equations. Each term is specified by its use and this may require measuring voltages at unusual currents and vice-versa. Some of the parameters may not be available--remember that many of them are the extreme values that any member of the whole population may ever attain during the whole intended period of operation from beginning to end.

The discussion is limited to the ON/OFF states and does not consider dynamic properties at all. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to evaluate resistor performance

AUTHOR: Lyman S. King, Corning Electronic Components, Bradford, Pennsylvania

SOURCE: Electronic Equipment Engineering, vol. 10, December, 1962, pp. 40-43

PURPOSE: To discuss the various tolerances of a resistor.

ABSTRACT: The factors which cause a resistor to deviate from the nominal value are initial tolerance, temperature coefficient variations, load-life performance deviations and environmental exposures. Each of these is discussed briefly. Excessive current noise can be an indication of poor reliability. The solutions to the reliability dilemma lie between lot-acceptance and process-control philosophies. Some checking must be done to ensure that the process has been kept under control and that failure mechanisms are understood.

REVIEW: This is a good general summary article on the problems of fixed resistors. Much is applicable to other components. The dilemma has yet to be solved to anyone's ultimate satisfaction, although reliable parts are being made, tested, and used. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designers fight valve fatigue with salt bath treatment

AUTHOR: D. R. Dorff, Double A Products Company, Manchester, Michigan

SOURCE: The Iron Age, vol. 191, January 10, 1963, pp. 54-55

PURPOSE: To show how a solenoid valve was redesigned.

ABSTRACT: It was decided to redesign a 10 gpm, solenoid-operated, hydraulic 4-way, 3000 psi valve to fit in the previous 1 gpm package. The fluid passages, solenoid forces and spool loads, all had to be increased without sacrificing performance or life. Rapid serviceability was to be added which took up more space. The final big challenge was to find spool assembly materials which would last 10^7 cycles and not fatigue or flatten out. Conventional magnetic and non-magnetic parts were far from satisfactory. A 6150 steel hardened to R_c45 was the best, but missed the fatigue life requirement. The conventional hardening was replaced by a salt bath treatment (trade name: Tufftriding) and the fatigue strength and surface toughness were vastly improved. At 0.2×10^7 cycles there was no wear or fatigue; after 1.5×10^7 cycles they are still functioning well and the test is continuing. In addition to increasing the strength, the spool assembly cost was reduced 35%. (The salt bath process is described briefly.) In addition to these advantages, the efficiency loss that previously took place with time has been eliminated.

REVIEW: By redesign of materials and processes, this company improved the life of its product and reduced the cost. (The figure of 10^7 cycles in fatigue is usually picked since if a steel part lasts that long, it probably will not fail in fatigue.) It is worthy of note that fatigue was the major problem to be solved in the redesign. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: System reliability using redundant elements (Abstracted from an article by H. Ströhmer, Archiv der Electricken Übertragung, vol. 16, July, 1962, pp. 317-327)

AUTHOR: (Abstracted by E. Brenner, Associate Professor of Electrical Engineering, City College of New York)

SOURCE: Electronic Design, vol. 11, January 4, 1963, pp. 78-81

PURPOSE: To show some reliability formulas for redundant systems.

ABSTRACT: Two cases are considered for redundancy: (1) redundant elements are always operating, and (2) redundant elements are perfectly switched in as needed. Several configurations of elements are possible. In addition to the reliability as a function of time, other parameters which are useful are: (1) time before first system failure, (2) average time before first system failure, and (3) minimum time before first system failure, guaranteed with given probability. Several graphs and approximate formulas are given for some cases. More complete formulas are available in the original paper.

REVIEW: The original is a mathematical paper; the condensation has no derivations at all. One implicit assumption is not stated, namely, the failure probability of an element is independent of the number of failed elements. This will not be the case, for example, with two resistors in parallel. When using all such results as these, extremely careful attention should be given to all the assumptions used in the derivation--especially those the author may have neglected to mention. In the approximate formulas, no mention is made of the parameter ranges for which the approximation is satisfactory--a serious omission. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductors in a hyper-nuclear environment

AUTHORS: Leonard B. Gardner and Alvin B. Kaufman, Litton Systems, Incorporated, Woodland Hills, California

SOURCE: 12 pp., presented at the Western Electronic Show and Convention (WESCON), San Francisco, California, August, 1961

The content of this paper is quite similar to part of the paper covered by Abstract and Review Serial Number 255. The latter paper was published in April, 1962, and cites the earlier work as a reference. ##

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Serial Number 618
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How good are thin film triodes?

AUTHOR: W. Tantraporn, Electronics Laboratory, General Electric Company, Syracuse, New York

SOURCE: Electronics, vol. 35, December 28, 1962, pp. 29-32

PURPOSE: To provide a brief survey of what is now known about and expected from thin film transistors.

ABSTRACT: Three types of triodes are described, namely the space charge limited (SCL), the hot electron type, and the field effect type. The principles, typical constructions, state of the art, and probable future of the three types are outlined and compared. No operating data are given but potential performance is estimated. Demonstration of the feasibility of the SCL and hot electron types is predicted by the end of 1963. The field effect type has been demonstrated. References are given for each type.

REVIEW: The article contains useful and pertinent information for those active or interested in the future of thin film devices. From the viewpoint of reliability, two of the three types have not yet been fully demonstrated and the third is still in the laboratory. Thus no reliability data are yet available. As for an estimate of potential reliability, it is hard to see why these devices should be as good as devices made of single crystal material. They are all of polycrystalline or amorphous material and use fields close to the breakdown values. The critical dimensions are so small (approximately 100 Angstrom units for the hot electron type) that minute flaws can be serious. Nevertheless, the problems are not insoluble. Short of a major technological breakthrough, it will take more than a year or two to put reliable units on the market.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: New approaches to electronic self-repair

AUTHOR: (Editorial material based on paper by Jerome Klion, Rome Air Development Center, Griffiss AFB, presented at Aerospace Science and Engineering Symposium at Brooks AFB, no date given)

SOURCE: Electronics, vol. 36, January 4, 1963, pp. 96-102

PURPOSE: To suggest some methods of circuit self-repair.

ABSTRACT: The mechanical force for switching could come from osmosis or differential gas or vapor pressure. Chemical removal of gas is suggested for creating the gas pressure and heating is suggested for increasing the vapor pressure. A mechanical arrangement for making and breaking connections to components is proposed. The forces are provided by air pressure and electromagnetism. An analogy with biological repair is also given.

REVIEW: These are speculative philosophical ideas rather than practical methods. They assume no failure of many of the mechanical features of the apparatus. In addition, in allowing for failure of one correction mechanism, a continuously correcting mechanism is used. If the original corrector fails, the equipment may stay dead for a while until the continuous corrector operates. If there are no failures, this auxiliary corrector will still operate and use up all the spares, eventually. Failures in storage are not accounted for very well.

Man is suggested as the best system going and the average life is given as 70 years. During the time of useful performance, man's catastrophic failure rate under very good average conditions is about 0.02%/1000 hr. and can get much worse under unfavorable environments. This does not include "drift" failures. Another factor neglected in biological analogies is that the system is extremely redundant with all parts working all the time (not standby redundancy).

This type of study is important, but it seems to be presently in a very primitive stage. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Making reliable welds in 3-D modules

AUTHOR: David W. Herold, General Dynamics/Pomona Division, General Dynamics Corporation (Pomona, California)

SOURCE: Electronic/Electromechanical Production, vol. 2, November-December, 1962, pp. 8-9

PURPOSE: To show how reliable welds are made.

ABSTRACT: Nickel strip is used for welding to the component leads. Proper weld schedules can be developed, but do not always work out in production. The two basic reasons for this are poor positioning and restraint. These can be alleviated by the methods shown in the article.

REVIEW: No data are given on weld reliability. The article is a general discussion of techniques for making reliable welds. ##

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Serial Number 621
Codes 810;833;834;
836;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Potential applications of reliability techniques to commercial products

AUTHOR: Richard M. Jacobs, Contributing Editor

SOURCE: Electronic/Electromechanical Production, vol. 2, November-December, 1962, pp. 24-26

This is a slightly cut-down version of the paper covered by Abstract and Review Serial Number 382. A number of minor changes have been made in the text, and the references cited at the end of the earlier paper have been omitted from this one. There are two type-setting errors in that the author's middle initial is shown incorrectly (correct form given above) and three paragraphs are out of place in the first column on page 25. The author in a private communication has indicated that he was not given an opportunity to check page- or galley-proofs on this article before it was published. ##

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Serial Number 622
Codes 715;782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation vs electronic components (third and concluding part)

AUTHORS: E. J. Rohrbach and H. S. Goldstein, Airborne Instruments Laboratory, Deer Park, Long Island, New York

SOURCE: Machine Design, vol. 35, January 3, 1963, pp. 101-104

PURPOSE: To indicate what is known about the effects of radiation on electronic components.

ABSTRACT: The results are summarized in two tables: (1) Atomic displacements per year caused by space corpuscular radiation, and (2) Radiation tolerance limits of electronic components.

The permanent damage to transistors is caused by fast neutrons and subsequent lattice changes; the transient effects are caused by ionization. Transistors deteriorate by increasing in leakage and decreasing in current gain. Both n and p type germanium tend toward p type with intrinsic conductivity. Silicon transistors have a decreased minority carrier lifetime and an increase in resistance toward the intrinsic value. The reverse resistance and forward conductivity of diodes decrease. The most stable transistors are generally germanium with diffused-junction and thin-base. Germanium tends to be better for diodes, too. The method of manufacture has a large bearing on the amount of degradation.

Resistors are more resistant than semiconductors, depending on type. From best to worst are wire-wound, metal-film, carbon-film and carbon-composition.

The capacitor performance depends mostly on the dielectric. Inorganic materials are the more stable.

In relays, switches and magnetic devices, the insulation is usually first to go, then the ordered magnetic (and ferrous) materials, and last, the metals. Most of the electrical degradation of insulators is due to physical deterioration.

REVIEW: The tables should be used in conjunction with the text. In the first table the volume of the material in which the displacement is produced is not clear.

The article gives a good general summary of radiation effects. The design information is general; for high reliability, individual components should be tested.

The first two parts in this series were covered by Abstracts and Reviews Serial Numbers 514 and 515. ##

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Serial Number 623
Codes 823;824;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Predicting bearing reliability

AUTHOR: T. A. Harris, SKF Industries, Incorporated, Philadelphia, Pennsylvania

SOURCE: Machine Design, vol. 35, January 3, 1963, pp. 129-132

PURPOSE: To show how to predict the reliability of short life, high load bearings.

ABSTRACT: The standard bearing rating is for 90% reliability (R). The Weibull distribution tends to hold for $50\% \leq R \leq 90\%$. For R above 90%, the formula must be modified. In a sample of over 2500 bearings, modifications to the Weibull equation were determined for fairly high loads and short lives. Formulas and curves in the text give the necessary revisions to the Weibull equation. Examples are worked out. For a given standardized life, the reliability is higher than calculated from the Weibull formula.

REVIEW: This seems to be a good paper, although it is rather short. However, references are given to the original work and these should be studied by those who intend to use the modifications. In this paper, because of brevity, all of the test conditions could not be given; the careful designer will want to see how well his application fits those test conditions. ##

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Serial Number 624
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic equipment reliability
(a report on the Second I.E.E. Symposium)

AUTHOR: R. C. Winton

SOURCE: Radio & Electronic Components, vol. 3, pp. 1011-1013, 1016, December, 1962

PURPOSE: To summarize some of the ideas expressed at the symposium.

ABSTRACT AND REVIEW: This is a rather brief summary of some of the ideas presented at the Second Symposium on Electronic Equipment Reliability which was sponsored by the Institute of Electrical Engineers (British) in London on October 24-26, 1962. (Any published papers which appear will be abstracted and reviewed separately.) ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Parts specifications being rewritten by several groups to improve reliability

AUTHOR: (Editorial Matter)

SOURCE: Industrial Electronic Distribution, vol. 2, December, 1962, pp. 1, 2, 28

PURPOSE: To show the activity in the writing of specifications for high-reliability parts.

ABSTRACT: Right now there is only one "assured reliability" specification: the new MIL-R-55182 (fixed film resistors). The EIA is seeking to implement the Darnell Report recommendations on specifications for high reliability, except that they want a consumer confidence level of 60% instead of 90%. This would allow a manufacturer to have more of his product accepted. The reliability levels are M, P, R, and S or 1.0-, 0.1-, 0.01-, and 0.001%/1000 hrs, respectively. Lot by lot acceptance and the sampling plans are specified. The EIA hopes to have initial drafts ready in six months. Each Task Group has three producers, two users, and one professional who provides guidance on statistics, etc.

The Defense Electronics Supply Center is requiring a form of reliability reporting that will give clear, adequate information. Lot by lot reporting is required and the results for each lot are plotted as a point on a sequential type of chart. If the line crosses the upper control limit, delivery is stopped; if the line crosses the lower one, the process is sufficiently better so that the specification can be upgraded significantly. In between the two limits, the customer is getting adequate protection. The conditions of each test--including failure definition--are carefully specified. Each manufacturer must have his process in close control. The Air Force now purchases a 6AH6 with 0.65%/1000 hr failure rate for only about 10% more than it paid prior to any reliability control.

The DOD has assigned the Army Electronics Command to draft a standard on the subject of reliability specifications.

The Space Parts Working Group is a cooperative effort of 35 users of extremely high-reliability parts. They are working on a general specification to be used as a basis for all functional part specifications. They have three environmental levels: below, in, and above the Van Allen belt. So far, 34 specifications have been developed to the Darnell report format; 18 have been released to industry through IDEP.

REVIEW: This is a review article based on three papers read at the 1962 Northeast Electronics Research and Engineering Meeting (NEREM).

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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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Digests of the papers appear in Section 9 of the NEREM Record--1962. (This information was supplied by the Editorial Director; no references are cited in the article.)

It is unfortunate that the work in this area proceeds so slowly; the need for proper specifications for high-reliability parts continues to be urgent.

The EIA effort is discussed also in the paper covered by Abstract and Review Serial Number 478. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component failures predicted by infrared

AUTHOR: Philip J. Klass, Avionics Editor

SOURCE: Aviation Week & Space Technology, vol. 77, December 3, 1962, pp. 85, 87, 89, 90

PURPOSE: To report on a new technique for spotting potential component failures in electronic equipment by measuring their infrared radiation intensity.

ABSTRACT: A new technique being developed by the Raytheon Company shows promise of being able to spot potential component failures by measuring their infrared radiation intensity. A report on the technique was given by Dr. Riccardo Vanzetti at the recent Northeast Electronics Research and Engineering Meeting.

The operating temperature of a component is a major factor affecting its reliability and longevity. Infrared provides a means of measuring component temperatures while the circuit is operating, without the inconvenience of attaching thermocouples or the risk of changing component temperatures by the measurement process. The intensity of the infrared radiation emitted by each component is proportional to the fourth power of its temperature.

Raytheon uses a commercially available radiometer which can detect differences in temperature as small as a few thousandths of a degree Centigrade, which is far greater sensitivity than the technique requires. Through the use of suitable calibration factors, the output of the radiometer is made to render a direct indication of the temperature of the component at which it is aimed.

Some evidence has been obtained to indicate that abnormal rates of temperature rise after the application of power may be important clues in the prediction of component longevity. Extensive controlled tests are now planned to check on this and other points in connection with the technique. Other uses of the technique include evaluation of the potential reliability of different circuit designs, quality control of items coming off a production line, troubleshooting for faulty components, and the making of measurements within microcircuits. These uses are briefly described and illustrated. (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. While it is indicated that only limited evidence is so far available on the technique, it does look very promising, and testing and development is still in process. ##

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Serial Number 627
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Potential failures detected by RF noise

AUTHOR: Philip J. Klass, Avionics Editor

SOURCE: Aviation Week & Space Technology, vol. 78, January 7, 1963, p. 78

PURPOSE: To report on a new technique for detecting incipient malfunctions and locating intermittent faults in avionics equipment through the detection of RF noise.

ABSTRACT: A new technique for detecting incipient malfunctions and locating intermittent faults in avionics equipment has been developed by the Aeronautical Division of Minneapolis-Honeywell in Minneapolis. The idea is credited to Frank Hagert, an evaluation engineer at M-H.

The technique is based on the discovery that imperfections in solder joints and minute breaks or discontinuities in internal component connections generate a radio frequency (RF) noise which is superimposed on the power supply voltage. It has been used to discover faulty diodes, transistors, capacitors, transformers, and connections which might otherwise have gone undetected until they failed under exposure to mechanical or thermal shock. It is not useful in discovering short or open circuits or components which are drifting in value, but other techniques can serve this purpose.

Honeywell uses a commercially available radio frequency interference noise meter to check for the spurious emissions. Sometimes it is necessary to subject the subassembly to mechanical or thermal shock to aggravate the incipient failure to the point where it reveals itself by RF noise. Once a defective subassembly has been detected, the faulty component can be located by tapping each component on the board with a phenolic rod to determine which one produces the highest amplitude of noise and thus contains the fault. It has been found that the initial test on a subassembly requires less than two minutes, while tracking down the fault to a specific component or connection may then require an additional ten minutes. The technique is planned for production line use. (Author in part)

REVIEW: Like the technique described in the paper covered by Abstract and Review Serial Number 626, this approach has considerable potential usefulness in dealing with electronic components and circuitry. The emphasis here is on the location of intermittent faults, and it will be evident from the descriptions that the two techniques supplement rather than duplicate one another. Both have a potentially important role to play in the improvement of the reliability of electronic equipment. The statement that the RF noise technique is new may be subject to challenge, but this would not detract from the claims for its usefulness. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistors face new radiation hazard

AUTHOR: Philip J. Klass, Avionics Editor

SOURCE: Aviation Week & Space Technology, vol. 78, January 21, 1963, pp. 85, 86, 91, 95

PURPOSE: To describe some new information on the surface-effect degradation of transistors produced by radiation.

ABSTRACT: Important new data on surface–effect degradation of transistors produced by radiation, which caused the initial blackout of the Telstar 1 communication satellite and which may explain the early demise of many spacecraft payloads, has been obtained by Bell Telephone Laboratories scientists. The discovery is credited to G. L. Miller of Brookhaven National Laboratory and Walter M. Gibson of Bell Telephone Laboratories.

While it has long been known that high-energy radiation particles could cause semi-permanent defects in semiconductor devices, it has now been discovered that an entirely different type of degradation results from ionization of the air or gas within a transistor or diode case when exposed for some time to comparatively low-energy electrons. Silicon transistors used in digital circuits are more vulnerable to the ionization surface-effect radiation damage than the same devices used in analog circuits.

Some of the significant findings that emerge from the Bell Telephone Laboratories investigation on surface-effect degradation due to radiation are:

(a) degradation shows itself as an increase in the collector reverse current of the transistor,

(b) reverse electrical bias on the transistor, particularly a silicon type, greatly increases its vulnerability to ionization damage,

(c) total radiation dose rather than dose rate appears to be the most important factor in determining the amount of degradation that occurs,

(d) electrical potential between the transistor's metal can and the semiconductor crystal appears to have some effect on surface degradation, but the chemical surface condition of the crystal is more critical than the can-to-crystal bias,

(e) ionization degradation is not inherently permanent, and removal of the semiconductor device from the radiation, or removal of its bias voltage results in at least partial recovery of its original characteristics, and

(f) recovery takes place faster when reverse bias is removed and the transistor is still exposed to the radiation which produced the initial damage.

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These findings are briefly discussed, together with some of their implications in terms of spacecraft use. (Author in part)

REVIEW: The research results on which this paper is based could have important implications for the designers of electronic equipment for spacecraft use. The mechanisms by which space radiation affects the operation of electronic components and systems are still far from completely understood, but a report like this indicates that progress is being made.

The attention of the reader interested in this paper is directed also to a letter printed in the same source, February 11, 1963 issue. In this letter it is pointed out that the phenomenon described in this paper is not true of planar transistors. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Stability of logical networks and its application to improvement of reliability

AUTHOR: K. K. Maitra, General Dynamics Electronics, A Division of General Dynamics Corporation, Rochester, New York

SOURCE: IRE Transactions on Circuit Theory, vol. PGCT-8, pp. 335-341, September, 1961

PURPOSE: To present a map and matrix approach to the design of circuits with improved operational reliability, using redundancy of states in a single module.

ABSTRACT: Von Neumann [1] posed the problem of accounting for the behavioral stability of human beings in 1955. McCulloch [2] in 1958 showed that certain networks composed of neuron-like elements exhibit logically stable input-output behavior even when the individual neurons show fallible behavior due to shift of neural thresholds. In this paper, the neural concept is extended to conventional logic modules. The knowledge of the existence of redundant functional states is used to construct logically stable networks, to be used in place of individual modules to achieve greater reliability.

A stability map method is developed which is used to find the members of a triplet network, which when subject to logical constraints gives a desired output. The stability map method is then used to fix the coefficients in a reliability matrix, and the reliability function is obtained from it.

These methods are then applied to the synthesis of stable triplet structures. An example is presented with a reliability analysis. Reliability is then further improved with a recursive construction. The results of the author's analysis of the probability functions are presented, along with several graphical presentations.

The paper concludes with some comments on the limitations and practical results of the method.

REFERENCES: [1] J. Von Neumann, "Fixed and Random Logical Patterns and the Problem of Reliability," presented at the American Psychiatric Association, Atlantic City, N. J.; May 12, 1955.

[2] W. S. McCulloch, "Agatha Tyche of nervous nets--the lucky reckoners," Proc. Symp. on the Mechanization of Thought Process, Natl. Physical Lab., Teddington, Eng., Her Majesty's Stationery Office, London, vol. II, pp. 611-625; November, 1958.

REVIEW: This paper, which is a condensation of a doctoral thesis, suffers

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in the abridging. It is excellent material, presented on a high level, and potentially useful. The original document is no doubt highly readable, but this paper leaves too much of the methodology for the reader to dig out, without much help from the author. Despite this, it is a fine paper, very well worth reading by one with adequate background. The bibliography is good. ##

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Serial Number 630
Codes 090;710;782;
833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Equipment design considerations for space environment

AUTHORS: S. N. Lehr, L. J. Martire, and V. J. Tronolone, Space Technology Laboratories, Inc., One Space Park, Redondo Beach, California

SOURCE: 122 pp., STL/TR-9990-6032-RU000, a revision of STL/TR-60-0000-09224, Space Technology Laboratories, Inc., One Space Park, Redondo Beach, California, February, 1962

PURPOSE: To present information on some types of materials and electronic parts which have been used successfully in space vehicles which have accomplished their objectives.

ABSTRACT: Information compiled from a literature survey and from STL experience is presented in this document as an aid to the design and fabrication of electronic equipment for space vehicles. Data are presented concerning the behavior of materials in space, covering information not available in the usual engineering handbooks.

Space environment is considered in terms of temperature, high vacuum, micrometeorites, radiation, and other phenomena, with particular attention to the effects of such environment, insofar as they are known or conjectured, upon plastics, organic and inorganic materials, metals, and upon electronic parts. (Authors)

REVIEW: This is a rather extensive compilation of information on the space environment which should be of use to designers of systems for spacecraft use. Some 145 relevant references are cited. The paper covered by Abstract and Review Serial Number 166 included part of the material in this report.

Another extensive review of this subject was covered by Abstract and Review Serial Number 525. Other, less extensive treatments of the space environment and its effects have been covered by Abstracts and Reviews Serial Numbers 145, 181, 242, 255, 361, 384, 413, 429, 514, 515, and 531. The papers covered by Abstracts and Reviews Serial Numbers 548 through 556, 588, and 622 have been concerned mainly with radiation effects. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A general survey of the materials problem

AUTHOR: A. J. Murphy, College of Aeronautics, Cranfield, Bletchley, Buckinghamshire (England)

SOURCE: Journal of the British Interplanetary Society, vol. 18, pp. 320-328, May-June, 1962 (Proceedings of the Symposium on Materials in Space Technology, London, England, November, 1961)

PURPOSE: To consider the various requirements to be met by structural materials of spacecraft during launching and re-entry, and in outer space.

ABSTRACT: The nature of the environment in outer space and its significance for materials of construction of astronautical vehicles are considered.

In the structure and especially the skin of the vehicle high temperatures are developed through aerodynamic heating on re-entry into the Earth's atmosphere. The most advanced experience with heat-resisting engineering materials has been gained in gas turbine applications. The potential developments towards higher operating temperatures of alloys based on iron, nickel and cobalt are approaching exhaustion. The next stage may use the higher-melting-point metals, especially molybdenum, niobium and tungsten, non-metallics such as carbon and ceramics, or combinations of metals and ceramics. The refractory metals are capable of stressed service at 1370°C. (2500°F.) and higher, if means of protection against oxidation can be found. On the same condition graphite can be used for still higher temperatures.

For the ballistic missile, ablation of surface layers on the nose-cone offers the best prospect of heat dissipation. The ablating substance may be an organic material, e.g., synthetic resin, or a ceramic compound. For longer spells at high temperatures, as in gliding space-vehicles on re-entry, the alternatives are thermal insulation by non-metallic surface coatings, and skins of metals having very high melting points.

The major technical difficulties in applying the refractory metals to service at very high temperatures arise from their reactivity with ambient gases, especially oxygen, and their tendency to brittleness at low and moderate temperatures.

Characteristics of materials which acquire special importance in astronautical applications are: thermal conductivity, specific heat, latent heats of fusion and evaporation, coefficient of thermal expansion, reactivity at high temperatures, sensitivity to irradiation, creep strength and resistance to high fatigue

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stresses at high temperatures and mechanical properties at low temperatures. (Author)

REVIEW: This general survey of the materials problem for spacecraft has value as an introductory source of information. In particular it serves to establish a perspective from which to contrast known facts concerning the environment of outer space and launch and re-entry conditions with the properties of presently used or potentially valuable structural materials. Much emphasis is directed toward the mechanical properties and chemical reactivity of structural materials at high temperatures. The author points out that any significant extension of the upper temperature limits within which reliable operation of, for example, turbine components may be expected must depend upon the bringing into service of entirely new classes of materials. ##

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782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Polymers in space

AUTHORS: N. H. Langton, National College of Rubber Technology, Northern Polytechnic, Holloway Road, London, N. 7 (England) and A. L Soden, Rubber and Plastics Research Association of Great Britain, Shawbury

SOURCE: Journal of the British Interplanetary Society, vol. 18, pp. 329-340, May-June, 1962 (Proceedings of the Symposium on Materials in Space Technology, London, England, November, 1961)

PURPOSE: To review present-day knowledge of the properties of high polymer materials and to indicate the significance of these rubbers, plastics, and textiles insofar as the space effort is concerned.

ABSTRACT: The excellent thermal and electrical properties, low densities, high physical strengths, general chemical inertness, and certain special properties of high polymers have many implications insofar as the use of these materials in astronautics is concerned. An important class of polymers are the so-called elastomers, the natural and synthetic rubbers, whose properties may in large part be attributed to cross-linking between the long-chain molecular structures. Such polymers are highly elastic and capable of undergoing large deformations without suffering permanent damage. In this respect, natural unfilled rubber is highly attractive. However, at temperatures above 130°C and in the presence of certain oils and heavy metal ions the use of acrylic rubbers, butyl, silicones, and fluorinated rubbers becomes particularly important.

High polymers, for example plastics such as polyethylene and polystyrene, are available with outstanding electrical properties. Nylon is now an engineering material with many uses being suggested by its strength; resistance to high temperatures; chemicals and abrasion; low coefficient of friction; and dielectric properties. Polytetrafluorethylene has a wider working temperature than any other plastic (- 80 to + 250°C) and a coefficient of friction approximately equal to that between two pieces of wet ice. Other types of high polymers of particular interest are the many textile materials and certain resins such as the epoxies and unsaturated polyesters. These resins are primarily of interest as adhesives.

At the present time, one of the major uses of polymers in the space program is as fuels for solid propellant rockets. In such applications, the polymer is intimately mixed with an oxidizer and acts not only as a fuel but also as a binder to give the final propellant charge its form. Polymers also are presently being used as ablative materials in connection with the re-entry problem, and are very important in the areas of protective clothing and space suits.

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REVIEW: This paper provides a very good introductory discussion of the general properties of polymers. By relating some of the unusual properties of polymeric materials to many of the materials problems within the space effort, the author succeeds in establishing a perspective from which to view the significance of polymers in various areas of space technology.

Information concerning the vapor pressures of selected polymers would have been interesting, especially since the author discusses the potential value of polymers as structural materials in the environment of space. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Magnesium in space technology

AUTHOR: E. F. Emley, Magnesium Elektron Ltd., Clifton Junction, Manchester (England)

SOURCE: Journal of the British Interplanetary Society, vol. 18, pp. 340-354, May-June, 1962 (Proceedings of the Symposium on Materials in Space Technology, London, England, November, 1961)

PURPOSE: To discuss in general the physical and mechanical properties of magnesium and its present and possible future significance as a structural material for spacecraft.

ABSTRACT: Both cast and wrought magnesium-base alloys are available for long-term use at temperatures up to nearly 350°C. Magnesium castings are shown to have higher strength-to-weight ratios than do castings of either iron or aluminum, whereas in the wrought state magnesium alloys do not compare favorably with high-strength aluminum alloys in this respect. Where stiffness-to-weight ratio is concerned, magnesium is advantageous in the wrought form as well as in castings, and this advantage is maintained at high temperatures.

Magnesium alloys are readily fabricated as castings, forgings, extrusions, or sheet. Readily weldable alloys are available, and large and complex welded structures can be built with alloys which need not be stress-relieved after welding. Weld strengths usually exceed 90% of that of the parent metal in the annealed state. Only limited cold working of magnesium is in general possible, but forming by standard methods is readily carried out in the range 250-400°C. Electroplating of magnesium may be used to facilitate soldering. No ductile-brittle transition takes place in magnesium alloys down to at least -180°C. The fatigue endurance of magnesium alloys is good. Magnesium has a high specific heat and good thermal conductivity, and, for these reasons, is often used as a "heat sink." Magnesium is characterized by a relatively high vapor pressure, reaching 1 Torr in the neighborhood of 600°C and being about 10^{-4} Torr at 300°C.

REVIEW: This paper provides a sood summary of the physical and mechanical properties of magnesium and of a variety of magnesium-base cast and wrought alloys which seem suited for structural usage in spacecraft. However, the author places more emphasis upon examining in detail the advantages of magnesium and the areas in which it contrasts in a highly favorable manner with competitive materials than in pointing out areas in which the contrast is not so favorable. ##

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830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aluminium in space engineering

AUTHOR: E. G. West, The Aluminium Development Association, 33 Grosvenor Street, London W.1, England (now with the Copper Development Association, 55 South Audley Street, London W.1, England)

SOURCE: Journal of the British Interplanetary Society, vol. 18, pp. 354-359, May-June, 1962 (Proceedings of the Symposium on Materials in Space Technology, London, England, November, 1961)

PURPOSE: To summarize the properties of aluminum and some of the principal alloys of this metal, and to indicate, in general, the scope of present applications of aluminum in space technology.

ABSTRACT: Although materials having decidedly better high-temperature properties are available, it seems likely that aluminum will continue to play an important role in both supersonic aircraft and in equipment for spacecraft. The mechanical strength of pure aluminum is generally too low for engineering purposes but by alloying, combined with mechanical working and/or heat treatment where appropriate, tensile strengths up to about 40 tons wt. per sq. in. are obtained. Attention is drawn to the electrical conductivity which ranks next to that of copper, to the good thermal conductivity, and to the high reflectivity of aluminum. Aluminum and its alloys are non-magnetic. Static tensile properties of aluminum fall off rapidly at elevated temperatures, although certain alloys specially developed for service at raised temperatures are useful up to about 200°C. Aluminum is naturally a reactive metal but the oxide produced on exposure to the air confers a high degree of protection. Handling of certain normally corrosive liquids such as nitric acid and hydrogen peroxide is readily accomplished with aluminum vessels.

All of the usual metallurgical processes are applied to aluminum and its alloys, and the various forms which can be produced can be joined by welding. Some of the present uses of aluminum in space technology include its use in pressure vessels for liquid propellants, as electrical conductors, as a constituent of solid propellants, and for a variety of more minor components, such as pipework, valves, impellors, control gears and instruments which may be involved in the low-temperature end of a liquid-fuel system.

REVIEW: This paper provides a good but very short summary of some of the properties of aluminum and its presently used alloys, and points out some of the resulting advantages and limitations of this material for use in various areas of space technology. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The use of graphite in space technology

AUTHORS: A. E. S. White and R. K. Hurden, The Morgan Crucible Group, Battersea Works, Battersea Church Road, London, S.W. 11 (England)

SOURCE: Journal of the British Interplanetary Society, vol. 18, pp. 367-377, May-June, 1962 (Proceedings of the Symposium on Materials in Space Technology, London, England, November, 1961)

PURPOSE: To review the physical and mechanical properties of graphite in view of the special materials problems connected with space technology.

ABSTRACT: Graphite is primarily of interest in space technology as a high-temperature material, and in this respect it appears to have much potential value. Graphite does not melt, but sublimes at a temperature of approximately 3700°C. It has a density of only 2.26 grams per cubic centimeter which is quite low in contrast to most of the other high-temperature materials. Again in contrast to many other high-temperature materials, graphite is readily machined by conventional methods. Though graphite is brittle, its low coefficient of thermal expansion, low modulus of elasticity, and high thermal conductivity and strength make it very resistant to thermal shock. Compared to other materials, graphite is outstanding in its structural strength at temperatures above 2000°C. In the presence of air, however, even the most oxidation-resistant graphite will begin to oxidize at about 500°C at significant rates. Much of the present research concerning graphite involves ways in which to improve its oxidation resistance. Various coatings have been developed for this purpose, one example being a silicon carbide coating which is useful for periods of 50-100 hours at temperatures up to 1400°C. Another area where fundamental research is suggested is in reducing the brittleness of graphite so as to allow its use in a much wider range of structural applications.

In structural designs using graphite, it is desirable to avoid sharp changes of section or notches which will cause stress concentrations. Although joining of graphite components is possible by using special cements made from carbon fillers or brazing alloys containing more than 5% of carbide-forming metals, it is better to use no cement at all where possible, and to rely on loosely fitting interlocking joints which allow some relative movement of pieces without setting up large strains.

REVIEW: This paper provides a very good general discussion of the properties of graphite and of some of the advantages and problems relating to the use of this material to solve some of the high-temperature materials problems encountered in spacecraft. The paper is informative and very readable even for those persons to whom the subject

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is new. As implied by the title, the paper is a review of presently available information rather than a statement of anything new. ##

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Serial Number 636
Codes 715;781;782;
830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effect of the radiations encountered by materials in space

AUTHOR: R. S. Barnes, Metallurgy Division, Atomic Energy Research Establishment, Harwell, Berkshire (England)

SOURCE: Journal of the British Interplanetary Society, vol. 18, pp. 377-381, May-June, 1962 (Proceedings of the Symposium on Materials in Space Technology, London, England, November, 1961)

PURPOSE: To discuss presently available knowledge concerning the radiation levels to be encountered in space, and, on the basis of this knowledge, to discuss the effects which these radiations will be likely to have upon the materials to be used in spacecraft.

ABSTRACT: Despite the varied electromagnetic radiations present in space their intensities are believed to be low, and their only important effect on most materials is likely to be the surface heating due to the infrared radiations. The most radiation-sensitive materials, e.g., semiconductors and elastomers are likely to be affected by the electrons in the Van Allen belts if directly exposed. Most of the sensitive devices will be shielded from the less penetrating radiations, and then only the protons in these belts will be important and able eventually to impair semiconductors.

The outer shell of a vehicle should be made of a material insensitive to radiation. Most metals would be suitable in this respect. Erosion of this outer shell by collision with gas atoms in space is not likely to be appreciable except in the Earth's atmosphere. However, the bombardment of micrometeorites will pit the surface, and the surface will be subject to puncture by the larger particles which are occasionally encountered. This latter problem will determine the minimum shell thickness which should be used for a given application, and will restrict the choice of materials for this use. Several useful tables are given.

REVIEW: This paper is introductory in nature and is written so as to be easily read by those to whom the subject is unfamiliar. The author has condensed a considerable amount of information into a good general discussion of the effects of the radiations to be encountered by materials in space.

More extensive 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. Other, 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, and 531. The papers covered by Abstracts and Reviews Serial Numbers 548 through 556, 588, and 622 have been concerned mainly with radiation effects. ##

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Serial Number 637
Codes 821;860;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weapon system design and supportability: a function of failure prediction

AUTHOR: Col. Vernon J. Taylor, USAF, Materiel Evaluation Group, Headquarters USAF, Washington, D. C.

SOURCE: Industrial Quality Control, vol. 19, February, 1963, pp. 6-9

This paper was covered by Abstract and Review Serial Number 198.
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Serial Number 638
Codes 824;836;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Predicting the reliability of satellite systems

AUTHOR: R. H. Myers, Aerospace Group, Hughes Aircraft Company, Culver City, California (currently with NASA Headquarters, Washington, D. C.)

SOURCE: Industrial Quality Control, vol. 19, February, 1963, pp. 12-15

This is the full text of the paper covered by Abstract and Review Serial Number 193. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Getting on the trail of a high reliability vendor

AUTHOR: B. Schwartz, RCA Defense Products

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, January, 1963, p. 8

PURPOSE: To show how to get on the trail of a vendor of high-reliability parts.

ABSTRACT: There are four questions to ask the prospective vendor. After each has been answered, go on to the next. At the end you will have a good idea of his appreciation for the problems of producing components known to be of high reliability.

1. What is the failure rate of your component?
2. What are the major and minor failure modes of your component?
3. What is the contribution of each failure mode to the overall failure rate?
4. How do you, in producing a part, control or attempt to control your failure modes?

REVIEW: This is a short informative article. If the vendor goes on to state the conditions of test or service that caused failures, you are even better off. If finally he says he is not sure of the exact failure distribution and does not know if the failure rate (conditional) is constant, you may find out that he knows more about the subject than you thought. ##

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Serial Number 640
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Majority gate logic improves digital system reliability

AUTHORS: Gerry Buzzell, William Nutting, and Reuben Wasserman, Hermes Electronics Company, Division of Itek, Cambridge 42, Massachusetts

SOURCE: 22 pp., Publication M-943, Hermes Electronics Company, January 15, 1961, presented at the 1961 IRE International Convention, New York, New York, March, 1961

PURPOSE: To show the value of a redundant configuration (the majority gate module) as a device for improving circuit reliability.

ABSTRACT: Various simple redundant circuits are described, and the improvement of reliability resulting from each is analyzed. A simple, ideal majority gate is then considered, followed by a discussion of the less-ideal case. Triplication of majority gates is the next step, and a majority gate module is designed.

The authors design this basic module using magnetic core logic, giving their theory, and developing a six-core module, with comments on its performance. Next, the use of parametrons is considered (with a short sketch of parametron theory), and an adder stage is shown, with comments on the performance of the constructed device under various simulated failures.

REVIEW: This is a readable paper on a fairly elementary level, which describes the use of majority gate logic by a group of researchers. It would be useful reading for someone either starting out in this field or interested in a superficial look at it, as well as for the man who wants to see what his colleagues are doing. In most places it is well written. The bibliography refers to Hermes Electronics Reports (three of the six items), and these may not be readily available to an interested person. ##

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Serial Number 641
Codes 782;844;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A new approach to transistor reliability prediction

AUTHOR: B. Reich, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Semiconductor Products, vol. 6, January, 1963, pp. 28-31

PURPOSE: To give a new reason why operating life tests are usually more strenuous than storage life tests.

ABSTRACT: The key parameter in the operating life of transistors is the junction temperature. The temperature difference between the case and junction (collector-base), under operating conditions, is virtually always inferred from measurements on some temperature-sensitive parameter (TSP). The thermal resistance (Th Rs) from junction to case is measured before life tests begin and then the operating junction temperature during test is calculated from the power dissipation and the Th Rs. If the Th Rs has been misevaluated, the junction temperature calculation will be wrong.

This paper introduces a new method for evaluating the Th Rs by using a different TSP--the current gain. Naturally, this method is useful only on transistors whose current gain changes appreciably with temperature. An advantage of this technique is that the transistor is heating while the measurements are being made. The results of tests show that the Th Rs calculated in this way may be typically 20% to 50% higher than usual. Furthermore, this new Th Rs changes with collector current (I_c) and/or voltage. In one case, the Th Rs was multiplied by about 8 when I_c went from 100 to 700 ma. This effect would explain the greater severity of operating tests by saying that the calculated junction temperature was lower than the actual temperature.

REFERENCE: B. Reich, "Continuous transistor thermal resistance measurements," Semiconductor Products, vol. 5, November, 1962, pp. 24-27

REVIEW: This is certainly an interesting piece of work. If the hypothesis is true it could explain the life test discrepancy mentioned and eliminate many of the more expensive operating tests. It should be noted that there is presently no theoretical explanation for this effect. Therefore, if it is substantiated, further theoretical work will be necessary to explain it. (The title, it may be noted, is much more comprehensive than the subject treated.) ##

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Serial Number 642
Codes 838;873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Techniques for achieving operational reliability and maintainability in digital computers

AUTHORS: W. G. Brown, Cook Research Laboratories; J. Tierney, Raytheon Manufacturing Company; and R. Wasserman, Hermes Electronics Company

SOURCE: IRE Transactions on Electronic Computers, vol. EC-10, pp. 407-416, September, 1961

PURPOSE: To present and summarize ideas on reliability, and to compare various configurations so as to determine the degree of practicality of some redundant logical nets.

ABSTRACT: The authors proceed by establishing their ground rules and basic ideas. They are concerned with systems which either fail impermissibly soon or cannot be serviced, and in which cost considerations are only secondary. Redundant systems are analyzed for reliability. A majority gate module, using gates in triplicate, is developed and presented as a practical means of increasing reliability. An appendix shows the analysis of configurations by critical pairs, and a second appendix presents the derivation of the symmetrical chain reliability expression.

REVIEW: Although the authors present this as a "microscopic approach to logical redundant nets" it is quite thorough in its area and is in all respects an excellent presentation. All analytical work is nicely done, and the functions are graphed with full clarity. The authors have handled their subject well, and with a unity rarely appearing in papers with multiple authorships. The paper is highly recommended. ##

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Serial Number 643
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Influence of nonuniform basewidth on transistor failures

AUTHOR: M. Kocsis, Industrial Research Institute for Telecommunication Technique, Budapest, Hungary

SOURCE: Proceedings of the IEEE (formerly Proceedings of the IRE), vol. 51, p. 229, January, 1963 (correspondence)

PURPOSE: To describe a mode of transistor failure and suggest an experimental measurement related to the probability of its occurrence.

ABSTRACT: Collector-to-emitter shorts may suddenly develop in the operation of p-n-p alloyed junction transistors, although the emitter-base and base-collector diodes are still good. This phenomenon may be explained by the supposition that inside the transistor a p-type channel appears in the n-type base region. This p-type channel shorts the emitter to the collector. Such narrow channels have been observed and attributed to intense local heating and alloying at points of narrow basewidth in a transistor whose base is of nonuniform width.

A parameter $\eta = W_e/W_m$, where W_e is the equivalent basewidth (determined by cut-off frequency measurements) and W_m is the minimum basewidth (determined by punch-through or avalanche voltage measurements), is shown to be inversely related to the temperature at which the catastrophic instability commences.

REVIEW: The clear dependence of instability upon the nonuniformity parameter η justifies the conclusion that η be regarded as a primary characteristic of this type of transistor. It is easy to measure and is related to the failure probability by the particular mode described. This letter makes an excellent contribution, so it is unfortunate that the presentation is not more effective.

The opening paragraph cites the failure of transistors in switching circuits "<u>in spite</u> of provisions made to prevent overload," (underline by reviewer) and later states that the failure will occur "if no provisions are made to limit the collector current." Since the failure mechanism is related to internal heating caused by current flow, the initial inference is that switching circuits were not protected sufficiently, although some provision had been made. Later data show that static operation is more temperature-stable than pulse operation, suggesting that the failures cited may be due to the switching operation itself rather than to inadequate overload protection. This ambiguity is unintentional and due to a poor arrangement of ideas. It does not alter the conclusion or the experimental work which is excellent. ##

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Serial Number 644
Codes 770;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Testing electronic equipment for space application

AUTHORS: Frank W. Hallstein, R. C, Klein, and Charles W. Remaley, Environmental Laboratories, Bendix Systems Division, The Bendix Corporation, Ann Arbor, Michigan

SOURCE: 8 pp., The Bendix Corporation, Bendix Systems Division, Ann Arbor, Michigan, March, 1962

PURPOSE: To point out some of the more important space environmental problems, and to discuss methods of simulating these environments and some of their observed effects.

ABSTRACT: The design engineer must resist the temptation to use "handbook" information in his design of electronic systems for aerospace applications. Aerospace systems require an increasing degree of reliability, which becomes absolute for manned space flights. Our designs must be proven under actual orbital conditions as nearly as they can be simulated. For example, electronic systems designed to operate at a specific temperature while attached to a specific heat sink, usually a metal plate or bulkhead, must be proven under these precise conditions.

The current practice of using low altitude (125,000 ft.) chambers for space testing provides some useful design information; however, to raise the reliability factor and effect cost reduction, combined tests are required. If we can simulate the severe cold and solar radiation of deep space and altitudes of 200 miles or over, we will have qualified electronic equipment under one of the most severe of the space environments. The ability to test complete integrated aerospace systems under launch and orbital conditions will reveal some interface problems not now known, as well as internal subsystems problems.

As more space facilities become operational and the extreme vacuum, solar radiation and extreme cold of outer space can be simulated repeatedly, the electronic system designer's problem will be materially reduced. In the meantime, most aerospace electronic systems will require extensive testing to refine and confirm design concepts. (Authors)

REVIEW: This paper accomplishes its purpose only in a very general way. Principles which the designer of space vehicle electronic systems should keep in mind are cited. However, no specific details on actual testing or evaluation are given. The needs are indicated, but the solutions are not. The usefulness of a paper such as this would have been considerably enhanced if some case history studies and illustrative data had been included. ##

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Serial Number 645
Codes 823;831;840;
851

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

TITLE: A system approach to reliability testing

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

SOURCE: 18 pp., presented at the 1962 Reliability and Statistical Methods in Industry Course, University of California, Los Angeles, August 7, 1962

PURPOSE: To develop sample sizes needed for a system's component tests which will demonstrate an adequate level of system reliability.

This paper is substantially the same as the one covered by Abstract and Review Serial Number 232. The author, in a private communication, has indicated that the above is a clearer statement of the purpose of the paper than the one given in Serial Number 232. She has also indicated that investigation of the upper bound for components in series in which equal sample sizes are taken and no failures are permitted shows that the sample size for component testing is exactly the same as that required for testing the system itself, and that this is true no matter how many components there are in series. It was suggested in Review Serial Number 232 that this might be the case. ##

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Serial Number 646
Code 835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mechanical design for missile environments

AUTHOR: J. F. Campbell, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: Electronic Products Magazine, vol. 5, January, 1963, pp. 44-49

PURPOSE: To explain a system of assembly and manufacture for electronic circuits.

ABSTRACT: This paper presents a packaging method for electronic components which is rather versatile and adds little volume and weight. The leads are welded and nickel strip is used for the conductors. The package then looks somewhat like the "cordwood" structure except that there are no boards at either side. Mechanical rigidity is provided by potting in polyurethane foam. The final shape is a rectangular box. This box is then put in a nickel sheet (0.005 inch thick) container for shielding and mounting purposes. Leads for interconnections and testing are appropriately placed. Several examples and comparisons are given. The modules can be reworked or repaired since the cover is easy to take off and the foam can be removed by an air abrasion tool without hurting the components.

REVIEW: The system seems very flexible since the can size is not fixed. Much hardware is eliminated which allows a reduction in size and weight. No figures are given on the actual reliability to show that the system lives up to the hopes for it. If, in fact, it does not have unsuspected disadvantages, the system would be worth-while for many applications. ##

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Serial Number 647
Codes 835;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Try field-effect transistors for redundancy

AUTHORS: R. C. Burns and E. D. Crawfis, Sperry Phoenix Company, Phoenix, Arizona

SOURCE: Electronic Design, vol. 11, January 18, 1963, pp. 74-77

PURPOSE: To show how the field-effect transistors make redundancy easier because of their high input impedance.

ABSTRACT: With the advent of field-effect transistors (FET), some old redundancy tricks possible with vacuum tubes can be applied to solid-state circuits. The high input impedance of FETs allows the designer to parallel redundant amplification stages so that the system will continue to produce gain despite catastrophic failures of individual parts. (Authors)

An example is given of a two-stage amplifier and its calculated failure rate for the non-redundant case. There is a brief review of two-terminal redundancy.

REVIEW: The field-effect transistor will be a help to those engineers who learned electronics via vacuum tubes. This article is an example of how this new transistor can help in the design of redundant circuits. No reliability data are given on the FET vs ordinary transistors. ##

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Serial Number 648
Code 813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design disciplines to assure reliability

AUTHOR: R. G. Doyen, AC Spark Plug Division, General Motors Corporation

SOURCE: 12 pp., presented at the National Farm, Construction & Industrial Machinery Meeting, Milwaukee, Wisconsin, September, 1962, Society of Automotive Engineers paper 562A (summarized in SAE Journal, vol. 70, December, 1962, pp. 62-63 under the title "New design methods up reliability of electronic parts")

PURPOSE: To discuss the various disciplines necessary to assure reliability.

ABSTRACT: The degree of complexity of many types of equipment is either high or rapidly increasing. New methods are necessary to assure reliability and the reliability must be specified quantitatively. The life of equipment is split into three parts: (1) early failure or debugging, (2) normal operation, and (3) wearout. During the normal period the reliability, R, can be expressed as $R = \exp(-t/m)$ where t is the time-to-failure and m is the mean time-to-failure. Surveys have shown that modern military equipment costs too much to repair and maintain and that many of the problems are caused by poor engineering. Reliability must be designed in by having adequate knowledge of parts behavior, the environment, the manufacturing process, etc. There are specialists in components and various phases of engineering whose job it is to make sure that the designer has adequate information. Standards, both in components and design, are helpful because data have been accumulated on these and their adequacy is known. Non-standard parts do not have this background and are likely to cause more than their share of failures. Design reviews are essential at several points in the design. Their purpose is to be sure that the designer has not overlooked anything during his very complex job. Changes in specifications and design, during the design, make the review even more necessary, since the changes may not have been completely followed through. The variability in parts is something somewhat new to engineering and so it must be given special emphasis. Rules-of-thumb have grown up to help solve this problem; e.g., parts have a normal (Gaussian) distribution; but this is not always true. Sometimes the services of a statistician are necessary. After design, the prototypes must be tested under adverse conditions. Failures must be analyzed so that they can be corrected. Calibration facilities must be available to ensure that the measurements are accurate.

REVIEW: This is a typical introductory general paper on reliability. The assumptions of constant (conditional) failure rate and independence of failure probabilities are made implicitly; any such assumptions should be carefully stated so that the novice (or not-so novice) is not led astray by seeming general rules. ##

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Serial Number 649
Codes 817;825;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Programmed reliability in design for a V/STOL airplane

AUTHORS: R. G. Sharp and A. J. Wilcox, Ryan Aeronautical Company

SOURCE: 8 pp., presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October, 1962, Society of Automotive Engineers paper 580A

PURPOSE: To introduce a method for analyzing the reliability of a system.

ABSTRACT: Much is said about the need for reliability, but not enough is done because too many people think the problem is too complex. The system for design analysis and synthesis described here, called PRIDE (Programmed Reliability in Design), is simple to understand and use. Most designs will need a computer such as an IBM 704 to implement this program. The several requirements of a system are listed in terms of the main parts. Each main part is broken into sub-parts and so on down to elementary components. The failure probabilities of all parts at the same level are assumed independent. At first, the computer allocates reliability equally among parts at the same level, beginning at the top and working down. Trade-offs can be made and problem areas spotted. Reliability allocations for parts can be changed temporarily or permanently in the computer. The working of the system is generally described. The problems in initiating the program are discussed.

REVIEW: This is a not-too-detailed description of a method for reliability analysis/synthesis. Some of its limitations are listed in the paper. Its main advantage seems to be its presumed simplicity and the consequent willingness to use it. Anyone wishing to begin a program will need more information than is given in the paper.

It should be noted that the terms series and parallel are used in a logical sense, not in a physical sense. ##

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Serial Number 650 -1
Codes 822;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability through statistical material property definition

AUTHOR: H. G. Popp, General Electric Company

SOURCE: 9 pp., presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October, 1962, Society of Automotive Engineers paper 580B

PURPOSE: To show how the normal (Gaussian) distribution can be applied to the strength of materials.

ABSTRACT: The variability of stresses and strengths must be taken into account during design; this paper is limited to the strength-variation problem. It is not enough to take the minimum strength obtained in several experiments because this procedure gives variable results. The strength of most materials has a normal (Gaussian) distribution or a logarithmic normal distribution. The experimental strength distribution can be plotted on normal probability paper and the parameters estimated by drawing a straight line through the points. Creep and rupture data can be represented by the Larson-Miller formula and an example of its use is shown. If a specification is established for minimum strength of a sample, the whole distribution can be upgraded. The censoring below the minimum is not complete because of the variability within a lot and the fact that only a sample from each lot is tested.

A final example is given in which the variability of the stress and strength are both known.

REVIEW: This is a rather standard treatment of the problem of material property variation. The presentation is not rigorous and care should be used in extracting any particular portion for use. Some examples of this are:

1. Figure 1 shows one point at each temperature, yet each one lies on the average line--a most unusual circumstance. Figure 2 has a similar problem where "scatter" is introduced but in a very artificial way. If the scatter in both diagrams were shown more properly, it would be more obvious how a standard deviation could be calculated.

2. In Figures 1 and 2, the average 100 hr creep strength is shown higher than the average yield strength (both at the same temperature and with the same criterion for failure); this is a most unusual circumstance.

3. In the formula for probability density (normal population) y is not the frequency of occurrence, but is the probability density; $y \Delta x$ is the frequency of occurrence of X in the range between x and $x + \Delta x$.

4. The central limit theorem does not "state that the sum of more than four independent effects is normally distributed."

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

It is much more general and states that if a population has a finite variance, then the distribution of the sample mean approaches the normal distribution as the sample size increases.

5. When a portion of a population is censored by a sampling procedure as described in the paper, the whole distribution is changed, not just the half on the censored side. (Figure 10 is misleading in this respect.)

6. In the example on page 8, the 3000 psi refers to the standard deviation of the stress, not just the variation; furthermore, the stress is implicitly assumed to be normally distributed. P is not the reciprocal of the reliability, R, but is more likely 1-R, the failure probability. ##

Serial Number 651 -1
Codes 715;782;838;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable solar power supply design

AUTHORS: I. Doshay and W. F. Emrich, Space-General Corporation

SOURCE: 7 pp., presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October, 1962, Society of Automotive Engineers paper 580C

PURPOSE: To present some of the information which is presently available concerning the degradation and complete failure of solar cells caused by radiation and meteoroid impact, and to illustrate how this information may be taken into account in the design of a power supply for an orbiting spacecraft.

ABSTRACT: The use of solar cell arrays continues to be an important means whereby electrical energy is provided to orbiting spacecraft which are to have long operational lifetimes. This paper chooses a set of example energy-conversion requirements for a given power system and discusses some of the considerations which would enter into the design of such a system. A reliability goal of 94% for a lifetime of one year is assumed. The satellite is assumed to have a 100-minute orbit with 60 minutes of each orbit being spent in the sunlight, 10 minutes being spent in the outer Van Allen radiation belt, and 10 minutes being spent in the inner Van Allen radiation belt. The average power required is 51 watts, and batteries are to be used to provide power during the portion of each orbit spent in the shadow of the earth. Using standard relations for determining the reliability for series- and parallel-connected components, the reliability of an example power supply design employing redundancy is calculated. Emphasis is placed on the design of the solar-cell array for this power supply, and two alternate designs are considered. Curves are presented which relate the degradation of solar cells to the proton flux to which they are subjected, and which relate the mass of meteoroids to the number of impacts per unit area per unit time which may be expected. This information is used in the design of two solar-cell arrays, each meeting the power requirements of the satellite and each having a predicted reliability of 99% for a period of one year. One array, built of modules each having 5 series-connected cells, is shown to require 40% more solar cells than an alternate array, built of modules each having 10 parallel-connected cells. The difference in the number of cells required to attain the given level of reliability arises because of the advantage of the parallel-connected modules insofar as the expected meteoroid damage is concerned.

REVIEW: This paper points out the fact that as more information becomes available concerning the environment of outer space and its effects upon, for example, semiconductors or other sensitive materials, engineers will be able to predict with a higher degree of confidence

R E L I A B I L I T Y   A B S T R A C T S
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the reliability of various power system designs. In particular, this will lead to improved designs. This paper is useful because of the short summary of environmental information and the references it provides, and because it is illustrative of one manner in which environmental factors can influence the comparative reliabilities of alternate designs. However, the scope and depth of the paper are rather limited, and it is not written as a general guide for engineers concerned with reliable solar power supply design as might be implied by the title. Several typographical errors were noted, although these cause little confusion. Of these the most significant is the error in the expression of the reliability of the pair of redundant relay-switches, Item 3 of Table 1. This reliability should have been expressed as

$$R = 1 - [(2.3)10^{-2}]^2 = .9995 \; .$$ ##

Serial Number 652
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The application of failure rates

AUTHOR: Martin Polen, AeroSpace Division, Vickers Inc., Chairman, SAE Failure Rate Panel of the Subcommittee on Reliability

SOURCE: 3 pp., presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October, 1962, Society of Automotive Engineers paper 580D

PURPOSE: To express cautions about the use of failure rates for mechanical hardware.

ABSTRACT: A progress report of the investigation of the Failure Rate Panel of SAE is contained in a discussion of the errors associated with establishing a failure rate for a component type of mechanical hardware. Recommendations as to a graphical presentation of failure history and a method of utilizing these graphs is presented with example failure rates from 180 populations of typical aircraft applications. (Author)

REVIEW: This is a very short general paper although the cautions expressed are good ones. Most of the discussion is directed toward how not to apply failure rates. Only two failure rate examples are given: hydraulic pump, fixed displacement and variable displacement. ##

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Serial Number 653 -1
Codes 715;782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Surface effects of radiation on transistors

AUTHORS: D. S. Peck, R. R. Blair, W. L. Brown, and F. M. Smits, Bell Telephone Laboratories

SOURCE: The Bell System Technical Journal, vol. 42, pp. 95-129, January, 1963

PURPOSE: To report the effect of ionizing radiation upon the surface properties of semiconductor diodes and transistors and to describe a method of screening them for sensitivity to such radiation.

ABSTRACT: A qualitative model is developed to explain the observed increases in reverse saturation current of p-n junctions which are exposed to gamma or other ionizing radiation at the same time as a reverse bias is applied. The fringing field adjacent to the junction is pictured as trapping ions which react with surface contaminants to produce a species which tends to create an inversion layer on the surface of the underlying semiconductor. The deterioration of reverse saturation current is attributed to the increase of surface currents associated with the induced inversion layer. The importance of the magnitude and direction of the fringing field is demonstrated both during radiation and recovery.

The trapping is shown to be primarily dependent upon total dose rather than dose rate. Long term exposure to low dose rate radiation can be simulated by a short exposure to high dose rate radiation.

REVIEW: This paper is a clear, well-written description of a series of experiments which attempt to define a mechanism of radiation-induced junction failure. The proposed model is consistent with the reported data and is similar to that developed by Atalla et al. [1] to explain the effect of water vapor on oxidized silicon junctions.

The large spread in behavior among similarly treated, identical units is interpreted as extreme sensitivity to processing variables. No mention is made of the substrate concentration which should be an important parameter in determining the magnitude of inversion layer current.

The inability of the described screening technique to avoid transistor failure in Telstar I is offset by the remarkable success of the proposed model in diagnosing the failure and prescribing the corrective action. A subsequent publication [2] indicates that the radiation encountered by Telstar I was 100 times greater than that anticipated and the fault seems to lie with the screening standards rather than with the technique itself.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REFERENCES: [1] M. M. Atalla, A. K. Bray, and R. Lindner, "Stability of thermally oxidized silicon junctions in wet atmospheres," Proc. Inst. Elec. Eng. (London), vol. 106, pp. 1130-1137, March, 1960

[2] "Telstar transmits transatlantic pictures again," Bell Laboratories Record, vol. 41, pp. 22-23, January, 1963 ##

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Serial Number 654
Codes 720;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contamination of sealed switching devices for special weapons

AUTHOR: Paul Mahler, Picatinny Arsenal, Dover, New Jersey

SOURCE: 21 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 2)

PURPOSE: To discuss a method of relay contact contamination.

ABSTRACT: A description is given of a series of tests which show that vapors of reactive metal are evolved during soldering and welding operations. When these operations are carried out in close proximity to contact surfaces the vapors may contaminate these surfaces and cause erratic circuit resistances or occasional circuit failures. During the tests a number of relays, assembled so as to leave no doubt that their contacts would be uncontaminated, were found to be electrically unreliable. Subsequent experiments showed that the trouble was most probably caused by the deposition of reactive metal vapor upon the contact surfaces during soldering or welding. The author suggests that this hazard could be eliminated by coating the contacts during these operations with a grease which would be subsequently dissolved. Alternatively, a stream of inert gas could be passed across the contact surfaces whilst maintaining a lower pressure at the soldered joint or weld, thus forcing the evolved vapor away from the contacts.

REVIEW: This is an interesting description of the steps taken in tracking down the cause of a failure of a critical circuit in a missile system. The importance of these results to the designers and manufacturers of reliable low-current switched circuits is considerable. One wonders how many of the ills and failures that have in the past been attributed to "gremlins" may, in some cases, have been due to this very cause. ##

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Serial Number 655 -1
Codes 837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determinate relay reliability

AUTHORS: Delmar F. Diel and L. G. Reynolds, Martin Company, Orlando, Florida

SOURCE: 9 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 3)

PURPOSE: To propose a method for establishing the "determinate reliability" of relays.

ABSTRACT: The probability distribution of stresses and strengths (for all performance measures) is normal (Gaussian). Therefore, if the mean and standard deviation are known for each performance measure, the probability of failure (probability that stress exceeds strength) can be calculated. The words stress and strength are used in a general sense and can mean pull-in voltage, contact bounce, vibration resistance, dielectric strength, etc. If the distribution parameters are estimated from small samples, suitable correction factors can be applied to the standard deviation estimate. This discussion closely follows that introduced by Robert Lusser some years ago. The overall reliability is calculated by multiplying the survival probabilities for each stress.

If this plan were followed, some of the burden for relay failures could be shifted to the user who has, in many cases, used them under unwise conditions.

REVIEW: If the physical world were patterned after the assumptions in this paper, reliability groups would have a much easier life; unfortunately it is not. There are several controversial points in the paper; some of these are listed below.

1. (a) Not all stresses and strengths are distributed normally. For example, if the strength is in terms of number of cycles to failure, a very common distribution is the log normal.

(b) Even though a distribution can be found, normal or otherwise, which fits the data reasonably well, the fit in the tail region is rather uncertain. Beyond 1% the problem is difficult, beyond 0.1% the problem is extremely so, and beyond 0.01% (10^{-4}) the situation is virtually impossible. A more extended discussion of this point can be found in Review Serial Number 131.

2. The estimation of the parameters of a distribution from a small sample is rather a guessing game. Rarely does one have high confidence that the estimate is accurate; rather one may have high confidence that an estimate is above or below the true value. The higher the confidence that is required, the larger must be the range in which the true value is guessed to fall. The table given in the text is unaccompanied by any confidence measure and is thus, by itself, difficult to evaluate.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

3. The term "determinate reliability," used throughout the paper, is defined only as "the reliability figures established by the methods described herein." It should not be confused with the now more popular, restricted, quantitative definition of reliability.

4. The formula for combining probabilities assumes that the events are all independent. It is very doubtful that the properties of relays listed in the paper are independent; thus the product rule will give a value of the final reliability which is too low. Additional discussion of this point may be found in Review Serial Number 199.

5. Some properties (strengths) such as pull-in voltage and dielectric strength may vary with time. This is not taken into account explicitly.

The basic idea in the paper, that of safety margins based on standard deviations is a good one. The strengths of relays could be expressed statistically by some sort of cumulative distribution for each property of interest. But when very high reliability (or quality) is desired, there is a real and much-discussed problem of knowing what the distribution is. Getting the safety margin as large as feasible is necessary, but calculating the resulting failure probability (when it is less than, say, 10^{-3}) is presently impossible. ##

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Serial Number 656
Codes 770;833;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fallacies in life testing

AUTHOR: F. F. Yanikoski, Sigma Instruments, Incorporated, South Braintree 85, Massachusetts

SOURCE: 7 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 4)

The content of this paper is essentially the same as that of the one covered by Abstract and Review Serial Number 369. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Considerations of pulse operation of micro-miniature magnetic latching relays

AUTHOR: Hugh O. Wells, Potter & Brumfield Division, American Machine & Foundry Company, Princeton, Indiana

SOURCE: 13 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 5)

PURPOSE: To discuss pulse operation of micro-miniature magnetic latching relays.

ABSTRACT: The nature and behavior of micro-miniature latching relays is discussed briefly. Justification is given for pulse operation. Some of the more common pulse excitation methods are described. Consideration is given to the choice of capacitance, voltage, and resistance for maximum efficiency and reliability of operation. The effects of temperature on the relay operating requirements are discussed. The relative efficiencies of the various pulse methods are compared.

REVIEW: This paper makes an elementary qualitative presentation of some of the factors and considerations concerning the pulse operation of micro-miniature magnetic latching relays. The utility of the paper would have been increased by the inclusion of one or more drawings of the relays under discussion. (Little of interest is said on the subject of reliability.) ##

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Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fast growing whiskers near arcing contacts

AUTHOR: G. R. Lawson, General Electric Company, Wiring Device Department, Providence, Rhode Island

SOURCE: 14 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 6)

PURPOSE: To describe the phenomenon of whisker-growth near arcing contacts.

ABSTRACT: An investigation into the cause of abnormal erosion of silver alloy contacts was successfully terminated by the discovery of fast-growing cobweb-like whiskers in the vicinity of the arcing contacts. The contacts were part of a 15-ampere AC switch of the type used in residential wiring. The abnormal erosion occurred during the course of a standard performance test of 10,000 cycles of operation in a circuit with a source voltage of 120 volts AC and a load of 15 amperes. It had been noted that certain switches, when run on this test, would exhibit explosive arcing. Those switches which displayed this explosive arcing would undergo more contact erosion in two or three thousand cycles than a normal switch would show in the complete 10,000 cycle test.

REVIEW: The fact that an apparently new physical phenomenon has been discovered in connection with the performance testing of an ordinary residential switch is very stimulating. As the author points out, a more fundamental research program into the causes of this phenomenon and the physical properties of the whiskers would be well worth-while. The possibility that such whisker formation can occur should be kept in mind when evaluating the reliability of devices using contacts at which arcing may occur. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contact chatter indicator

AUTHORS: Roland Rotunda and Ronald Tetz, Jennings Radio Manufacturing Corporation, San Jose, California

SOURCE: 12 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 8)

PURPOSE: To describe a circuit which measures relay contact chatter.

ABSTRACT: Chatter is defined as the undesired opening of closed relay contacts and/or the shorting of open relay contacts. This report describes an automatic resetting contact chatter indicator developed to detect contact chatter under shock and vibration stress. The indicator will detect pulses of two microseconds duration resulting from contact chatter. Observations made with this indicator revealed that pulse lengths were generally greater than 10 microseconds, with a few shorter ones occurring randomly. These chatter pulses were observed at a G level just sufficient to cause their occurrence.

REVIEW: This paper contains very little more than a circuit description of the contact chatter indicator. It has the form of a rather poorly-written equipment-operation manual. The text is supported by 16 assorted figures, circuit diagrams, graphs, and photographs. Presumably the paper could be of interest to other people engaged in the vibration testing of relays. ##

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Serial Number 660
Codes 782;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The application of basic heat transfer principles in optimizing relay design

AUTHOR: L. A. Rice, R-B-M Switch Division, Essex Wire Corporation, Lancaster, Ohio

SOURCE: 19 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 9)

PURPOSE: To illustrate the application of basic heat transfer principles in the physical design of a relay.

ABSTRACT: The author points out the importance of heat transfer considerations in the design of electrical and electronic equipment. The basic principles of conduction, radiation, and convection heat transfer are presented. The application of these basic principles to the physical design of a relay is discussed. Some concern is expressed regarding the confusing array of units used to describe heat transfer phenomena.

REVIEW: The author's concern with the lack of heat transfer considerations in the design of electrical and electronic equipment is well-grounded. However, it is doubted that the lack of progress in this area stems from a confusing set of units. In fact, if units are impeding progress, then it is probably due to the type of thinking illustrated by the author when he proposes a mixed British-metric system of heat transfer units. The author's presentation of the basic principles of heat transfer is satisfactory, although certain restrictions pertaining to the theoretical treatment are not brought out. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Environmental testing of relays at Sandia Corporation

AUTHOR: R. W. Russell, Environmental Test Operations Department, Sandia Corporation, Albuquerque, New Mexico

SOURCE: 15 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 10)

PURPOSE: To discuss the "do's" and "don't's" of environmental testing of relays.

ABSTRACT: The serious lack of generally-recognized standards to govern the performance of the environmental testing of relays is discussed. The establishment of standard test methods together with the uniform specification of instrumentation, equipment, and techniques to be used in conducting environmental tests on relays is strongly recommended. Examples are given of current testing procedures that may easily produce ambiguous or erroneous results. Some recommendations are made for the improvement of these procedures. A sample check list taken from the Sandia Corporation Standard Test Methods is given.

REVIEW: The author points out some of the difficulties involved in making meaningful environmental tests on relays. Some of the more obvious pitfalls are pointed out as examples. The technical level of the paper is quite elementary (although many of the points are easily overlooked) as can be judged from the following excerpt on vibration testing:

"Holding fixtures should mount the test relay by its normal mounting means if at all possible, but from that point on the mounting should be as rigid as practicable. The shaker system is meant to drive the test relay, not vice versa. Unless the shaker armature and fixture are massive compared to the test relay, the relay will tend to drive the table when it goes into resonance. This distorts the input wave form, making precise control of the input nearly impossible."

The check lists for detailed test specifications may prove to be quite useful to anyone setting up environmental tests for the first time. ##

Serial Number 662 -1
Codes 716;775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contact resistance testing of relays at low level switching

AUTHOR: Norman E. Hyde, Royal Radar Establishment, Malvern, Worcs., England

SOURCE: 21 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 11)

PURPOSE: To discuss the testing of low-level relays

ABSTRACT: The testing of a relay for use in a particular circuit must involve the measurement of its contact resistance. This apparently simple quantity which had, until 1950, been studiously avoided, is still widely misunderstood and, too frequently, inaccurately measured. It is noted that in many modern applications the voltages switched are too small to break down the thin films which form on the relay contacts. The phenomenon of contact resistance is discussed together with methods of measurement. Suitable apparatus for contact resistance measurement is described.

The results of low-level tests on several types of relays involving more than 100 million contact resistance measurements are discussed. It was observed that several hermetically sealed relays displayed increasing contact resistance, but a higher degree of low contact resistance reliability was obtained in relays where the contacts were contained in a separate sealed compartment. A theoretical explanation is given as to why separate contacts should be tested rather than a number in series.

REVIEW: This is an excellent paper, well written, and to the point. The author recognizes at the outset that in a low-level circuit Ohm's law does not necessarily apply. Conduction is by tunneling through thin contaminating films or by true metallic contact, without electrical breakdown or excessive heating. The author argues that present methods of contact resistance measurement are unsuitable because the measured value depends upon the method of measurement. He comments: "Contact resistance measured by a method which is unaffected by the measuring circuit is not only a 'low-level' test but is a fundamental physical property of an electric contact."

The testing apparatus described is designed to measure every operation of the relay up to at least one million operations. This is much more consistent with operational requirements than the usual figure of 100,000 operations. A four terminal measuring method is used for each contact, once again in contrast to the usual two terminal method across many contacts in series.

One of the interesting results of the tests was that the supposition that the majority of contact failures occur during the first 5,000

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

operations is not valid. The indication was that failure usually took place after about 100,000 operations. A significant observation from the point of view of relay reliability was that the relays with the contacts and coils sealed in separate compartments were the only ones tested that gave a stable low contact resistance performance throughout their life. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interesting mechanical and physical properties for some precious metal contact alloys

AUTHOR: Clifford S. Barker, Engelhard Industries, Incorporated, Newark, New Jersey

SOURCE: 13 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 12)

PURPOSE: To show the results of tests on some precious metal contact alloys.

ABSTRACT: Mechanical properties of some precious metal alloys used for conductive metal springs, determined at room and elevated temperatures, show that the highest tensile strengths were obtained by some of the gold alloys. Exceptional modulus of elasticity values at room and elevated temperatures were measured for the platinum alloys. The best conductivity of the precious metals investigated was demonstrated by the silver-copper eutectic alloy and the silver alloy containing magnesium and nickel. The conductivity of the ordered palladium-40 copper alloy was found to be similar to Be-Cu No. 25 alloy.

The physical properties of these materials which make them desirable are high-melting point, excellent corrosion resistance and good arc-erosion resistance. Where the requirements are such as to demand reliability and long life, precious metals and alloys offer the designer materials which can meet virtually every situation. (Author)

REVIEW: This is a straightforward account of an investigation of the properties of certain precious metal alloys used as conductive spring materials on relays. ##

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Serial Number 664
Codes 801;811;817

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An inquiry into reliability and quality control

AUTHOR: Frank Schleicher, Cook Technological Center, Division of Cook Electric Company

SOURCE: 14 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 15)

PURPOSE: To present the philosophy and general working of a reliability program.

ABSTRACT: The manufacturing of a reliable product is an exacting task which requires the application of many disciplines. Reliability requires dedication, discipline, and money. The IRE definition of reliability is in terms of probability, time, and environment. The problems are similar to those in evaluating a horse race. A different type of description of reliability is that it is a product characteristic that can be measured by expending the life of a product, can be estimated from data during reliability tests, can be predicted from an analysis of the design and can be made a specific design requirement. The design engineer gets his hands on the problem near the beginning and then it goes through the production process. Each group does its best to make the reliability as high as possible. The biggest problem each group in the chain has is "paying enough attention to detail." This is aided by design reviews and reliability predictions for the designers, tests of failure modes by a development group, process reviews by production people, etc. These and similar factors are discussed at more length in the paper.

REVIEW: This is a good general philosophical introductory paper on reliability. It will be of most value to those who are beginners in the field; but a beginner is not one who has but recently opened the door; he is one who has not yet learned the basic philosophy--regardless of how long he has been around. The paper gives the usual emphasis to the designer as the "sine qua non" of the product. This is somewhat unfair to the designer as well as to the other groups. Rather it might be better to say that all of the groups in the production process from planners and specification writers to final testers and shippers are necessary and no one group alone is sufficient. Each group will vitally affect the final reliability, and bears part of the responsibility for it. Each group can tear down or maintain the high reliability--it can even, in practical circumstances, improve it over what was envisioned. ##

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Serial Number 665
Codes 711;782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Development of a relay for 650°F ambient

AUTHORS: H. J. Wise and C. A. Stewart, Price Electric Company, Division of Consolidated Electronics Industries Corporation, Frederick, Maryland

SOURCE: 10 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 16)

PURPOSE: To describe the development of a 4-pole, double-throw high-temperature relay.

ABSTRACT: A description is given of the peculiar problems that were encountered in the development of a 4-pole, double-throw, hermetically sealed relay to withstand an operating ambient temperature of 650°F. The system for which the relays were required was to control the speed and frequency of an A-C generator drive system operating directly from an aircraft engine. The anticipated high ambient temperature resulted from the close proximity of the jet engine. The major problems met were the construction of a suitable coil and the design of a hermetic seal to withstand the extreme temperature range. A life of 100,000 operations was obtained on units with a contact load of 2 amperes resistive at 28VDC.

REVIEW: This paper gives an interesting account of some of the problems facing the designer of a relay required to work in the temperature range -65°F to +650°F. One of the most noteworthy observations was on the difficulty of finding a suitable insulating material for the coil construction. Eventually this problem was solved by the use of a vitreous enamel coating on nickel-clad copper wire and then painting each layer of the coil with a glass ceramic substance; after firing, each turn became embedded in a durable glass-like solid.

It is not clear from the paper whether the life of 100,000 operations represents MTBF or some other value, nor is any indication given of the degree of confidence associated with the statement. This leaves the reader to wonder how many units were tested, and how many failures occurred.

The author makes one comment that may be of importance to those engaged in the design of space systems: "The selection of materials for high temperature provides a design that also offers promise of adequate performance under exposure to radiation." ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability--a design and production reality: the MM-22 relay

AUTHORS: R. E. Jurewicz and G. S. Lychyk, Automatic Electric Sales Corporation, Northlake, Illinois

SOURCE: 25 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 19)

PURPOSE: To describe the design and production of a microminiature relay.

ABSTRACT: As a result of a constantly growing demand for relays that are extremely small and absolutely reliable the Automatic Electric Laboratories undertook the design of a two-transfer microminiature relay capable of establishing a new high standard of reliability. The objective of the design was to meet or exceed the requirements of Military Specification MIL-R-5757D. An important feature of the design of the relay was that the manufacturing process was worked out as an integral part of the design problem.

REVIEW: One of the important features of MIL-R-5757D is that the relay shall have a reliability failure rate of 0.01% per 10,000 operations. The authors state that: "A percentage of MM-22 relays are random-selected for dry-circuit tests to 100,000 operations, in a low-level test circuit. The maximum contact load applied by this circuit consists of a 400-cycle peak-to-peak signal of ten microvolts, open-circuit voltage, and ten micro-amperes, closed-circuit current. ... At the time of this writing, the resistance of MM-22 relay contacts, under dry-circuit tests, has not, in any case, exceeded 70 milliohms." Notwithstanding all of this the reader is left wondering how many relays were tested.

The description of the cleaning and assembly operation is interesting and obviously owes much to transistor technology.

In general this is a good paper, despite the excess of phrases dedicated to gilding the corporate image of the Automatic Electric Laboratories. ##

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Serial Number 667
Code 773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability analysis equipment--electromagnetic switching elements

AUTHOR: Francis J. Soychak, International Business Machines Corporation, General Products Division, Burlington, Vermont

SOURCE: 16 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 20)

PURPOSE: To describe a piece of test equipment for relays.

ABSTRACT: The test equipment described here was designed to permit contact reliability studies of electromagnetic switching elements when making and breaking variable resistive loads with variable open circuit voltages. Two immediate test operations were required and, as a result, two pieces of equipment were developed. One tester permits studies of synchronous switch criteria and the other permits study of asynchronous criteria. Both testers monitor each opening and closing of the switches. The testers were built using solid state circuitry and packaging philosophies. (Author)

REVIEW: The test equipment described was designed to monitor relay contacts for failure to close and failure to open errors as defined by the amplifier with the present oscillator. Tests can be made at drive frequencies from 20 cps to 1000 kc. However the logic is capable of testing relays much slower, i.e. 20 cpm or less. Both testers stop when a relay contact failure occurs, allowing the calculation of failure rate. One tester locks the relay in the state of error while the other tester stops on the next change of coil pulse. (Some of this information was supplied by the author in a private communication.)

This is a hardware-oriented paper with thirteen figures giving circuit details, waveforms, and photographs of the equipment. ##

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Serial Number 668
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The frequency-sensitive Photoreed as a device for relaying without contacts

AUTHOR: Carl Iaccarino, J-B-T Instruments, Incorporated, New Haven, Connecticut

SOURCE: 14 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 24)

PURPOSE: To describe an application of the Photoreed.

ABSTRACT: A new type of resonant reed relay without contacts is described. This device, called the Photoreed, consists of a basic reed driving system, light source, and photosensitive element. When an AC current, at the resonant frequency of the reed, is applied to the driving coil, the reed acting as a shutter will allow light to pass to the photo-conductive cell which changes resistance. The input power required to drive the reed coil is about 0.5 milliwatts. The operating bandwidth, when energized in series with a 50,000-ohm resistor, is 5 cps. for a 751 cps. unit.

REVIEW: The Photoreed is a very intriguing device and will no doubt find many uses in the communications field in connection with signaling on audio and carrier circuits. The reliability of the device will not be known until sufficient field experience is acquired. It is interesting to consider a development of the Photoreed consisting of one coil with several reeds tuned to adjacent frequencies and in which the light from each "shutter" is piped to the appropriate photoconductive element by a fibre optics bundle. The whole system would take up much less space than the same number of Photoreeds required for each individual frequency. ##

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Serial Number 669
Codes 770;844;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Crystal can relays with grounded cases--a second look

AUTHOR: K. A. Wantuck, Westinghouse Electric Corporation, Electronics Division, Baltimore, Maryland

SOURCE: 12 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 25)

PURPOSE: To discuss the grounding problem in crystal can relays.

ABSTRACT: As a result of receiving information which showed that discharge transients in subminiature relays with grounded cases and AC loads could, under certain conditions, completely destroy the units, a special test program was evolved. These tests were performed at standard line voltage (approximately 115 VAC, 60 cycles), using wire wound resistors as loads. The samples were operated at three-second cycles. Life testing of relays from three different vendors at 2.0 ampere and 1.25 ampere load currents, and with grounded cases, resulted in almost immediate violent failures.

REVIEW: This paper gives a prime example of the futility of running life tests which do not duplicate the conditions under which the components under test will actually be used. In this case early life tests of subminiature relays, in which the cans were not grounded, had given satisfactory results. However, in view of the fact that the user always grounded the cans for safety reasons a further series of tests was made. The life tests with grounded cans were completely unsatisfactory; many relays were found to suffer catastrophic failures in early stages of the tests. The apparent reason for the failures was that, in many of the relays examined, the distance between the common contact and the case was no greater than the gap between the contacts, thus allowing arcing to take place between the contacts and the can. ##

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Serial Number 670
Codes 782;835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Miniaturization pro and con

AUTHOR: John Schmidt, Jr., Guardian Electric Manufacturing Company, Chicago, Illinois

SOURCE: 11 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 27)

PURPOSE: To discuss some of the problems involved in reducing the size of relays.

ABSTRACT: The intent of this paper is to create an industrial awareness of the fact that while relay miniaturization does provide many design advantages, there are some drawbacks too. The pros and cons of miniaturization are discussed under the following headings: (1) Shock, Vibration, and Acceleration, (2) Contact Rating, (3) A.C. Coils, (4) Dielectric, (5) Operating Characteristics, and (6) Mounting and Installation.

REVIEW: This article is based on a comparison of two relays made by the same manufacturer. The main point is that although the miniature relay may provide greater resistance to vibration, shock, and acceleration forces, and will show an improvement in faster switching and release speeds with contact bounce of a shorter duration, there are some disadvantages. The smaller mass and area of the miniaturized type cannot dissipate heat as readily as the larger type. The reduction of size may bring troubles through dielectric breakdown. In relays operated on AC the close proximity of the necessary diodes to the relay results in heating of the diodes and precludes their most reliable operation. ##

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Serial Number 671
Codes 221;761;815;
850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effect Darnell recommendations on relay specifications

AUTHOR: Harry G. Romig, Leach Corporation

SOURCE: 21 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 31)

PURPOSE: To explain and extend the application of the Darnell report to the reliability of relays.

ABSTRACT: The Darnell report is discussed in the first part under the headings:

- Why the Darnell report?
- What is in the Darnell report?
- Technical basis for relay reliability provisions

Additional headings are (second part):

- Relay specifications proposed by customers per influence Darnell report for high reliability relays
- How to obtain and evaluate reliability
- Controlled processes for reliability evaluations for stated confidence levels
- Mathematical appendix
- References (23)

REVIEW: The first part is a technical review of the recommendations in the Darnell report. Fortunately for the relay conference, one of the three examples in the Darnell report was relays. In the second part, the first section contains an interesting discussion of some of the less effective ways of trying to upgrade relay specifications.

When various plans, such as are suggested in the paper, are considered for acceptance or sampling tests, all of the assumptions involved should be listed explicitly. Then an optimum test can be selected that will provide protection according to the assumptions that are considered to be correct. Many of the different plans have been optimized for different parameters; thus a blind using of one when the constraints are such that one of the others would be more appropriate may not give the best results for the situation at hand. ##

Serial Number 672
Codes 712;775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of production relays and its relationship to operate phenomena

AUTHOR: Kenneth M. Miracle, Control Dynamics, Incorporated, North Hollywood, California

SOURCE: 9 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 32)

PURPOSE: To explain a non-destructive test which checks some of the factors affecting relay reliability.

ABSTRACT: The usual qualification tests and acceptance tests do not provide concrete evidence of the reliability of production relays. The determination of failure rates for specified operating conditions over a particular duration of time or a specified number of operations is very difficult. In an effort to cope with this problem, a search was made for quality characteristics that are related to reliability. The force-function methods of T. R. Welch (this conference, 1958) are good, but are too expensive for 100% inspection. The operate-time, displayed on an image-retaining oscilloscope, along with several other characteristics gives a good indication of proper adjustment. Contact bounce is also important. Both contacts should act the same. The relay is open for these tests and corrective adjustments are made where necessary. Then the relay is sealed and rechecked. This in itself has reduced customer rejects by 55%.

Next a 5000-cycle operate test is used at room temperature and rated load. Relays which are poorly constructed are likely to fail this test. Failure modes are investigated and corrective action is taken. For ultra-high reliability relays there is a vibration test followed by another 5000-cycle operate test. This 100% inspection does not seem to damage good relays.

The experience here is limited to a particular two-pole double-throw relay.

REVIEW: While the results are probably not generally applicable, they do show that progress can be made in finding quality characteristics (measured at time = zero) which are related to life performance. While it may be difficult to predict the life accurately, the components can be made to have a generally longer life. It should be noted that, unless they are supported by correlated test results obtained under the specified operating conditions, laboratory results by themselves are not valid for most applications. ##

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Serial Number 673
Codes 782;815;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Atmospheric effects on relay reliability

AUTHOR: W. M. Crawford, Autonetics, A Division of North American Aviation, Incorporated, Downey, California

SOURCE: 5 pp., presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962 (Paper Number 34)

PURPOSE: To discuss some of the effects of the atmosphere on relays.

ABSTRACT: Motivation for this study was provided when evidence of seal failure and the consequent contamination of hermetically sealed relays was found by Autonetics after making an analysis of system checkout and field service failures.

The paper reveals that, although the hermetically sealed relay was intended to eliminate the problems of contamination associated with relays having closed contacts, sealed relays still suffer from contact troubles. The basic requirements for the internal atmosphere of the sealed relay are discussed and related to the effects of the external atmosphere. Several methods of measuring leak rates are compared and explained. As a result of some calculations on the effects of a typical leakage rate on the moisture content of a crystal can relay together with an evaluation of data obtained from failure analysis it is recommended that the relay manufacturers voluntarily use a minimum permissible leak rate of 1×10^{-9} standard cc per second.

REVIEW: This paper is a good illustration of the way in which a rigorous failure analysis and evaluation program can discover failure modes and environmental effects. The results obtained under such programs should, as in this case, be used to recommend necessary changes in specifications. Suitable action on such recommendations should do much to promote the production of reliable components. ##

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Serial Number 674
Codes 815;823;835;
837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relays: 10th annual conference report

AUTHOR: (Editorial Matter: Special Report)

SOURCE: Electromechanical Design, vol. 6, July, 1962, pp. 48-73

This report summarizes some of the papers presented at the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962. Topics covered include: pros and cons in reliability, Darnell recommendations, fallacies in life testing, causes of relay failure, predicting product performance, contact chatter indicator, low energy level testing, user applications, heat transfer in relay design, and current state of the art. The report also includes, in a "relay news" section, descriptions of a number of specific relays.

The report is useful in presenting a cursory view of some of the most important papers presented at the conference. The papers most likely to be of interest to reliability engineers have been covered by Abstracts and Reviews Serial Numbers 654-673. ##

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Serial Number 675
Codes 815;823;835;
837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Emphasis on reliability at relay conference

AUTHOR: John R. Riggs, Associate Editor

SOURCE: Electro-Technology, vol. 70, July, 1962, pp. 132-136

This is a summary report on the Tenth National Conference on Electromagnetic Relays, Oklahoma State University, Stillwater, Oklahoma, April, 1962. Several papers dealing with various phases of reliability as well as more specific design factors are summarized.

The papers from this conference most likely to be of interest to reliability engineers have been covered by Abstracts and Reviews Serial Numbers 654-673. ##

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Serial Number 676
Codes 816;817;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A new reliability tool--the Darnell report plus

AUTHOR: John D. Hepp, A.C. Spark Plug Division, General Motors Corporation, Milwaukee, Wisconsin

SOURCE: Evaluation Engineering, vol. 1, March/April, 1962, pp. 16-19, 24

PURPOSE: To propose a "profile" system of presenting reliability criteria for components.

ABSTRACT: Reliability is important and the implementation of the Darnell report will give it a big boost. The designer generally considers the failure rates of parts as the reliability parameter. The conditions for failure are generally poorly stated if at all. The plan proposed here would have a failure rate, for each of the performance factors, in terms of the criterion for failure. For example, for a capacitor three performance factors might be capacitance change, dissipation factor, and leakage current. These failure rates, for the given failure criteria, are added together for the capacitor failure rate. Different curves may be necessary for different capacitance values. In this way a designer can make an intelligent trade-off. The temperature is at some safe level for all these tests and is no longer used as a parameter. Reliability profiles based on different test times can also be used. It is expected that these profiles can be generated in the course of Darnell Specification implementation.

REVIEW: The use of all the measures of performance in determining the reliability of a part is a good idea. As a "thinking out loud" paper, this is a good introduction to the subject. There are some problems however:

1. If the failure rates for different performance criteria are to be added, the criteria must be independent. It is doubtful, for example, that the drift in dissipation factor and leakage current are entirely uncorrelated.

2. The adding of failure rates, when the mission time is unspecified and variable, is equivalent to making the "exponential" assumption. If this is justified, then the real-time duration of the life tests is unimportant. Conversely if the real-time duration of the life test is important, as implied by the author, then the adding of failure rates, as mentioned above, is not justified.

3. Temperature is one of the important parameters in determining life. Just because it is difficult to find the true operating temperature, is no justification for ignoring it.

4. If the points on the curves in the several figures are intended to represent the data, the curves have been drawn either with some abandon or some "a priori" behavior in mind. ##

Serial Number 677
Code 813

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 engineering and commercial product warranties

AUTHOR: G. Ronald Herd, Booz, Allen Applied Research, Incorporated

SOURCE: Evaluation Engineering, vol. 1, May/June, 1962, pp. 18-19 (This is an abstract of Mr. Herd's paper "Reliability Engineering and Statistical Techniques in the Development of Commercial Product Warranties")

PURPOSE: To show the need for and some of the weaknesses of reliability programs for commercial products.

ABSTRACT: A reliability program is economically feasible for commercial products. Commercial reliability programs can be successful if (1) a program objective and a measure of effectiveness is established; (2) a good history and catalog of recent customer experience data is available; (3) the reliability analysis and design of the system are integrated prior to finalization of design; and (4) failure effects analysis is used to evaluate the relative importance of various failure modes. There are major weaknesses in many programs. There is a lack of knowledge concerning the analytical techniques available to design engineers to evaluate realistically the proposed designs. There is inadequate data collection on the system under design. Failure analysis is incomplete and sometimes nonexistent. There is inadequate testing of the system before release to production. A good reliability program can result in a better product, lower costs, and better customer satisfaction. (Author in part)

REVIEW: This is a good general paper on the subject of reliability. The comments about reliability programs are applicable to all, regardless of whether the customer is the government, industry, or "just people." ##

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Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure case histories--is hindsight becoming 20-20?

AUTHOR: E. W. Kimball, The Martin Company, Orlando, Florida

SOURCE: Evaluation Engineering, vol. 1, September/October, 1962, pp. 15-17

The topic of this paper is very similar to that of the paper by the same author covered by Abstract and Review Serial Number 233. However, several different case histories are presented. ##

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Serial Number 679 -1
Codes 512;553;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability handy dandy table #1
Reliability handy dandy tool #2

AUTHOR: Gerald B. Cohen, Sylvania Electronic Systems, Buffalo, New York

SOURCE: Evaluation Engineering, vol. 1, September/October, 1962, pp. 30-31, and November/December, 1962, pp. 20-21

PURPOSE: To present tables for calculating confidence limits on a mean life from experimental data.

ABSTRACT: Tables are presented for the following purposes: (1) The calculation of confidence limits, (2) The design of sequential analysis type tests, and (3) The calculation of the level of confidence which may be placed on a set of test data. Several good examples of the uses of the tables are given.

REVIEW: While these tables and the accompanying explanations are somewhat better than some that have been published to "simplify" statistics for engineers, they do leave several things to be desired. For example:

1. The type of test is not stated; i.e., this table is for a test that runs for a fixed length of "total testing time." The number of failures is the experimental result. Another type of test which is not uncommon is to run for a fixed number of failures; the total testing time is then the experimental result. The table can be modified to be used for this case.

2. The confidence levels listed are minimum levels. A typical confidence statement would read "The confidence level is 95% or more that ...." The need for this would be obvious if the 50% level had been given for the maximum limit factors.

3. The maximum limit factor for 99% and one failure should be 0.010, not 0.02. The other values seem to be correct except for rounding errors.

4. a) The table or graph should under no circumstances be used for the design of sequential tests. They will not give correct answers. They should be used for a single sample only.

b) The sequential test that is proposed is not such in the sense used by Wald.

5. The problem in Part II is not well stated and the answer for it is the answer to some other question.

6. In tables such as this it is a good idea to give the equations that are being tabulated and a list of the restrictions under which the use of the table is valid. While the article does state that it is valid for a Poisson distribution, many "non-statis tical" engineers will not relate it to the "exponential" distribution, and they may not understand the implications of the term "Poisson." The terms tabulated are $\frac{1}{2}\chi^2_p(2r)$ and $\frac{1}{2}\chi^2_{1-p}(2r+2)$ for

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

the maximum and minimum factors (r is the number of failures, p is the tabulated confidence--see number 2 above, $\chi_p^2(\upsilon)$ is the value of χ^2 which is exceeded a fraction p of the time, and υ is the degrees of freedom).

Review Serial Number 713 contains a further discussion of some of these points. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability, value engineering, and quality--how they work together

AUTHOR: R. L. Crouse, Minneapolis-Honeywell Regulator Company

SOURCE: Evaluation Engineering, vol. 1, November/December, 1962, pp. 6-8, 24

PURPOSE: To link, in their true operating climate, value engineering, reliability, and quality programs.

ABSTRACT: A Quality System will assure that supplies or services meet the standards established by the customer or the contract. A Reliability Program insures the probability of a device or system operating within the specified limits for the time and operating condition specified. A Value Engineering Program insures the performance of only necessary functions at minimum cost. These programs should not be competitors, but are excellent management tools that must be used concomitantly.

Value Engineering sees that we deliver a product or service that is in conformance with the customer's actual need at minimum cost. Value Engineering people work from the precept that the customer puts forth many requirements that cost more in the terms of dollars and complexity than were visualized at the time these requirements were made. Quality accepts the requirements placed upon our people and makes every effort to see that these requirements are adhered to at lowest cost. Quality does not provide for a questioning concerning the basic needs of the requirements of the customer.

Reliability normally accepts the requirements in the contracts and makes every effort to adhere to them. Reliability does not provide a questioning atmosphere concerning the basic needs of the customer except in cases where it is felt that specifications are impossible to meet. Value engineering, on the other hand, will always question the customer's requirements when the cost appears to be out of line for the desired or specified results.

While all three management programs--value engineering, reliability, and quality assurance--were sired by complexity in our present equipment, systems and services, they also have a common mother--simplification. (Author in part)

REVIEW: This is an attempt to define the three programs in such a way that they overlap little if at all. A member of any one group will probably feel that the mission of his group has been understated. All in all, the treatment seems to be fair within this limitation, although it is too categorical in several places. Certainly, the design engineer should be aware of the precepts of all three groups. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Physics of failure

AUTHOR: Joseph Brauer, Applied Research Laboratory, Rome Air Development Center, Air Force Systems Command, U. S. Air Force, Griffiss Air Force Base, New York

SOURCE: Evaluation Engineering, vol. 1, November/December, 1962, pp. 9-11 (This is an abstract of a paper presented by Mr. Brauer at the Physics of Failure Symposium, Armour Research Foundation, Chicago, Illinois, September, 1962)

PURPOSE: To show how the physics-of-failure approach can overcome the difficulties in the prediction of life for components.

ABSTRACT: The present method of producing reliable parts consists of making them as alike as possible, then testing them enough to find out what their failure rates are. This is expensive in time and money, but has been the main fruitful approach so far. As parts become better, this approach becomes even more expensive. The reliability methods for systems are soundly based and improvements are built on past work. The existing reliability data on components is not likely to fill a designer's need for several reasons, such as: the various stress parameters for the tests are not likely to be right; the newer the part, the fewer the data; parts which fit the data may be hard to buy; it is difficult to extrapolate from one set of test conditions to another.

The key to the problem is a failure mechanism (f.m.) method. For each part, the mechanisms of failure are listed; many parts will have some mechanisms in common. Thus, the list of f.m. will be shorter than that of components. If each f.m. is analyzed enough its behavior can be catalogued as a function of stress and time. Now each f.m. can be replaced by a very general equation and these equations can be programed on a computer for all the f.m. The system designer selects the proper equations and the computer gives the life probabilities. The program is easy to keep current since new parts will have few if any new f.m. Minor changes in equation parameters will be necessary as advancements are made. Integrated circuitry is just a special case and presents no significantly new problems.

The task is being approached by a planned program so that each piece of research fills a different need. The ultimate objective will be reached when the behavior of any part can be correctly predicted without making the part.

REVIEW: The physics of failure approach is an excellent one, although not altogether new. The further advances in making components more reliable will come largely from this direction. But the author's

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

hopes for this system are projected well into the future. Even in gross mechanics, such predictions of behavior are not possible and a great deal of effort has been put into it. While many f.m. will be similar for different parts, they will have variations and interactions, and these may become legion.

While physics of failure may be the hope for the future, its use will make failure prediction less quantitative as it is more successful in prolonging the life of parts. This will be true because it will be virtually impossible to evaluate the very low probability of failure. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Diode burn-in for reliability

AUTHORS: F. M. Schriever, J. Fabbroni, and R. Ullman, Ford Instrument Company, Division of Sperry Rand Corporation

SOURCE: Evaluation Engineering, vol. 1, November/December, 1962, pp. 12-15

PURPOSE: To show how a diode burn-in improved its life.

ABSTRACT: The object of this paper is to show the increase in Mean Time to Failure (MTTF) obtained on a particular piece of equipment as a result of a diode burn-in program. Details of the burn-in plan and comparative figures between pre burn-in and post burn-in diode failure rates are presented.

Table 1 shows on a comparative basis the results achieved:

Table 1

Diode	Vendors	% Fallout	CP-289 Failures After Sealing
Pre-burn-in	A, B, C	1.7	6
Post burn-in	A	.7	0
Post burn-in	B	.8	0

Observation should be made of the fact that with a total of approximately 8,000 diodes no failures occurred after sealing. Failures after sealing are particularly troublesome.

A burn-in plan, whether of the operating or thermal impedance variety, is highly effective in eliminating infant mortality failures. For the specific equipment of interest, the reliability of the CP-289 was increased by 11 percent, while at the same time production costs were decreased. So successful have these diodes proved that no equipment field failures, due to diodes, have been reported since their introduction.

REVIEW: This is a short informative paper on a case history. The results are rather impressive, although one is led to wonder who the vendors could possibly have been. ##

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Serial Number 683
Code 810

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability money wasted?

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 1, November/December, 1962, pp. 18-19

This is a summary of a panel discussion held at the NEC Reliability Conference in Chicago on October 8, 1962. As such, it covers the same basic points as the summary covered by Abstract and Review Serial Number 557. ##

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Serial Number 684
Codes 812;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability through redundancy and error-checking codes

AUTHOR: Leonard S. Schwartz, College of Engineering, New York University, New York, New York

SOURCE: Electro-Technology, vol. 67, February, 1961, pp. 123-130

PURPOSE: To present, with some explanation, a survey of redundancy and coding methods of improving reliability.

ABSTRACT: System reliability is considered from the points of view of increasing component reliability and of improving reliability by introducing redundancy or self-checking coding.

Circuit redundancy is analyzed, using series, parallel, and bridge circuits. Von Neumann's synthesis of logic circuits using Sheffer stroke gates, with improvements of reliability by this means, is discussed [1]. Moore and Shannon's relay approach is described briefly [2] and compared to Von Neumann's methods. A description of parallel transmission [3] and message iteration as methods of improving reliability leads to the introduction of the subject of error-correcting codes, with Hamming's methods [4] discussed and compared to the pedagogical erasure channel method [5]. Parity checks and the binary symmetric channel are explained in some detail.

The author concludes with material on multiple-error correction on the binary symmetric channel.

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[1] "Probabilistic Logics and the Synthesis of Reliable Organisms from Unreliable Components," J. Von Neumann, in Automata Studies, C. E. Shannon and J. McCarthy, eds., Princeton Univ. Press, Princeton, New Jersey, 1956

[2] "Reliable Circuits Using Less Reliable Relays," E. F. Moore and C. E. Shannon, Part I, J. Franklin Inst. 262, pp. 191-208; Part II, 262, pp. 281-297, 1956

[3] Automata of High Complexity Information and Control, Lars Löfgren, Academic Press, pp. 127-147, May 1958

[4] "Error Detecting and Error Correcting Codes," R. W. Hamming, BSTJ, 29, 147, 1950

[5] "Coding for Noisy Channels," P. Elias, IRE Convention Record, Pt. 4, pp. 37-46, March 1955

REVIEW: This is a tutorial article reviewing these methods of achieving reliability, and summarizing the work of Von Neumann, Hamming, Moore and Shannon, and others. The author presents his material well, although he makes some assumptions. He goes into sufficient detail in his explanations to give the reader some insight into how the problems are handled. On the whole, this is an excellent survey. ##

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Codes 831;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Minimization of switching circuits subject to reliability conditions

AUTHOR: E. L. Lawler, Sylvania Electric Products, Needham, Massachusetts

SOURCE: IRE Transactions on Electronic Computers, vol. EC-10, pp. 781-782, December, 1961 (correspondence) (Note: Corrections to the article are found in IRE Transactions on Electronic Computers, vol. EC-11, p. 289, April, 1962.)

PURPOSE: To point out a relatively simple formulation for a restricted class of switching circuits subject to reliability conditions.

ABSTRACT: The class of circuits considered is of the two-level "AND-to-OR" type, and the failures considered are those due to the failure to close of a normally open switch. The author develops a minimization procedure using a constraint matrix and a cost vector, which results in a standard linear program. The rest of the paper is devoted to minimization with reliability conditions, replacing the elements of the original constraint matrix with new, probabilistic elements. The solution of this new problem gives the number of times each series path is to be duplicated in the final circuit to achieve the desired reliability. The paper concludes with an example.

REVIEW: This is a nice method for designing a particular type of reliable circuit subject to a particular type of failure (failure of a normally open switch to close). These specifications, of course, are limitations on the usefulness of the method, but within these limits it is a good one. The derivation of the formulae is well done. ##

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Serial Number 686
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Worst case design of variable-threshold TRL circuits

AUTHOR: W. J. Wray, Jr., Burroughs Corporation, Paoli, Pennsylvania

SOURCE: IRE Transactions on Electronic Computers, vol. EC-11, pp. 382-390, June, 1962

PURPOSE: To present design criteria that will give acceptable logical performance in variable-threshold TRL circuits under the worst possible circuit operating conditions.

ABSTRACT: Now that standard Transistor Resistor Logic is well understood and widely used, the possibilities for reducing component count by changing the height of the switching threshold, as measured in units of input, are being explored. This paper presents the worst case design formulation, both steady-state and transient, for such variable-threshold circuitry. In addition, there is a brief discussion of the logic represented. Numerical results illustrate the logical possibilities and the effect of increasing the threshold on transient behavior.

REVIEW: This paper presents a thorough analysis of transistor-resistor logic circuits whose "on" condition is achieved by the application of multiple inputs. The level of mathematics in the paper does not exceed basic algebra but the computations do become involved and the author wisely chooses to leave most of the algebraic manipulations for the reader to check, presenting only the basic steps and conclusions.

The conclusions of the author are accurate and well presented. They should be of very considerable interest to anyone working in the area of logic circuitry design. ##

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Codes 716;770;780;
850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Development of solderless wire connector for splicing multipair cable

AUTHORS: H. J. Graff, J. M. Peacock, and J. J. Zalmans, Bell Telephone Laboratories

SOURCE: The Bell System Technical Journal, vol. 42, pp. 131-153, January, 1963

PURPOSE: To describe the development and laboratory testing of a new high-reliability solderless connector for splicing cable conductors.

ABSTRACT: The engineering risks involved in appraising a device design for very high reliability and long service life can probably never be reduced to zero. The techniques described here are believed to have minimized these risks in the B Wire Connector, however, and they have permitted substantial reductions in the laboratory effort required to develop and prove-in this device. Early field experience is considered good confirmation of the basic statistical predictions of initial reliability that were made. Final confirmation of the aging predictions must, of course, await the passage of time.

The experimental techniques described are based largely on the use of laboratory measurements of improved sensitivity which permit the collection of data suitable for more rigorous statistical and experimental analysis than otherwise possible. The data analysis itself has two distinct goals: (1) the study of the fundamental mechanisms which influence the physical behavior of the device, and (2) the formulation of reliability and aging estimates based on a minimum of experimental data through the use of various established statistical and other analytical techniques. The degree to which these principles have been applied in the past to the design of connectors has been limited, at least in part, by the experimental difficulties in making resistance measurements on actual devices to a sensitivity of much better than $\pm$ 0.5 milliohm. The measuring circuit and apparatus discussed here are simple and permit an improvement in resolving power by at least two orders of magnitude. The work on the B Wire connector clearly shows that important information is lost without this refinement. Many of the specific methods presented here are directly applicable to a broad class of engineering problems having to do with electrical contacts. (Authors)

REVIEW: This is a well written report on what appears to be an excellent piece of work. The discussion of the risks of engineering decisions and accelerated testing is well founded. The quantitative estimate of probabilities by extrapolating a normal distribution beyond about three standard deviations is risky. The further one goes, the better, but accurate probabilities are impossible to assign. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating worst-case conditions (the systems side of digital design)

AUTHORS: Y. C. Lee and R. J. Merkert, Surface Communications Division, Radio Corporation of America, Camden, New Jersey

SOURCE: Electronic Design, vol. 11, March 1, 1963, pp. 54-61

PURPOSE: To give a close look at areas where pulse timing is likely to be critical.

ABSTRACT: Worst-case timing problems can only be overcome by a careful initial design followed by a comprehensive design review. The review process centers on the areas where pulse timing is likely to be critical. In general, the following steps must be included in reviewing a system design: Review the customer specifications and contract requirements, all circuit capabilities and restrictions, all block diagrams and logic flow charts, all critical paths and timing charts. Timing is usually the critical factor in any worst-case design. The most important timing factors are: maximum and minimum "pair delay" of logic elements, stage delay for flip-flops and other regenerative circuits, settling time in binary counters, reliable triggering for capacitive input circuits, pulse-width variation in pulse forming networks, oscillator (clock) frequency tolerance. Examples are given. (Author in part)

REVIEW: The use of a worst-case analysis is helpful in pin-pointing the weaknesses in any design that are likely to show up as time goes by and cause malfunction. In addition to the initial tolerances, the drifts due to time should also be taken into account. ##

Serial Number 689
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some reliable redundant circuits

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

SOURCE: Publication 21G-8001, 25 pp., Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Massachusetts, June 7, 1961 (ASTIA Document No. 284793)

PURPOSE: To describe some typical digital computer circuits built to demonstrate Moore-Shannon redundancy in conjunction with gate connector redundancy as a method of improving reliability.

ABSTRACT: The paper begins with a description of Moore-Shannon redundancy and a brief discussion of its applications and their problems. Gate connector redundancy is considered next and briefly described and illustrated. A demonstrator was built using an oscillator unit feeding a series of flip-flops which operate a lamp. (This was a modification of a Lockheed Emergency Reset Timer.) The oscillator unit consists of four oscillators connected through gate connector redundancy, and having their inputs synchronized with the gate connector output. Four flip-flop stages were constructed, each with Moore-Shannon redundancy. The driver for the output lamp was also made redundant by the same technique.

Hardware reliability is then discussed, along with failure rates of components. Reliability of the redundant demonstrator is compared with that of a non-redundant unit. Oscillator reliability is compared using the two types of redundancy, and none. Flip-flop reliability is compared with no components redundant, with all redundant, and with redundant diodes and transistors only.

The author concludes that if Moore-Shannon redundancy can be used it is preferable to gate connector redundancy, and that only the most unreliable components should be made redundant.

REVIEW: This is an interesting paper describing reliability demonstrations. The author has achieved his purpose of showing that the circuits could be built, and his comments along the way are useful. His conclusion that only the most unreliable components should be duplicated is supported by the reliability graph.

For those who have time, this document makes interesting reading, but it is not basic material. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Modular redundancy for spaceborne computers

AUTHORS: D. P. Rozenberg and H. L. Ergott, IBM Space Guidance Center, Owego, New York

SOURCE: IBM Technical Report No. 62-825-494, 13 pp., presented at the Spaceborne Computer Engineering Conference, Anaheim, California, October 30-31, 1962

PURPOSE: To discuss modular redundancy and to present the results of a simulation program.

ABSTRACT: Redundancy methods are used to achieve the high level of reliability needed in spaceborne computers. The majority organ is the device chosen here. The authors discuss fundamental concepts of reliability at some length and in considerable depth. Modular redundancy is analyzed and input voting compared to output voting. The methods were compared on the 7090 EDPM, and it was determined that output voting was superior.

Guide rules for design are given which apply to modular redundancy with output voting. These are (Authors):

1. The reliability of all modules should be equal, and
2. With most logic circuits, one may designate a minimum logic circuit which may be used.

Two special cases are investigated.

A TRL circuit is used and some of its features are discussed.

To simulate the behavior of their redundant configurations, the authors use a Monte Carlo technique, with the process programmed for an IBM 7090 computer. The program is described in some detail and its results tabulated. The confidence level is examined.

REVIEW: This is an excellent paper, which starts by giving a short course in reliability on a high level. The authors develop their theory impeccably and not only claim that they have proved their points, but show that they have with facts and figures. Every step is spelled out most clearly, and their techniques are splendid. This is a valuable contribution to the literature. ##

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Codes 813;831;837;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to set up a program for product safety analysis ... a tool for optimizing reliability

AUTHOR: Richard R. Landers, TAPCO Research, Development & Engineering, Thompson Ramo Wooldridge, Inc., Cleveland, Ohio

SOURCE: Machine Design, vol. 35, February 28, 1963, pp. 98-103

PURPOSE: To show how to analyze the safety of a product.

ABSTRACT: The effect of failures in a product on the product itself or on its environment should be considered before the product is marketed. An analysis should be made to determine: (a) potential hazards which could cause damage to the equipment or injury to personnel, (b) location, modes of failure, and number of design and operational weaknesses which can cause unfavorable consequences, (c) probability of failure occurrence because of these weaknesses, (d) extent of damage that could result from a given failure or accident, (e) nature of design or operational change required to eliminate a hazard, reduce the probability of its occurrence, or mitigate its consequences, (f) the effect a failure-reducing design or operational change has on other product parameters such as weight, cost, performance, and reliability, and (g) whether, in the light of the safety analysis, changes should be recommended.

Charts, graphs and examples are used to illustrate the method. (Author in part)

REVIEW: This is a good article on the subject. The suggested technique is similar to that recommended for reliability/performance analyses or effectiveness studies.

The use of failure probabilities in failures per million cycles can be somewhat misleading. There is a very strong implication that the number of cycles used to get the failure probability is unimportant, whereas the implication may well not be true. It would be better to give failure probability in the first million cycles, or the second 5000 cycles, etc., so that no distribution in time is being unwisely assumed. The use of four significant figures for failure rate lends an air of precision to the process which is completely unjustified. More appropriately the failure rates are called "ballpark" estimates. When there is more than one of a component used in similar circumstances, there may be some justification for treating the group as a whole. The plot of Figure 1 is said to usually follow an exponential curve. Why this should be so is quite hard to see and the hypothesis should not be confused with the common "exponential life" assumption. ##

Serial Number 692
Codes 300;810;812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The management of quality control and reliability

AUTHOR: Denver T. Johnstone, Jr., Torrance Plant, Aerospace Division, Vickers, Inc., Division of Sperry Rand Corporation, Torrance, California

SOURCE: Machine Design, vol. 35, March 14, 1963, pp. 132-138

PURPOSE: To explain the management problems brought on by today's product-reliability requirements.

ABSTRACT: Traditionally, quality control does not begin until the design has been released to production; this is too late for the reliability effort. In order to be effective, reliability must occupy a position on the same level as marketing, engineering, etc. This position must be implemented by active groups on the working level. One problem a producer must deal with is the varying reliability requirements of his customers. Several suggestions are made for handling this problem.

It is important that purchasing departments, salesmen, and application engineers understand the reliability program of their organization. Otherwise the program may inadvertently be subverted. All employees should be indoctrinated with the reliability precepts on the level at which they need to understand and use them. Without this, the reliability program is doomed.

REVIEW: This is a good introductory article on the subject of reliability for management. Although this type of paper has appeared in many places for a long time, it seems that there is still a need for more. A minor criticism is that the author perpetuates the error of inferring that reliability and mean-time-between-failures (MTBF) are uniquely related. This is true only for the one-parameter distribution of life. ##

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Codes 711;715;782;
833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Teflon resins in the space environment

AUTHORS: C. E. Jolley and J. C. Reed, Plastics Department, E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Delaware

SOURCE: Space/Aeronautics, vol. 39, February, 1963, pp. 105-109

PURPOSE: To report on tests on the performance of Teflon TFE and FEP as spacecraft materials.

ABSTRACT: The literature on the behavior of plastics under space conditions has assumed fairly staggering proportions by now. In a recent du Pont study limited to just Teflon TFE and FEP as spacecraft materials, no fewer than some hundred papers had to be reviewed. To a large extent, these papers contained material of primarily theoretical interest, but they also presented valuable data on the changes in the physical and electric properties of TFE and FEP during and after exposure to radiation and/or vacuum. This report is a summary of these data as well as of recent du Pont test results on the performance of TFE and FEP in the space environment.

Summary of Findings

Teflon TFE and FEP resins will not evaporate in a vacuum of 10^{-7} mm Hg. Theoretical calculations show that they will not evaporate in any anticipated space vacuum to an extent that would limit their usefulness. Although some outgassing occurs initially, the volatiles are all absorbed atmospheric gases.

The presence of oxygen greatly influences the physical and electric properties of TFE and FEP irradiated at more than about 4×10^4 rads. Properly applied, TFE remains useful after irradiation at 10^7 rads (or perhaps more) in the absence of oxygen. FEP irradiated at more than 2.6×10^6 rads in the absence of oxygen and at more than 80 deg C shows an improvement in certain desirable physical properties.

The low-frequency loss properties of TFE polymers are drastically affected by X-ray irradiation, the high frequency loss properties considerably less so. The increases in dielectric constant and dissipation factor depend on the ambient oxygen concentration during exposure and recovery. The dielectric constant and dissipation factor of FEP remain unaffected by X-ray irradiation in vacuum at frequencies from 60 CPS to 100 kc. (Authors)

REVIEW: The findings in this paper constitute a worthwhile addition to the literature on the behavior of materials in the space environment. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The never-ending challenge

AUTHOR: Vice Admiral H. G. Rickover, United States Navy

SOURCE: Nondestructive Testing, vol. 21, pp. 59-68, January-February, 1963 (presented as keynote address for the 44th Annual National Metal Congress, October 29, 1962, and reprinted in its entirety, in response to numerous requests from SNT members)

PURPOSE: To show the technical and managerial challenges to improve our production processes so that the products are as good as we like to think they are.

ABSTRACT: Successful operation of a nuclear power plant depends on the reliability of all its parts, the reactor as well as the conventional components--the heat exchangers, pressure vessels, valves, turbogenerators, etc. Although these are all designed and manufactured by long established procedures, and so should present no special difficulty, delivery and performance of these conventional items have been less reliable than of the nuclear reactors themselves. Compared with the complexity of nuclear engineering itself, these problems individually are minor in nature, yet they occur so frequently as to require a disproportionate amount of our time. If we are to build successful nuclear power plants at reasonable cost and in reasonable time, the whole plateau of industrial workmanship, engineering inspection, and quality control must be raised well above the present level. This is the responsibility of management. There is no substitute for constant personal supervision of production work by management.

During the past few years, hundreds of major conventional components, such as pressure vessels and steam generators, have been procured for naval nuclear propulsion plants. Less than 10 per cent have been delivered on time. Thirty per cent were delivered six months to a year or more later than promised. Even so, reinspection of these components after delivery showed that over 50 per cent of them had to be further reworked in order to meet contract specification requirements. The most prevalent inadequacy found in our audits is failure to recognize that timely production of high quality components requires almost infinite capacity for painstaking care and attention to detail by all elements of the organization, both management and nonmanagement; this is as true for a so-called conventional "old-line" product as for a new one. We often found it necessary to run our own tests to determine the true physical properties of many conventional materials under varying conditions. And this, despite the fact that these materials have been in widespread industrial use for over 30 years.

Two areas that are in need of continuous and painstaking attention

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

to detail by management, by engineers, and by workmen are:

First. Incomplete understanding of basic manufacturing and inspection processes, and

Second. Poor workmanship and poor quality control.

Let me give you specific examples: There are 99 carbon steel welds in one particular nuclear plant steam system. The manufacturer stated that all these welds were radiographed and met specifications. Our own re-evaluation of these welds--using correct procedures and proper X-ray sensitivity--showed however that only 10 per cent met ASME standards; 35 per cent had defects definitely in excess of ASME standards, and the remaining 55 per cent had such a rough external surface that the radiographs obtained could not be interpreted with any degree of assurance. We found this condition of unsatisfactory welds and improper radiography to be quite prevalent in many segments of industry. There have been many problems in material identification and control. Recently, we discovered that a stainless steel fitting had been welded into a nickel-copper alloy piping system. The fitting had been certified by the manufacturer as nickel-copper, and had all the required certification data, including chemistry and inspection results. In fact the words "nickel-copper" were actually etched in the fitting. Yet, it was the wrong material! The system was intended for sea water service; had it been placed in operation with this stainless steel fitting a serious casualty would have resulted. Not long ago, we discovered a mix-up in the marking and packaging of welding electrodes, which also could have had very unfortunate consequences. During the next three months, while we were checking this matter in detail, we detected similar incorrect marking and packaging of electrodes in cans from nearly every major electrode manufacturer in the United States.

These examples illustrate there is no such thing as a "detail" which does not require careful review by experienced people. In our program, we try to overcome our quality control problems by setting up special quality control evaluation teams. These teams visit our suppliers and audit the effectiveness of their quality control organizations. The teams discover many deficiencies. Some have been corrected, many have not. The same practice could profitably be applied by companies, both for internal quality control audits and for audits of their sub-vendors. In all the cases I have cited, the chief responsibility for unsatisfactory delivery and performance rests with industry management. I only wish I could tell you that the somber situation I have described no longer exists; that our efforts over the past 15 years have been successful in eliminating these problems. But I can't. I have no sweeping solution for this never-ending problem, but several things can be done:

1. More effective management and engineering attention should be given to the routine and conventional aspects of our technology.

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Nothing must ever be taken for granted. Management must also remember that things once corrected do not stay corrected. A credo of management ought to be that every human endeavor has a "half-life."

2. Management and engineers must not conclude that their job is over once drawings have been completed and the first component successfully built and tested to these drawings. This is far from the whole story. To be satisfactory, a component not only must perform its function, it must do so reliably and consistently.

3. Industry must take responsibility for developing better understanding of many basic processes in use today.

4. Specifications and standards must be thoroughly understood, respected, and enforced by manufacturers as well as by customers. It should be of concern to us that specifications are normally written by the manufacturers and therefore usually represent the lowest standard of engineering to which all manufacturers are willing to agree.

5. Quality control must be recognized as an essential tool to enable management to meet today's technological imperatives. Customers must reject deficient equipment and insist that manufacturers meet their commitments.

I submit we must progress, and so we must pay the price of progress. We must accept the inexorably rising standards of technology, and we must relinquish comfortable routines and practices rendered obsolete because they no longer meet the new standards.

This is our never-ending challenge. (Author)

REVIEW: This is a rather strong indictment of much of our industry. While there are some valid excuses for the less-than-perfect performance of products in the past, there are many areas in which these excuses have no validity whatever.

The challenge is a real one; most of the challenge could be met by "merely" doing as well as we know how, right now. From time to time, those who are responsible for quality and reliability (and this really does include engineers--besides management) need to be taken to task as the author has done. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Elements of a practical reliability-engineering program

AUTHOR: E. L. Royal, Ampex Computer Products Company, Culver City, California

SOURCE: Electro-Technology, vol. 71, January, 1963, pp. 59-62

PURPOSE: To give the elements of a practical reliability-engineering program.

ABSTRACT: A reliability organization is necessary if the product must meet reliability specifications. The reliability function is more basic than the quality control function. The reliability program should begin when the equipment specifications are firm. A preliminary prediction can be made of the system reliability. Further predictions are based on statistically planned tests and more refined estimates. Accurate failure rate data require extensive, expensive tests of components. Failures must be defined; some types are catastrophic, random, drift, and wearout. Random failures are no longer a mystery since statistics is able to deal with them adequately.

The system MTBF referred to in the literature is important, but the determination of component failure rate figures is more of a problem. Failure rates are available from several sources and some fairly realistic ones can be obtained. The effect of stress level on the failure rate must not be disregarded. Probability is the key to the determination of reliability because it pervades all failure-rate computations.

Two tables are provided which summarize a) Primary Engineering Tasks under Jurisdiction of a Reliability Function and b) Key Objectives to Consider in Planning a Reliability Program.

REVIEW: The first part of this paper is a good brief discussion of a reliability engineering program. The two tables are especially helpful in this regard.

The remainder of the paper is largely a discussion of failure rates. Some of the concepts and ideas are rather poorly explained. In particular the concept of random failure is presented inadequately. While statisticians are able to provide mathematical methods based on random models which are useful in predicting the occurrence of failures, it is not to say that these failures are without physical cause. Many recent articles on the physics of failure attest to the importance of this point. The entire article implicitly assumes Poisson statistics (constant conditional failure rate); while these are very useful, they are not completely satisfactory. The contention that small errors in component failure rates produce large

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

errors in MTBF has little, if any, meaning. A proper statement is that small relative errors in failure rates will produce even smaller relative errors in MTBF, except for bias. Some of the errors in failure rates may look "small," such as 0.0001%/1000 hr, but may represent a factor of two or more.

All in all, the first part of the paper which deals with the program is good; the mathematical/statistical concepts introduced in the second part are not adequately treated. ##

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Serial Number 696
Code 816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability (letter to editor)

AUTHOR: Gordon H. Beckhart, Chairman, Reliability Training Conference, IRE-ASQC

SOURCE: Electronics, vol. 36, February 1, 1963, p. 4

PURPOSE: To point up a major problem in the reliability effort.

ABSTRACT: One of the major problems today in reliability for military products is the chaotic bidding situation. If too much reliability is required and too much documentation of the reliability phases is required, then too much effort may go into documentation and not enough into well designed and well built hardware. Some contractors have to promise a lot and then produce only the effort really required in order to meet requirements. The field of reliability prediction is much abused and easily gets out of hand.

REVIEW: The highest reliability requires the highest attention to detail. Lesser reliability requirements need less attention to detail and, as the author says, should be accompanied by less detailed paper work. It is not so much that overspecifying the reliability is bad, it is specifying more than is reasonably achievable that is detrimental to optimum design. This letter points out that we must always keep a reasonable set of goals in mind, but they should not be so "reasonable" that we become complacent and do not strive to improve. ##

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Serial Number 697
Codes 775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electron tube materials, gases and getters

AUTHORS: (Prepared by J. C. Turnbull, W. G. Rudy, and R. H. Collins; Approved by R. H. Zachariason, Electron Tube Division, Radio Corporation of America, Lancaster, Pennsylvania)

SOURCE: Final Report, Contract No. DA-36-039-SC-87390, Task No. 3A99130010124 for U.S. Army Signal Research & Development Laboratory, Fort Monmouth, New Jersey, 1 February 1961 to 31 January 1962 (ASTIA Document No. 277167)

PURPOSE: To report on a research study of gases and getters for electron tubes, with the objective of obtaining greatly improved electrical reliability, performance, and life.

ABSTRACT: The primary emphasis in the report is on getters. Various forms of zirconium and titanium, and some of their alloys were tested in the form of pressed pellets and as sintered coatings on molybdenum strips. The rate of gettering was measured as a function of temperature for the several common gases, as well as total gettering capacity.

Four different types of power tubes were evaluated for gas evolution on operation at different power levels. By suitable connection to a mass spectrometer both rates and total quantity of gas evolved were measured. Hydrogen and carbon monoxide were found. Attempts were made to add a getter to one of these types that did not normally have a getter. This work was not completed, but preliminary findings are reported.

REVIEW: Although a large amount of data was taken under well controlled conditions and with good technology, it must be summarized as inconclusive. For example, it is not possible to compare directly the data on gettering by pellets with that by coatings on molybdenum strips. The latter were well activated and degassed by firing at 1300°C but this could not be done for the pellets because the mounting procedure involved the use of nickel supports that prevented heating to above 900°C. The method of adding a coated getter to a power tube led to an inconclusive result because getter heating could not be separated from that of the cathode. As a result, the finding of an inactive getter could be attributed to poisoning of the getter by gas evolution during activation of the barium type cathode coating. Gas evolution during operation of the power tubes raises the undiscussed question of whether modified pumping procedures could have reduced the amounts of gas, or, for that matter, whether this is necessary, since the tubes are presumably satisfactory production types. The work apparently suffered from trying to cover too much ground in too short a time. ##

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Serial Number 698
Codes 820;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Adaptive decision elements to improve the reliability of redundant systems

AUTHOR: W. H. Pierce, Solid State Devices Department, Westinghouse Research Laboratories and Carnegie Institute of Technology, Pittsburgh, Pennsylvania

SOURCE: 1962 IRE International Convention Record, Part 4, New York, New York, pp. 124-131, March, 1962

PURPOSE: To provide an exposition of the statistical decision theory approach to the use of redundancy, and the adaptive decision elements which are the inevitable product of that approach.

ABSTRACT: Redundant but unreliable binary or analog signals are used most effectively when each signal's error probability is used to compute a statistical estimate of the correct signal. When errors in the inputs are independent, the statistical estimates can be made by simple summing circuits. Adaptive circuits are proposed which give the most reliable inputs the largest weights. Reliability of each input is estimated by comparing it with: (1) an answer supplied externally during a check routine, or (2) the output of the decision element. Adaptive decision elements are most valuable when used throughout systems with quite unreliable signals. (Author)

REVIEW: This is a mathematical paper concerned with the application of decision theory in optimizing the use of redundant information in electrical circuits. The results obtained are clearly summarized. The orientation of the paper relative to other work in the area is indicated, and 16 references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A manufacturing approach to long life requirements for unmanned spacecraft

AUTHORS: Robert Waite and Christopher Balzano, Missile and Space Vehicle Department, General Electric Company, Valley Forge, Pennsylvania

SOURCE: 1962 IRE International Convention Record, Part 5, New York, New York, pp. 312-319, March, 1962

PURPOSE: To describe the major elements of MSVD's manufacturing reliability program.

ABSTRACT: This paper covers MSVD's experience in preparing processes, personnel, and procedures in advance for the production of unmanned spacecraft. It describes a program for getting "ready to do by doing" in a preprototype manufacturing demonstration.

The philosophy underlying MSVD's approach to achieved reliability is founded on the premise that reliability is built into, not inspected into, a product. Thus, the prime objective of the program is to protect the inherent reliability based on design from degradation during the manufacturing cycle. In addition to the aforementioned preprototype manufacturing demonstration, the means used for accomplishing this objective are the manufacturing reliability matrix and degradation controls. (Authors)

After discussing some of the problems involved in implementing a reliability program in manufacturing, the authors present their material under the following headings:

A Manufacturing Reliability Organization
The Manufacturing Reliability Matrix
A Preprototype Manufacturing Demonstration
Reliability Audits.

REVIEW: This is a description of the approach of one company to the problem of producing equipment to serve for long periods without failure. As such, it may be of interest to others who are concerned with similar problems. ##

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Serial Number 700
Codes 816;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thin-film circuit packaging and the numbers game

AUTHOR: Arthur R. Meehan, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 101-104, March, 1962

PURPOSE: To place in proper perspective the practical electronic part densities obtainable by various packaging techniques.

ABSTRACT: By neglecting to define their terms, some electronics manufacturers have played "the numbers game" in their claims to the customer. In discussing any form of microsystems electronics, claims of millions of parts per cubic foot have become commonplace. The rub is that it is seldom clear whether one is discussing the number of individual parts stacked on a shelf, the parts in one circuit, a module, or an actual operating equipment. Indeed, if complex assemblies were built using some of the parts density figures quoted, the equipment would become a molten mass in seconds.

Using a typical missile computer as a reference, a "loose" printed wiring board design may have a packaging density of 4,000 parts per cubic foot, a production model a density of 14,000 parts per cubic foot, and with best design, 38,000 parts per cubic foot. A thin-film version of the same computer will have a packaging density of 300,000 parts per cubic foot, a factor of only 10 better than optimum conventional design.

Design factors of importance include a throwaway level of cost for individual modules, repairability, and thermal limitations. (Author in part)

REVIEW: The author contributes nothing that is new, but effectively reminds the reader that any highly touted claim must be rather carefully examined. An impression is gained from reading the paper that thin-film techniques are being downgraded, but while the techniques do not live up to the implications of some of the more extravagant claims, a 10 to 1 volume reduction is still a substantial advance. ##

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Serial Number 701
Code 835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thermal characteristics of potted electronic modules

AUTHORS: J. I. Gonzales and C. E. Waugh, Orlando Aerospace Division, Martin Marietta Corporation, Orlando, Florida

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 105-119, March, 1962

PURPOSE: To discuss the correlation and development of an analytical model for determining thermal transients in potted electronic modules.

ABSTRACT: The primary objective is to develop an analytical technique that can be used by the design engineer to predict thermal transients. By means of such an analysis it is hoped he can rapidly and efficiently (with a minimum of tests) design a thermally satisfactory and thus reliable potted electronic module.

The prototype module used in initial experiments had a high concentration of heat in a limited volume and thus indicated the need of efficient heat removal. Among the methods considered were direct forced air cooling, finned heat exchangers, liquid cooling and flat plate heat exchangers. Due to the size and shape of the module and space limitations, direct air cooling was used in conjunction with a flat plate heat exchanger (embedded heat sink).

Module heat loads and internal components were simulated during the experimental investigations because actual internal components were not available. These tests provided data for analytical correlation as well as background on different techniques for mounting the heat load simulators. Extensive tests were conducted which investigated the effects of air paths and variations in percentage of silica filler.

Epoxy filled with 50% silica is 2.5 times as thermally conductive as unfilled epoxy. (Authors in part)

REVIEW: The technical approach to the problem is sound and well presented by the authors. Note that Figure 3 shows the effect of filler to be negligible for $h = 50 BTU/Hr\text{-}Ft^2\text{-}^oF$. A curve for internal node 5 in Figure 5 would be informative because of the heat-dissipating component (transistor) located there. ##

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Serial Number 702
Codes 710; 770; 782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Space radiation resistor evaluation

AUTHOR: I. Doshay, Space-General Corporation, El Monte, California

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 192-205, March, 1962

PURPOSE: To describe tests and results of gamma irradiation of two Sprague film resistor types.

ABSTRACT: In this paper we describe an evaluation of 324 Sprague resistors of types RN65B and RN65C. It involves a statistically designed experiment of functioning and non-functioning parts exposed to a combined vacuum-radiation environment. The paper includes observations of resistors under load during exposure to a maximum of 7.2×10^7 Roentgens of gamma radiation (in a vacuum environment of 10^{-5} to 10^{-3} mm Hg) from a 10 Kilo Curie Cobalt-60 source.

The metal film resistors (1kΩ and 750KΩ, type RN65C) showed no measurable changes (less than 0.1%) in resistance either during or after the tests. The deposited carbon resistors (RN65B of 1KΩ were likewise unaffected, but the 1MΩ resistors showed some changes. These changes were between 0.2% and 0.7%, but appeared to stabilize at the new values after about 4×10^7 Roentgens.

There is also a discussion of the testing methods. (Author in part)

REVIEW: This appears to be a carefully planned and executed experiment. While caution should be exercised in generalizing these results, they will be of use to designers. ##

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Serial Number 703
Codes 710;770;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effect of radiation environment on film resistors

AUTHORS: Stanley O. Dorst and Leonard H. Wurzel, Sprague Electric Company, Nashua, New Hampshire

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 206-214, March, 1962

PURPOSE: To describe the results of gamma irradiation of two Sprague film resistor types.

ABSTRACT: This paper is a continuation of the one covered by Abstract and Review Serial Number 702. It deals with effects other than resistance change and weight loss. In general, except on the 750 KΩ carbon film resistors, there was no appreciable increase in current noise; the noise in the 750 KΩ units approximately doubled after 7×10^7 Roentgens of gamma irradiation. There was negligible change in temperature coefficient and physical properties.

REVIEW: The experiments in the first paper were considered to be carefully planned and executed. These results, as well as those of the first paper, should be of interest to designers. ##

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Serial Number 704
Codes 716;782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability studies of mesa transistors

AUTHOR: Frank Aubin, Airborne Instruments Laboratory, A Division of Cutler-Hammer, Incorporated, Deer Park, Long Island, New York

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 215-221, March, 1962

PURPOSE: To report the results of tests on the 2N1132 and 2N699 transistors.

ABSTRACT: The general philosophy of the test program has been to use sequential stressing or step-stressing to failure. In the first case, a representative sample is subjected to the stresses of shock, vibration, thermal cycling, humidity, and life testing, usually in that order. Characteristics are measured after exposure to each of the environments, and the resulting data analyzed with a view to prediction of characteristics variations. In the second case, the sample is subjected to repetitive stresses, either mechanical or electrical, of increasing severity, until failure occurs. The step-stress method yields data which indicates the strength of a part type and the available safety margins. The results may also be used to determine what, if any, selection procedures are necessary when purchasing particular transistor types to eliminate weak units and potential failures.

The most common mode of failure observed in these studies was that of failure of thermo-compression bonds. Failures of this type are generally caused by inadequate control of this portion of the manufacturing procedure. Nearly all semiconductor manufacturers have experienced this trouble at one time or another, and many still experience it periodically. Transistors that fail in this mode or other modes are generally not of high density in the end products. Though a given manufacturer's product may pass the requirements of military specifications on a lot-by-lot basis, units which are potential failures may still be delivered. Because the few potential failures cannot be tolerated under a high reliability requirement, techniques for culling out the worst of these have been developed.

The results are presented in a series of charts and cover the usual critical dc parameters. Some of the factors that have to be applied to original test limits as a result of the environment are quite large. (Author in part)

REVIEW: The experimental work seems to have been well done and the results, while not general, will be of some interest to designers. (Not all of the statistical data are given and thus it is not possible to judge the adequacy of the analysis.) ##

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Serial Number 705
Codes 831;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Establishing reliability requirements

AUTHOR: L. R. Diamond, General Telephone and Electronics, Inc., Sylvania Electric Products Inc., Sylvania Electronic Systems, Amherst, New York

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 222-231, March, 1962

PURPOSE: To show how design reliability estimates are made for bidding purposes.

ABSTRACT: The bid requests which are issued for research and development projects act as triggers to set in motion a number of activities within the organization of each potential contractor. At Sylvania, one of these deals with reliability. The first action taken by the Reliability Engineering Group is to develop specific reliability requirements for the particular type of equipment specified in the bid request.

To complete the evaluation, functional criteria are analyzed and reliability estimates are made to compare the feasibility of the proposed concept with the requirements. Some of the criteria considered are: physical environment, which includes the external and internal effects on the equipment as well as the use; maintainability; accessibility; skill level of the user; allowable downtime providing for necessary preventive maintenance; replacement of failed items; and availability. If the resulting evaluation fits the hypothesis, an optimum reliability statement can be written.

The possible design solutions are then postulated. After defining the basic system configurations and characteristics, functional block diagrams are developed. Factors influencing unreliability are screened carefully. At this point in the design, a rough reliability estimate is made utilizing current prediction techniques. Component part failure rates suitable for the design application and physical environments are evolved. Finally, the design is reviewed for its relative capabilities versus economic factors, technological factors, and customers need. (Three examples are given.) (Author in part)

REVIEW: The techniques presented here are reasonably standard. The examples are worked out in enough detail to be interesting but not tedious. Two minor criticisms are: (1) the use of four significant figures in the failure rates implies a precision much too large; two significant figures are usually quite adequate, and (2) in Example I, redundancy is used in one part, but the conditional failure rate is still presumed constant. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A quantitative approach to the evaluation of system reliability

AUTHORS: V. Lasewicz and S. Newman, Federal Aviation Agency, Atlantic City, New Jersey and H. Thomas, Federal Electric Corporation, Paramus, New Jersey

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 241-254, March, 1962

PURPOSE: To propose an evaluation index to completely describe the operational performance of a system.

ABSTRACT: System reliability prediction must be based on more than an evaluation of design excellence. Operational factors concerning personnel, maintenance, technical support, and logistics can greatly overshadow the inherent effects of good design. The authors propose an Operational Reliability Index (ORI) to encompass a complete system and reflect the combined influences of all the above factors.

The ORI, when finally calculated, becomes a system outage time in hours per thousand hours of operation. The expression converted to other terms is a measure of the system's percentage availability. It includes design parameters, population effects, maintenance and logistic efficiencies, and a number of personnel factors.

The algebraic expression used in calculating the ORI is shown semi-diagrammatically. It is seen to be a composite of system factors and hardware factors, each of which in turn is a composite of a number of sub-factors. The factors and sub-factors are briefly described. Failure report forms for the gathering of the necessary maintenance and operational data are illustrated.

REVIEW: This paper describes a concept which would appear to be very worthwhile for application in situations where sufficient data can be made available on all of the pertinent factors. The availability of data would appear, however, to be one serious limitation in many practical cases. If the suggested approach has been successfully applied in a situation of any complexity, it would have been useful if the authors had provided a case history study in a fair amount of detail, citing the difficulties involved, as well as the accomplishments of the method. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some aspects of test equipment reliability

AUTHOR: Frank A. Applegate, Light Military Electronics Department, General Electric Company, Utica, New York

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 255-261, March, 1962

PURPOSE: To derive equations which can be used to estimate the number of test equipments needed to service electronic units.

ABSTRACT: The parameters that need to be known are the mean time-between-failures (MTBF) and the mean-time-to-repair (MTTR) of the test equipment and the length of time required to check out the electronic unit to be tested. If the requirement is added that there be no waiting line for the test equipment, all of these parameters can be related if the probability of no waiting line is given; the required reliability can also be calculated. Graphs are provided which show the relationships among the parameters, and they can be used for making trade-offs. (An example is given.)

REVIEW: This is an adequate treatment of the subject within the framework laid down by the author. The "exponential" assumption is made about the time-to-failure distribution and the curves will be incorrect for cases in which this is not reasonable. ##

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Serial Number 708
Codes 813;816;860

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability in real time

AUTHOR: Thomas J. Scanlon, Epsco, Incorporated, Cambridge, Massachusetts

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 312-320, March, 1962

PURPOSE: To describe the methods used to manufacture a computer when the schedules were very compressed in time.

ABSTRACT: It was required to deliver some computers under a schedule which did not allow time for the usual lifetesting and reliability growth. In addition, the first model was both the prototype and the first finished unit. Under these conditions the design had to be quite conservative so that failures could be prevented rather than cured. Worst-case design and standardization were combined with design review and a fluid organization to solve the problem. A test program was set up for the modules. Serviceability was enhanced by modular/logical construction, elimination of field adjustments, self-testing features, good accessibility to the circuitry for maintenance, and training of field maintenance personnel.

The majority of failures during system growth were caused by printed circuit board defects. These were not solved until in-plant facilities were developed and used. Other problems were largely eyelet failures, mechanical damage to components during manufacture and test. An environmental test (thermal shock, humidity cycling, vibration) on finished boards helped to weed out the weak ones. A good field service follow-up helped to solve the usual field service problems. The system MTBF was 330 hr with an average downtime of 1/2 hr for maintenance by military personnel.

REVIEW: This is a good discussion of the trials and tribulations of rush work and the methods used to achieve success. The discussion of problems with suppliers of printed circuit boards gives the impression that the reliability advertised by these suppliers may be somewhat exaggerated. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Individuality in small-plant reliability

AUTHOR: Irvan J. Bearer, Martin Marietta Corporation, Baltimore 3, Maryland

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 321-330, March, 1962

This paper is the same as the one covered by Abstract and Review Serial Number 409. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Short term prediction of hook-up wire insulation cold flow

AUTHOR: Homer W. Hicks, International Business Machines Corporation, General Products Division, Development Laboratory, Endicott, New York

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 331-337, March, 1962

PURPOSE: To present an analysis of hook-up wire insulation cold flow.

ABSTRACT: This paper describes an investigation conducted to predict wire insulation cold flow which could result in short circuits between hook-up wires used in high-density wiring applications. The objective of the investigation was to qualitatively compare insulation resistance to cold flow. Approaches to solve this problem were both analytical and experimental. All data was obtained using a device (described in the paper) to stress the hook-up wire insulation. Although predictions were computed to 100,000 hours, they were checked experimentally to only 100 hours. No claims can be made for results to 100,000 hours except that, on a comparative basis, they follow the same trend as those checked to 100 hours. Experimental and predicted values agree within approximately 20 per cent. (Author)

REVIEW: This seems to be an adequate piece of work. No extravagant claims are made and the arbitrary assumptions are clearly stated. ##

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Serial Number 711
Codes 090;820;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Flow graph techniques for reliability engineering

AUTHORS: J. L. Burroughs and W. W. Happ, Microsystems Electronics Department, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: 1962 IRE International Convention Record, Part 6, New York, New York, pp. 338-366, March, 1962

PURPOSE: To show how flow graphs can represent relationships that are used in reliability calculations.

ABSTRACT: Essentials of flow graph techniques are concisely summarized emphasizing those aspects directly useful in reliability analysis. Illustrative examples of applying flow graphs to reliability problems include:

1. Reliability of systems with many types of variables.
2. Error propagation in systems with interacting variables.
3. Optimization of multistage decision processes.

A survey of over 100 cited references pertinent to the application of flow graphs to reliability engineering leads to the conclusion that a large number of reliability problems can be reduced to a few basic patterns. Flow graphs clearly reveal these patterns, thereby providing a systematic approach to solve a wide range of problems by reverting to existing patterns, if possible, or by adapting or combining known solutions. (Authors)

REVIEW: The use of flow graphs does not make the setting up of equations any easier, since the graphs are created from the equations. Because the presentation is graphical instead of literal, some of the relationships between parameters may be more obvious. It is not very clear how this technique will improve methods in reliability analysis, although it is well and comprehensively presented. The bibliography is extensive, including some 111 items. ##

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Serial Number 712 -1
Codes 812;832

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Development and evaluation of a simulator for evaluating troubleshooting performance on a complex electronics system

AUTHOR: A. J. Bernstein, Defense Systems Department, General Electric Company, Syracuse, New York

SOURCE: 1962 IRE International Convention Record, Part 9, New York, New York, pp. 192-199, March, 1962

PURPOSE: To describe a simulator for evaluating troubleshooting performance on a complex electronics system.

ABSTRACT: As a result of the high availability requirement on the Atlas Radio-Command Guidance System, it is important to maintain peak proficiency of the in-line maintenance crews. However, since faults in the system occur at relatively low frequency, the crews are not able to maintain their troubleshooting skill through the natural conduct of their work. While in some systems, maintenance crew proficiency has been maintained by "bugging" the line equipment, such a procedure on the Atlas system would have very deleterious effects on the weapon's availability. As a consequence, a simulator was developed to enable periodic exercising and evaluation of personnel in system troubleshooting.

This simulator, called the Data Flow Evaluator Set, replicates the system logic in binary form. A "trouble" is introduced by activating one of 250-odd switches, each representing a faulty assembly. When a switch is activated, the device will provide a replication of the symptom pattern in binary form. Symptoms which are automatically displayed in the line equipment are continuously displayed on the simulator while the fault is present. For symptoms which must be detected with test equipment, the subject needs to perform a simulated check to get the information.

By reading status lights and making checks the subject can localize the trouble to a removable assembly. In order to remove an assembly, he pushes the button which represents that assembly on the face of the simulator. If he has removed the proper assembly, the trouble will be automatically cancelled. If he has not removed the proper assembly, the symptom pattern remains and he continues signal-tracing until he finds the trouble. While the man is working, an automatic record is kept of the elapsed time and the number of checks and replacements he makes before correcting the trouble. For the purposes of test development, a manual record was also kept of his errors in following a logical signal-tracing procedure.

In order to test the capability of the simulator, a study was performed on two samples of Air Force personnel. As a result of this research it was learned that the time and check scores are

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reliable and independent parameters, while the replacements scores and the error scores are too unreliable to be used. Moreover, it was learned that scores on three different tests representing three subsystems of the major system are independent of each other and that the three different personnel specialities on the in-line maintenance crews may be considered samples from a single population. Validity studies were attempted but were handicapped by the absence of useful criterion data. Those validity data that were available (correlations with observer's rankings of performance on the actual equipment) did show some positive evidence of the value of the device as a predictor of actual job performance.

The value of the device as a trainer seems obvious in that practice in simulated troubleshooting should generalize to the job. Moreover, it is possible to use the device as an aid in lecturing, since a plastic overlay, showing the data flow lines, is provided with each machine and the machine has the capability of displaying all symptoms at once whether they appear at displays or check points on the line equipment. The use of the device as a trainer has not been systematically tested, however, and therefore further research on training applications is recommended. (Author)

REVIEW: The descriptions of the simulator, its development and evaluation are clearly presented, and the author has been frank about the limitations of the device as well as its advantages. Perhaps the most important question is that of how well performance on the simulator tends to correlate with actual job performance. The author in a private communication has indicated that the most critical problem in this connection is that of having valid criteria of job performance against which to correlate test scores. This problem has been of continuous concern to applied psychologists and thus far has proven to be quite intractable. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nomographs make for quick life-test calculations

AUTHOR: Victor Azgapetian, R & D Center, Servomechanisms, Incorporated, Goleta, California

SOURCE: Space/Aeronautics, vol. 38, September, 1962, pp. 203, 205, 207, 209, 211

PURPOSE: To present nomographs for making calculations based on life-test data.

ABSTRACT: Given a certain number of unit-hours of testing, and a certain observed number of failures, it is desired to calculate (a) the most probable life, (b) the median life, and (c) confidence limits on the true life of the unit under test. It is assumed that the units fail randomly and that all units have the same life. Two nomographs are presented for making these calculations. Criteria for determining when testing may be stopped and cost considerations are also presented.

REVIEW: This paper is an all-too-good example of an author giving an explicit solution to a problem that is not well defined. It demonstrates the fact that the basic assumptions and restrictions of the method should be stated, and that the equations which the nomograph represents should be indicated. If these two things are not done, a person has no idea whether or not the nomograph is one he wants to use, nor can he check the nomograph for accuracy should he want to do so.

The main errors, omissions, and debatable points in the paper, as well as the pertinent restrictions, are discussed in the following paragraphs.

The word "life" is used ambiguously, if not incorrectly. In most places where it appears, the expression "mean time-to-failure" should have been used. In life testing theory, life or time-to-failure (which we shall denote by t) is a random variable, whereas mean time-to-failure is a parameter of the distribution of this random variable.

The main assumption is said to be that the units fail randomly; but this by no means yields a unique distribution. The clue to finding the proper assumption is the use of "units x test time" as one of the parameters; it is characteristic of a Poisson process. A Poisson process is one in which the probability of an event in a short length of time, Δt, is $\lambda\Delta t$, where λ is a constant. (The probability of multiple events in Δt is negligibly small.) This assumption leads uniquely to the exponential distribution of times-to-failure. (See, for example, [1], p. 127.) There are other

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

random processes which lead to other distributions; e.g. if, instead of being a constant, $\lambda = \alpha t^{\beta}$ (where α and β are constants), the Weibull distribution is generated. The other assumption made in the text, that the units all have the same life (which should have read " ... same mean time-to-failure") would have been expressed more clearly by the statement that the units come from the same population.

The sentence (first paragraph) "Since failed units may have been replaced, we ..." is misleading. In the examples as worked out, the failed parts must have been replaced. In general, the parameter labeled "units x test time" is the summation of the operating times for all the units and it will make no difference whether all, some, or none of the failed parts have been replaced. The term "equipment hours" is sometimes used to express the concept of total operating time. Let us denote it by T.

If the failure pattern can be accurately described by a Poisson process, any operating unit is equivalent to a new one from the same population. Thus 100 units operating for one hour will give the same failure experience (value of T) as one unit operating for 100 hours, or any other combination of units and operating times yielding T = 100 unit hours.

From the tone of the article and the type of nomographs, it is reasonable to infer that the underlying assumptions are those of a Poisson process, leading to an exponential distribution of times-to-failure. It may also be inferred that the purpose of the testing is to obtain both point estimates and interval estimates of the true mean time-to-failure. The parameter T, representing total operating time as defined above, may be presumed to be equivalent to the nomograph parameter "units x test time." Let the number of failures during the test (on all units) be r. Now there are at least three ways to run the test. One might (a) test until a given number of failures (say r_o) has occurred, or (b) test for a fixed time (say $T = T_o$), or (c) continue the test until either $r = r_o$ or $T = T_o$, whichever happens first. The problems of parameter estimation are not the same in these three cases, but the author does not indicate the manner of testing to which his nomographs pertain. In reviewing this paper, an effort has been made to verify the author's results for cases (a) and (b), using the inferred assumptions and appropriate tables. As a result, the reader must be cautioned that any attempt to use these nomographs, or the other results in the paper which are based on them, will lead to misleading results.

The following additional points should also be noted.

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1. Figure 1 does not represent a typical life-time distribution, but is merely a sketch to show the relative positions of the estimates referred to in the paper.

2. Because of the lack of clearly stated assumptions, it has not been possible to check on the validity of Figures 2 and 3. A curve such as Figure 2 is calculated and used only before the test results are known. It should be noted that the upper line in the figure would most likely be used where T is the experimental result and the bottom one correspondingly for r. The use of this figure as some sort of sequential test is wrong. Cautions to this effect should have been included since the dotted line in the figure looks suspiciously similar to that for the progress of a sequential test.

3. In two places in the text on p. 209 the term "curve" is used where presumably the word "confidence" is meant. This is corrected in a larger version of these charts available from the author, which is somewhat easier to use. In a private communication the author has pointed out that "inner lower scale" was inadvertently substituted for "upper scale" and "outer lower scale" for "inner lower scale" in the text accompanying the larger version.

4. On p. 205 the directions " ... we would line up 6.3 on scale A ..." should read " ... we would line up 6.3 on the upper scale with 3 on scale A and read ... ."

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

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Serial Number 714
Codes 712;775;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determination of temperature profiles in microcircuits

AUTHORS: M. Walker, J. Roschen, and E. Schlegel, Philco Corporation, Lansdale Division, Lansdale, Pennsylvania

SOURCE: 28 pp., presented at the Electron Device Conference, Washington, D. C., October 25, 1962

PURPOSE: To present an infrared scanning technique for the experimental determination of temperature profiles in microcircuits.

ABSTRACT: An infrared scanning method for the experimental determination of the temperature profiles in microcircuits is presented. Results of tests on several thin-film tantalum resistors, a tantalum microcircuit, and a silicon microcircuit are given. Preliminary work indicates that this method of determining temperature profiles in microcircuits may become a valuable tool in the topological design of microcircuits where efficient circuit performance and high reliability are the goals. In addition, this method appears to hold promise as a means of predicting failure in microcircuits.

REVIEW: The authors' infrared scanning method of determining the temperature profiles in microcircuits appears to be a large improvement over existing experimental techniques in this area. However, the calibration of the experimental apparatus could become quite involved since it must be calibrated for each material of a specific microsystem with material thickness as a parameter (because the films are so thin). ##

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Serial Number 715
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of electronic equipment--an introductory paper

AUTHOR: N. Griffin, Royal Radar Establishment, St. Andrews Road, Malvern, Worcs.

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 3-10, January-March, 1962

PURPOSE: To give an introduction to reliability.

ABSTRACT: The limit to our technical achievements is fixed by the reliability that can be predicted for them. (The AGREE definitions are given for reliability terms.) Performance, availability, and long life are all desirable, but acceptable compromises must be made for a given equipment. It is wrong to regard reliability as predominantly a statistical matter just as it is in quality control. The total life of equipments is separated into three parts: (1) a short period of high failure rate, (2) a long period of low constant failure rate, and (3) a final period of increasing failure rate. During the period of constant failure rate, the probability of survival is given by the usual exponential formula. At high reliabilities, the mean life can be increased by a large amount and the reliability increase is quite small numerically. In order to prove high reliability statistically, a very large number of pieces must be tested--even with no failures (a table is given). Thus the economical method of establishing and maintaining reliability is by close control of the production line. The early failures can be eliminated through suitable tests. (A table of failure rates of typical components is given.) There is a need for parts with failure rates less than 10^{-4}%/1000 hr. Solid state techniques have the potential to lower rates appreciably. Management must be sure each project contains its share of reliability effort.

REVIEW: This introductory paper used the "exponential" assumption throughout; the beginner might get the false impression that this was the only failure distribution. The impression that low failure rates can be established without testing "astronomical quantities" of components is unfortunate. These samples may be selected from many production periods wherein the quality is presumed not to change, but they must be tested. (Accelerated testing is not mentioned.) There are misprints in numbers in the text dealing with reliability of components in service. It would have been helpful to give some reference to the source of the failure rates in the table. No criteria for failure are given so that the table could be for small drift failure or for catastrophic failures. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The statistical approach to the improvement of reliability

AUTHOR: E. D. van Rest, Department of Engineering, University of Cambridge

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 11-20, January-March, 1962

PURPOSE: To show how statistics is valuable in reliability studies.

ABSTRACT: Reliability can only be studied by observing more than one occasion or equipment. A statistical view of the problem is therefore essential. The frame of the statistical view is the pattern of variability experienced. One source of variability is the manufacturing process, another the whole-life environment of the equipment. The designer cannot design a reliable part for an equipment unless he knows the patterns of both of these. All stages of production, namely, approval, inspection, manufacture and use can contribute this information.

Because the reliability of an equipment is the product of the reliabilities of its parts, the standard of reliability required of the parts to produce even an equipment of poor reliability is high, unusually high by the ordinary standards of manufacture.

A general principle is stated for seeking and using the information recommended. It is that it is more efficient to seek it in the bulk of the product rather than from the rare failures of parts. The application of this principle in design, approval, inspection, manufacture and use is briefly discussed. (Author)

It is important to remember that so called "chance" variations and failures do have causes, and if necessary, these causes can, in principle, be isolated.

REVIEW: This article introduces statistics to designers and others; it treats the subject in a general way. No explicit distribution functions are given, so that the beginner in statistics is not misled into thinking that one formula will solve all his problems. The product rule and comments on numbers of parts apply to independent catastrophic failures. The introduction to response surfaces is good, although the engineer may be disappointed when he tries to get reliability information by making measurements at high stresses; in order to actually get quantitative estimates of reliability at stresses actually encountered, he must extrapolate by using some assumed distribution function (which may be difficult to find). There is, of course, much qualitative information to be gained by such measurements, including some idea of failure modes. All in all, it is a good article for the designer whose knowledge of statistics is deficient. ##

Serial Number 717
Codes 821;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and operability of systems of components in series and in parallel

AUTHOR: J. C. Turner, The War Office, Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent (Now at Nottingham and District Technical College)

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 21-26, January-March, 1962

PURPOSE: To examine the time to closure of simple systems of switches in series and parallel when the time to close of each switch has a normal distribution and a reliability which may be less than one.

ABSTRACT: In this paper the performance of various simple systems of components in series and in parallel has been examined in terms of the performance of the individual components. The particular concepts considered are reliability and operability, the first being defined as the probability that a component (or system) will operate at all, and the second describing the operation of a component (or system) with respect to a particular variable. The general system examined is that of mn components arranged as n sets, of m parallel components, connected in series. Several assumptions are made as to the parameters of the systems, and the reliability and operability functions, for various values of m and n have been calculated and are presented in tabular or graphic form.

Reliability is reduced by reducing n and increased by increasing m (a useful limit to m is three, even when n is quite large). Adding components in series will shift the operability distribution to the right, whereas adding them in parallel will shift the distribution to the left. In both cases the spread (or dispersion) is reduced, although skewness may be introduced. (Author)

REVIEW: This is an informative article and treats a subject that is not apparent from the title. The case for a useful limit of three to the number of parallel switches regardless of the number of series switches is not convincing. The largest n considered is three. ##

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Serial Number 718
Codes 821;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Digital-circuit reliability through redundancy

AUTHOR: A. A. Sorensen, Research and Development Division, Space Technology Laboratories, Inc., Los Angeles, California

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 27-37, January-March, 1962

This paper is identical to the one covered by Abstract and Review Serial Number 40, and gives an acknowledgement to the earlier publication. ##

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Serial Number 719
Codes 431;821;838;
872;882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability prediction for repairable redundant systems

AUTHOR: S. J. Einhorn, Auerbach Corporation, Philadelphia, Pennsylvania

SOURCE: Proceedings of the IEEE (formerly Proceedings of the IRE), vol. 51, pp. 312-317, February, 1963

PURPOSE: To develop equations for the prediction of the mean time to failure and mean down time for a system composed of a set of repairable subsystems.

ABSTRACT: It is assumed that the mean time to failure and mean repair time are known for each of the subsystems of a system. The subsystems conform to the usual exponential failure (and repair) laws and their behaviors are mutually independent. The system includes redundant subsystems in active standby status. Whenever, after a system failure, repair of a failed subsystem re-establishes an adequate configuration, the system as a whole is returned to active status while repair of other failed subsystems (if any) continues.

Under this set of assumptions, equations are developed which permit prediction of mean time to failure and mean down time for the system. The development differs somewhat from the use of birth-and-death equations which has been customary for similar problems in the past. (Author)

REVIEW: As indicated by the PURPOSE, this is a mathematical presentation; however, the use of the formulas developed is illustrated with a numerical example. The underlying assumptions are clearly stated. The background of the problem and its orientation relative to previous work in the area are indicated. Ten relevant references are cited. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability or liability?

AUTHOR: Robert G. Malech, Dorne and Margolin, Incorporated, Westbury, New York

SOURCE: Proceedings of the IEEE (formerly Proceedings of the IRE), vol. 51, p. 360, February, 1963 (correspondence)

PURPOSE: To satirize some of excesses in statistical calculations.

ABSTRACT: Typical reliability numbers associated with a part (system) have been R, MTBF, etc. But now we have a confidence, C_1, for each number. Pretty soon we will need a confidence, C_2, in C_1, and then a C_3 in C_2, ad infinitum. All this calculation takes time that should have been spent on engineering, so that reliability will actually decrease. Eventually, we will spend all our time on arithmetic and none on equipment. Everything fails, but who cares; the calculations are the important thing.

REVIEW: This is a short satire on some of the preoccupation with reliability statistics rather than with hardware. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A second evaluation of the industrial "300-volt" relay

AUTHORS: William Ketterer and William Frank, Research Center, The Warner & Swasey Company, Solon, Ohio

SOURCE: Electro-Technology, vol. 71, March, 1963, pp. 171-172, 174

PURPOSE: To report on the results of reliability tests conducted on three brands of "300-volt" industrial control relays.

ABSTRACT: The new 300-volt relays can be used in 115-volt ac control circuits and save space and money over the old 600-volt relays. A qualification test for the 600-volt relays has been applied to the 300-volt ones. This accelerated reliability test simulates actual service; four contact operations are checked: make a circuit but not break a circuit (make contact), break one but not make one (break contact), seal one without making or breaking one but where an inductive voltage surge may occur (seal contact), and interlock one without making or breaking one where an inductive kick does not occur (interlock contact). The sequential test circuit (shown in the text) is designed such that each relay picks up the next if all four contact operations have been performed properly. If a failure occurs, the system stops in a manner providing for the location of the failure. The system provides about 210 operations/min. with each relay energized about one-half the time.

The results of mechanical and contact failures for three manufacturers are shown in a series of graphs. The contact reliability depends on the mode of operation and depends greatly on the brand; the mechanical life is about the same for all. Overall reliability shows that one brand was definitely poorer and that none were as good as the 600-volt relays.

It is expected that the reliability and life of the 300-volt units will be improved to be better than those of the 600-volt ones. The manufacturers are all cooperating in correcting the faults shown by these tests.

REVIEW: The word "reliability" is not used in the probability sense and its meaning must be inferred from the text. One might guess that it refers to overall or contact life as opposed to mechanical life. In a private communication the author has stated: "We would like to point out that what we actually were trying to determine was the reliability of each relay and not necessarily the life. While in some cases reliability and life of a relay were equal, in other cases the reliability was quite low while the life high. We think it is important that you make clear that the term reliability does not mean long life."

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Since it was apparently feasible to present only average data, an analysis of the statistical methods is not possible. No mention is made of possible adverse effects of the speed-up by a factor of 20 or so.

These tests are quite interesting and useful, but one wonders why the customer has to do the life testing and failure analysis instead of the manufacturer. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Assuring reliability of encapsulated electronic units

AUTHOR: Leonard S. Buchoff, Kueffel and Esser Company, Hoboken, New Jersey

SOURCE: Electronic Evaluation & Procurement (formerly "IED" Industrial Electronic Distribution), vol. 3, March, 1963, pp. 28-29

PURPOSE: To point up the problem areas in selecting a potting compound.

ABSTRACT: The first step is to assure that the unit is properly designed. Five tips are given such as avoiding sharp corners and large masses of unfilled resin. The vendor should be chosen with care; extravagant claims or promises of everything are reasons to proceed with caution. The supplier's representative should have enough knowledge of the subject to at least appreciate the various problems you may have. The supplier's past performance should be investigated. This experience should be enough that he can recommend just a few formulations for you to try. All failures should be carefully analyzed. Suggestions are made for the type of batch tests to be run and the type of specifications to be used. There is an abbreviated table which lists the general properties of potting resins: epoxy, polyester, silicone, polyurethane.

REVIEW: This is an informative article for those who are just getting into the potting business. It deals more with vendor relationships than with materials properties and is most useful in that regard. The article deals only implicitly with reliability. ##

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Serial Number 723
Codes 710;720

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Typical reliability and performance characteristics for stored welding equipment

AUTHOR: James F. McFann, Weldmatic Division, Unitek Corporation, Monrovia, California

SOURCE: IRE Transactions on Product Engineering and Production, vol. PEP-6, December, 1962, pp. 6-11

PURPOSE: To discuss the present status of expected equipment performance, and how this performance can be related to process reliability.

ABSTRACT: In general, a significant portion of the overall responsibility for a reliable weld lies with the maker of the welder. The energy storage and capacitance measurements on capacitors are discussed. In the pulse transformer, the width and height of the pulse are both important. The variation in force at firing should be kept small. A final check on a system is making a series of test welds and analyzing them by strength and metallographic tests. In very critical cases, voltage regulation can be used to keep the weld energy independent of line voltage.

REVIEW: This is more a discussion of quality factors than reliability. All the points made are worthwhile. The discussion of capacitance could have been improved by giving the voltage which is used to measure the capacitance. A small voltage will not come as close to measuring the desired property as a large one would. In fact, for critical operations, one should probably measure the integral corresponding to the stored energy. ##

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Serial Number 724
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Assured reliability in soldered connections

AUTHOR: L. Pessel, Central Engineering, Defense Electronic Products, Radio Corporation of America, Camden, New Jersey

SOURCE: IEEE Transactions on Product Engineering and Production, vol. PEP-7, January, 1963, pp. 28-33 (presented at the Sixth National Conference on Product Engineering and Production, San Francisco, California, November, 1962)

PURPOSE: To present a new and better criterion for solderability.

ABSTRACT: The reliability of any connecting process is statistically governed by the number of process parameters. Significantly, for reliable welding a multiplicity of parameters requires close control, but reliable soldering depends primarily upon one--solderability of the surfaces to be joined.

The theoretical and practical implications of solderability and tests for its evaluation are discussed. An entirely new test is described which is rapid, simple, and significantly correlated with connection quality. The test is based upon an estimate of the contact angle between a molten solder preform and the metal surface. This concept is also linked theoretically with the surfact tension-interfacial tension relationship controlling "wetting".

This test has been used extensively in the evaluation of component lead wires and in measures to raise their solderability to the highest possible level, with remarkable effects upon connection quality. Formation of perfect fillets having mechanical and electrical redundancy becomes automatic, independent from the human element and little affected by variations of solder, flux, or procedure. Non-aggressive fluxes, and, in some cases, flux-less processes may be used. Highly reliable connections are obtainable with very low-melting and very high-melting solder alloys. (Author)

REVIEW: This may well be a good and improved technique of testing for solderability, but in implying high reliability for the joints the author has made at least two implicit assumptions: (1) A properly made solder joint will "never" fail, and (2) The entire population will have excellent solderability if a sample has it. (No quantitative data on life or fraction of joints defective are given.) In a private communication the author has indicated that the first assumption is supported by evidence on the Minuteman program and that the second is likely to be true if the processing has been reasonably uniform. ##

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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: 15 pp., presented at the Sixth National Conference on Product Engineering and Production, San Francisco, California, November, 1962

PURPOSE: To show some examples of good and bad practice in materials handling and packaging.

ABSTRACT: Space Scientists and Engineers are under continuing pressure to establish increasingly rigid performance parameters in product design. Material handling and packaging engineers must devise techniques, devices and systems to protect product performance parameters. A practical concept is needed to enable application of optimum industrial engineering to problems related to protection of space product reliability. This concept embraces recognition that space product manufacturers are part of a vast invention complex--and that this complex, in turn, is nothing more or less than an involved material flow. Accordingly, to enhance chances of space products to reliably perform; thoroughly integrated, cradle-to-grave protective packaging and handling systems and programs must be devised to cover every segment of the material flow--from raw materials to consumption. The manner of adoption of this concept by Lockheed's Missiles and Space Company and its efforts to bring to fruition practical results is presented. (Author)

Many examples of proper packaging and handling are illustrated.

REVIEW: Most of the text of the article is an explanation of the need for special attention in the packaging/handling areas. The illustrations show what the author's group has actually tried to accomplish. This area is certainly an important one in high reliability, low cost production. In spite of this, it has received little attention in the reliability literature (although it is perhaps adequately treated elsewhere), and a paper such as this can serve an important purpose. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: "Reliability" Engineering

AUTHOR: George A. W. Boehm

SOURCE: FORTUNE, vol. 67, April, 1963, pp. 124-127, 181, 182, 184, 186

PURPOSE: To present a feature article on reliability engineering, which describes some of the basic concepts involved, discusses applications to management problems, and forecasts future developments.

ABSTRACT: Reliability engineering is now making headway in quantifying the usefulness of a product over a period of time (which is denoted in the article as "quality"). From testing and statistical reasoning, engineers derive a number representing the probability that a product will function for a stipulated period of time. Calculations of this sort were developed mainly for predicting and evaluating the performance of complex military electronic systems. But the practice is rapidly spreading, and is currently being applied to a host of consumer products. In contrast to conventional quality control, which is usually confined to manufacturing, reliability studies start at the early design stage and extend through the useful life of the product. The reliability approach subjects engineering to tight economic control. (Illustrations are given.)

In spite of its potential value to management, to logistics experts, and to military planners, reliability engineering has yet to stir up real enthusiasm in many of the people who stand to benefit most. In some quarters it has met with indifference or opposition on the part of designers, manufacturers, procurement officers, and others. Consumers lack information about the reliability of most products, and thus cannot reckon how much extra they can afford to pay for it. While claims of reliability often appear in advertising, it is not highly rated for sales appeal. However, reliability engineering has been largely responsible for some technological masterpieces. For example, if a home radio were as well engineered for reliability as the Minuteman missile, it might be capable of playing continuously for more than a hundred years.

Some of the actions which have resulted from concern about reliability on the part of the Department of Defense are summarized. Certain fundamental concepts in reliability engineering are briefly discussed. These include ways of expressing reliability, the problem of defining failures, the concept of confidence level, the exponential distribution, the bathtub curve, redundancy, and accelerated testing.

Reference is made to the disadvantage of the inevitable lack of engineering history on components and systems under development in crash programs in the defense and space fields. On the other hand,

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RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

the makers of commercial equipment can generally adopt a more economical approach. In some cases attention is being given to such concepts as "serviceability" and "availability." The production of designs which are both reliable and economical is presenting an ever-widening challenge to the ingenuity of the engineer and the wisdom of the executive.

REVIEW: This is a well written and very readable paper. As such it accomplishes its purpose admirably. From the source in which it appears, one may reasonably infer that the author was writing essentially for management personnel at a relatively high level. The paper therefore has considerable potential usefulness in "selling" an awareness of and an appreciation for reliability engineering to those who may be able to do the most about implementing it.

The discussion of the technical aspects of reliability is presented at the level of the general reader. The author is to be commended for avoiding the inaccurate and misleading statements which so often appear in over-simplified descriptions of technical subjects. He has apparently done a very competent research job and has put the results together carefully. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability through controlled environments and microminiaturization

AUTHOR: G. W. A. Dummer, Royal Radar Establishment, Malvern, England

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 11-20

PURPOSE: To describe the up-to-date position in the United Kingdom on high quality components, liquid cooling, and microminiaturization.

ABSTRACT: Some general failure rate data on components are given as a function of calendar year and application. Reliability of equipment can be improved by cooling. One technique is to use a hollow chassis and/or covers through which a coolant is circulated. Thin film and solid circuit processes have a great potential in reducing failure rates if their problems of fabrication can be solved. The status of these projects is given in some detail. Redundancy is easier to use at these size levels and will be exploited.

REVIEW: This is a fairly detailed article that summarizes the progress being made in the United Kingdom. This interchange of information is very worthwhile. ##

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Serial Number 728
Codes 782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluation of wrapped polyethylene terephthalate capacitors

AUTHOR: Edward Bushnell, Engineering Department, Sprague Electric Company, North Adams, Massachusetts

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 62-67

PURPOSE: To present the results of tests on some Mylar capacitors.

ABSTRACT: The capacitors have a polyethylene terephthalate dielectric and are wrapped in a thin, pressure-sensitive, tape of the same material. The ends are sealed with resin. The average life is inversely proportional to the seventh power of the voltage and the average life at 125°C is 1/65 of that at 85°C at similar voltage stresses. The capacitors are rather sensitive to moisture; they should be derated to 1/2 their 85°C voltage in the presence of moisture. (More complete details of the tests are given in the paper.)

REVIEW: The terms polyethylene terephthalate (PETP), PETP polyester, and Mylar are apparently interchangeable, although the last is a trade name. Since it was apparently not feasible to give the statistical analysis of the data, the adequacy and completeness of the analysis cannot be judged. It would have been helpful to have a better idea of the uncertainty in the voltage and temperature relationships.
##

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Serial Number 729
Code 844

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, Transitron Electronic Corporation, East Boston, Massachusetts (*Now with Arthur D. Little, Inc., Cambridge, Massachusetts, **Now with Hewlett Packard Company, Palo Alto, California)

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 90-97

PURPOSE: To present the results of some experiments on anodized titanium oxide and thermal silicon oxide capacitors.

ABSTRACT: Titanium oxide capacitors were made using both titanium foil and evaporated titanium films. These were anodized at 80-100 vdc. The capacitors were aged and then covered with a silicone resin. The capacitors yielded about 0.050 $\mu f/cm^2$ or 1 to 4 μf-volt/cm^2 at reasonable (less than 50v) voltages. The properties were quite good--especially dissipation factor.

The silicon dioxide capacitors were made on high grade, very low resistivity silicon wafers by thermal oxidation. The insulation resistance and dissipation factor were excellent at room temperature. Up to 300°C these qualities remained acceptable. The units were rather resistant to nuclear radiation. The life was satisfactory on accelerated voltage and temperature tests. (More complete information is available in the text.)

REVIEW: These two materials have not been reported extensively in the literature and this paper presents good information. The life properties have not been investigated in detail, but the silicon oxide units, especially, seem to have a high potential life. ##

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Serial Number 730
Codes 813;824;831;
853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component reliability in orbiting satellites

AUTHOR: Charles F. Willard, ARINC Research Corporation, Washington, D. C.

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 172-177 (also appeared in similar form in Electro-Technology, vol. 70, October, 1962, pp. 96-99)

PURPOSE: To set forth the procedure which has been used and the results which have been obtained in estimating component reliabilities from orbiting satellites.

ABSTRACT: The only information available from an orbiting system is from telemetered signals and the actual failures are inferred. Two important concepts are "operational function group" (a combination of electronic units in series, which accomplishes a specific task), and "active element group" (a transistor or an electron tube with its passive networks). Satellite schematics are also used in the inferring process. The experimental methods are explained and reliability curves vs time are given for both concepts above. Finally a table of component failure rates is given.

REVIEW: This is an interesting and worthwhile paper. The author has treated a difficult subject well. The lack of either firm guide lines or statistical theory has made the task even more of a problem. While further advances will undoubtedly be made, the worth of this paper will not be diminished. ##

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Serial Number 731
Codes 830;844;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fuse usage in reliable equipments

AUTHOR: Marvin A. Dean, West Hempstead, New York

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 178-183

PURPOSE: To analyze the failure behavior and mechanisms of 3AG fuses.

ABSTRACT: Some positive conclusions relating to the manufacture and usage of cartridge fuses, with particular reference to their usage in equipments with critical reliability requirements, can be made. Fuses, when operated close to their rated values, offer a substantial and unwarranted reliability hazard. Considering the failure mechanism, it would appear that the failure rate would increase substantially if vibration were present at high load current to rating ratios. Prolonged operation near its rating will generally cause a fuse to degrade, as evidenced by an increase of its resistance, even when a failure does not occur.

The following recommendations for fuse usage and improvement are therefore proposed. For high reliability equipments, fuse usage should be minimized. Any fuses used should not be employed at more than 50% of their rated value. The entire system of fuse ratings and tests should be revised. Fuses should be tested in situations approximating their normal service. Fuse construction should be modified either to provide more reliable soldering methods for the fuse element or to utilize a mechanical crimping (solderless) junction. Fuses should be required to meet definite temperature derating requirements. Further fuse tests should be conducted to determine the relative effects on fuse reliability of current rating, fuse type, vibration, and mounting in enclosed fuseholders. (Author)

REVIEW: This is a good article on a worthwhile subject. The test results and conclusions are somewhat surprising and alarming. Certainly the fuse manufacturers should be quite concerned. The author and his company are to be commended for carrying out this investigation.
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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The unimite relay--its characteristics and statistically planned test program

AUTHORS: R. A. Holcomb and W. H. Lesser, General Electric Company, Waynesboro, Virginia

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 184-189

PURPOSE: To describe the characteristics of the unimite relay, and to outline the test program planned for its evaluation.

ABSTRACT: Development of the unimite relay began in 1958 as a logical next step beyond the two-pole, crystal-can relay. The goal--to create a suitable mechanical embodiment of the concept of a versatile sealed unipole contact module. The desirable module was to be an entity, capable of operation singly or in multiple from any suitable source of magnetic flux, in addition to meeting all the other normal requirements for a high performance aircraft relay. The result of this work was a cylindrical single-pole, double-throw one-amp capsule, hermetically sealed by inert arc welding and containing no organic materials, flux, or solder. Basic capsule dimensions are 0.125 in. diameter by 0.65 in. long. As a finished relay, the capsule is placed in a suitable coil which, in turn, is enclosed in a steel shell. The external shell acts as a return magnetic path as well as a cover.

The scope of the fabrication and evaluation program is outlined. Possible applications of the relay are indicated. The design of a group of life tests aimed at expressing its performance and expected life in terms of the statistical response to selected applied test loads is described. The basic design for the investigation is a five load factor, two-severity level, one-half replicated fractional factorial experiment. It is expected that the results can be expressed in terms of a response function of the load factors. Plans for the presentation of the test results are indicated. (Authors in part)

REVIEW: This paper accomplishes its purpose quite well, and the planned test program is described in a reasonable amount of detail. Since the program had not been completed at the time the paper was prepared, no results could be given. Perhaps the authors will present these in a subsequent publication. ##

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Serial Number 733
Codes 771;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aging studies on transformer insulating materials (Class A) by means of infrared spectroscopy

AUTHOR: G. Lengyel, Ontario Research Foundation, Toronto, Canada

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 190-194

PURPOSE: To show how infrared spectroscopy can be used as a tool in insulation studies.

ABSTRACT: Aging tests have been carried out both on wire enamel and varnished wire enamel samples. The samples were tested for dielectric strength at 60 cps at different stages of aging. After the insulation had been removed from the wire, it was analyzed in an infrared spectrometer. The spectra showed gradual changes with increased amount of aging, particularly in the C-H stretching and O-H stretching absorption bands. These data were correlated with other measured parameters of the material particularly breakdown voltage and the possibility of the existence of such a correlation has been found. The data from the spectra can also be used to determine an approximate value of the rate constant B of the Arrhenius equation. (Author)

REVIEW: Techniques such as this are a worthwhile addition to the study of degradation and failure mechanisms. This physics-of-failure approach should be encouraged at each opportunity. ##

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Codes 731;771;813;
835;844

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: Micromodule reliability

AUTHOR: Donald T. Levy, Radio Corporation of America, Semiconductor and Materials Division, Somerville, New Jersey

SOURCE: Proceedings 1962 Electronic Components Conference, sponsored by AIEE, EIA, and IRE, with participation of ASQC and SNT, Washington, D. C., May, 1962, pp. 195-200

PURPOSE: To present an up-to-date status report on micromodule reliability.

ABSTRACT: Micromodule reliability is the direct result of a planned retention of the best aspects of the conventional-component industry to which is added the desirable features of the micromodule techniques. Data from more than 65-million element hours of high-stress life tests have established the present level of micromodule reliability. The operating life-test program for digital modules indicates a per-element failure rate of 0.0177 per cent per 1000 hours. Because the digital module life tests have been the most comprehensive tests undertaken, they are the best indication of micromodule reliability. The established micromodule reliability management system is the best assurance that micromodule reliability will reach still higher levels to match or surpass the finest of conventional components. (Author)

REVIEW: A summary of this paper was covered by Abstract and Review Serial Number 518. The paper is an updating of a report covered by Abstract and Review Serial Number 110. The results seem to show that the MTBF of some conventional equipment could be improved by factors of from 5 to 30 by using micromodules. The author stresses the fact that the life data are on production as of January, 1962 and that many failure modes have been eliminated since then. ##

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Serial Number 735
Codes 831;853

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component reliability in orbiting satellites

AUTHOR: Charles F. Willard, ARINC Research Corporation, Washington, D. C.

SOURCE: Electro-Technology, vol. 70, October, 1962, pp. 96-99

The material in this paper is essentially the same as that in the paper by the same author covered by Abstract and Review Serial Number 730. An acknowledgment to the earlier publication is cited.
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Serial Number 736
Codes 200;761;823;
850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The qualification test--an isolated case of success

AUTHOR: T. C. Bowling, The Boeing Company, Military Aircraft Systems Division, Wichita Branch

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 11-16, April, 1962

PURPOSE: To discuss the limitations of the conventional acceptance test and to suggest improvements.

ABSTRACT: The usual sample of one in a qualification test is too small and the adverse environments are not applied long enough. The life test phase is usually carried out under favorable environments. It neglects the effects of tolerance variations within the limits specified by the designer and it ignores the random failure problem which is linked to design, manufacture, quality control, and service environment. A random failure is one which occurs during the constant failure rate phase, but it has a physical cause which can be prevented. If several specimens are tested, the entire life used up in the adverse environments, and corrective action is taken on all failures, the product will be greatly improved. It will be more difficult to give an estimate of mean life or reliability if these fixes have been made, but the mean life should be longer than otherwise. This will cost money and time, but the improvement in reliability can be large for a reasonable outlay.

REVIEW: This is a good indictment of the single qualification test and has good suggestions for improvement. The discussion of the lack of statistical proof of mean life is interesting and well taken. ##

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Serial Number 737
Codes 771;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: One-shot system reliability prediction and demonstration

AUTHORS: M. Freitag and W. A. Cleveland, Reliability Engineering, Ryan Electronics

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 26-32, April, 1962

PURPOSE: To present a suggested model of failure for frequently cycled (on-off) equipments.

ABSTRACT: The cycling on-off of equipments appreciably shortens their lives. Make the following assumptions.

(1) The equipments parts have conditional failure rate $\lambda_i \gamma$ for "random" failures where λ_i is the uncycled failure rate and γ is an acceleration factor related to the cycling rate and the specific equipment--all for the i th part.

(2) The failure rate for wearout has a Gaussian distribution with mean M_i/γ and standard deviation σ_i/γ where M_i and σ are the uncycled parameters--all for the i th part.

(3) The total conditional failure rate is found by adding the conditional failure rates due to (1) and (2) for each part. This model is being checked. An example is given.

REVIEW: The model is arbitrary at the moment and its success will be determined by the experimental tests. The mathematical development seems correct (although the author does not distinguish too well between the words failure rate and conditional failure rate--he uses the concepts correctly). The example is a special case involving one part with large M and large σ and four other parts with small σ and different intermediate M. The conclusions about replacing early wearout parts apparently applies only to the latter parts, not the first one. ##

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Serial Number 738
Code 822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Structural reliability of re-entry vehicles using brittle materials in primary structure

AUTHORS: L. D. Gregory and C. E. Spruill, Astronautics Division, Chance Vought Corporation

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 33-45, April, 1962

PURPOSE: To present equations for estimating the parameters of the Weibull distribution, and to show how the distribution can be applied to tensile failures of brittle materials.

ABSTRACT: Brittle materials have a large scatter in tensile strength when compared to ductile ones; therefore the simple use of a safety factor is not adequate for reliability purposes. The Weibull distribution with three parameters gives a reasonably good fit to this type of data. A predetermined stress distribution parameter is also used. A method of moments and a "least squares" method of estimating the three parameters are derived. These were applied to samples from a known distribution and their exactness in estimating the true parameters is shown. In general, the moment method was more accurate for small sample sizes. An example is given.

REVIEW: This is basically a theoretical paper and should be judged as such. In general, the author has done a good job of stating the assumptions and there appear to be no errors in the mathematics. There are three areas, however, in which important implicit assumptions have been made.

(1) The problem of failure due to repeated stresses (fatigue) has been ignored.

(2) The model for failure is a very simple one. If the principal stresses are more complicated, and in practical cases they would be, a more adequate model for failure should be used.

(3) In the least squares derivation, a particular function of each empirical failure probability was given equal weight. This at least strongly implies that the variability of this function of the probability is independent of the probability level. It is quite unlikely to be true and may account for the poor showing of the least squares estimation.

It should be emphasized that any parametric distribution is extremely unlikely to fit well at very high reliability levels such as 99.9% and higher. While one may wish to take advantage of large safety margins in this region, it is impossible to express the resulting reliability in a quantitative way. ##

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Serial Number 739 -1
Codes 823;824;831;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A reliability analysis and prediction technique applicable to electronic and non-electronic systems

AUTHORS: J. S. Donaldson and F. K. Heiden, Temco Electronics Division, Ling-Temco-Vought, Inc., Dallas, Texas

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 46-55, April, 1962

PURPOSE: To present a method of combining probabilities of element failure into a system failure probability.

ABSTRACT: A general mathematical technique is developed for the analysis and prediction of the reliability of a system composed of functionally connected elements which can individually be electrical, mechanical, hydraulic, pneumatic, electromechanical, etc. Requiring only the probability of failure by mode for each element, the technique is independent of the failure distributions of individual elements. The extension of the technique to complex systems composed of systems is indicated. For purposes of illustration the technique is applied to a "hypothetical" electrohydraulic servo actuator. This paper is concluded with some general remarks on the technique.

The trend toward greater system complexity and increased performance requirements intensifies the need for more accurate and flexible system reliability analysis and prediction techniques. The technique in this paper was developed to meet five basic requirements. These requirements are to provide system reliability which

(1) is by mode of failure,

(2) is independent of the failure distributions of the individual elements,

(3) is limited in accuracy only by the accuracy of available information on the individual elements,

(4) can be a function of more than one variable, and

(5) is a continuous analysis and prediction that grows with the system from its embryo stage through refined design, testing, and ultimate use. (Authors)

Basically the method involves a set of probabilities for (effectively) mutually exclusive failure modes of each element. These probabilities can be combined to give a probability of failure for each system failure mode.

REVIEW: This is a theoretical paper and should be judged as such. The mathematics seems adequate except for the following points:

(1) The pertinence of the section involving N ways of combining n system states is not clear.

(2) The reliability of the system is given as the product of

the probabilities of the non-occurrence of failure by the various system failure modes. Since the modes are not independent, the product is incorrect.

(3) In one paragraph where it is suggested that the procedure be repeated "for a sequence of values for one of the variables ..." it is not clear what is meant. More explanation than is given in the paper would seem to be required.

(4) The terms "first-" and "second order" are used, but are not defined in the paper. In a private communication, the first author has indicated that he did not feel that it was necessary to define these terms. However, not all readers may be familiar with them, and a short defining statement would have been helpful.

The first author has stated that the error noted in (2) was discovered too late to have the manuscript corrected before publication. He has indicated that because of this the following errors in the paper should be noted:

(a) The last sentence of the sixth paragraph in the section Determination of System Failure by Mode is incorrect.

(b) The last sentence in the section Simple Illustrative Example should read "The reliability of the system is given by

$$R = 1 - (Q_{open} + Q_{shorted})."$$

(c) The last two sentences in the section Complex System Example are incorrect.

(d) Figure 3 (Complex System Breakdown) contains in the block marked Complex System a system reliability calculated incorrectly.

He has also pointed out that the equations in the section A Special Consideration should be written with n instead of N. ##

Serial Number 740
Codes 821;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some thoughts on reliability estimation

AUTHORS: H. R. Lawrence and J. M. Vogel, United Technology Corporation

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 61-66, April, 1962

PURPOSE: To show how the probability of failure can be estimated using the safety margin concept.

ABSTRACT: Reliability is the only performance factor in a rocket engine which many people feel must be proved from scratch--ignoring the engineering knowledge already obtained. If the distributions of stress and strength for each part are known, the safety margin and the probability of failure can be calculated. If both distributions are Gaussian the margin will be Gaussian with mean equal to the difference between the mean stress and the mean strength and variance equal to the variance of the stress plus the variance of the strength. Quantitative calculations can now be made of the probability of failure by finding the probability that the stress margin will be negative. An example is given of minimizing the weight for a given total reliability by using Lagrange multipliers.

REVIEW: This is a fairly standard example of the quantitative application of safety margins to the problem of estimation of failure probability. There are two large problems associated with this method.

(1) Since at least one of the variances is estimated from a few data, the Gaussian distribution cannot be used to find the probabilities. As an example of what this could mean, five standard deviations corresponds to a probability of 3×10^{-7} for a Gaussian distribution, while for the Student's "t" distribution with 14 degrees of freedom the probability would be 10^{-4}. If the stress and strength distributions have different variances, the calculation of the probabilities, for small sample sizes, is difficult.

(2) The use of any particular distribution for calculating probabilities less than 10^{-3} involves taking a lot on faith. While the safety margin should be large, and the larger it is the smaller the failure probability, it is difficult to evaluate realistically this probability. ##

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Serial Number 741
Codes 841;846

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Can failure rate data be trusted

AUTHOR: L. G. Reynolds, Orlando Aerospace Division, Martin Marietta Corporation, Orlando, Florida

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 67-69, April, 1962

PURPOSE: To point out the problems in obtaining accurate failure rate data.

ABSTRACT: It is extremely difficult to get accurate failure data from field reports. Reliability which is estimated using established failure rates may be far from the observed value. Some of the reasons for poor field failure data are the omission of easy-to-fix failures, reluctance to admit human error, lack of knowledge of running time of the part, and lack of knowledge of the maker of the part. For very short missile flights, two corrective factors are suggested for application to the exponential prediction of reliability.

REVIEW: This paper raises many justified comments about failure data. These are the reasons why many people use a term similar to "ballpark" estimates. It would be expected, however, that the failure rate predicted by a manufacturer under controlled conditions would be reasonably accurate for those conditions. Certainly the view in this paper would cast doubt on the propriety of using three or more significant figures in failure rate calculations. ##

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Codes 824;841;846

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The uncertainty of reliability predictions

AUTHOR: Marvin H. Walker, Jr., Electro-Mechanical Research, Inc., Sarasota, Florida

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 70-72, April, 1962

PURPOSE: To show that estimates of failure rate are uncertain due to sampling errors.

ABSTRACT: Reliability predictions are uncertain due to many implicit assumptions concerned with design, application, and maintenance. Even if these assumptions are fulfilled, the parts MTBF will be uncertain due to sampling variations. If the exponential assumption holds, the estimates of MTBF are approximately (Normally) distributed with a standard deviation = MTBF/$\sqrt{F}$ where F is the number of failures and should be no less than 9. Formulas for combining estimates of the failure rates of parts into an estimate of MTBF of the system are given. (Author in part)

REVIEW: The comments on failure rate uncertainties due to sampling variations are well taken. It may be of interest to know that the sample MTBF ($\hat{M}$) has a distribution given by $\hat{M}/M = \chi^2(\upsilon)/\upsilon$ where $M = \upsilon = 2F_o$, M being the population MTBF, and F_o the number of failures. Confidence limits can be put on M directly, without the approximations of Gaussian tables, by the use of the χ^2 tables. This, and the text comments, are valid where $F = F_o$ is fixed before the test and the total part operating hours is the random variable (result of the test). If the reverse is true, then the distribution is different. See also Abstracts and Reviews Serial Numbers 679 and 713. When $\hat{\lambda} = 1/\hat{M}$ is used in combination with that for other parts, some complications set in. The variance of $\hat{M}$ is still given by M^2/F_o (this is true regardless of the size of $F_o \geq 1$). But once several of the $\hat{\lambda}$ are combined, the distribution of the resulting λ_T is not known. The variance of a sum is the sum of the variances (for independent variables) but confidence limits cannot be determined if the distribution is not known. It should also be noted that if y has a Gaussian or Chi Square distribution, 1/y does not have that distribution. ##

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Serial Number 743
Codes 817;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of a solar cell array--a procedure for conducting a tradeoff study of reliability versus weight

AUTHOR: R. M. Sirull, Research and Advanced Development Division, Avco Corporation, Wilmington, Massachusetts

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 73-74, April, 1962

PURPOSE: To outline a procedure for conducting a tradeoff study of reliability versus weight for a solar cell array.

ABSTRACT: The problem of designing a series-parallel arrangement of solar cells for the purpose of optimizing reliability as a function of the weight of the cells is considered. In particular, given a series-parallel network of n cells in series in each branch of the network and there being N branches necessary to deliver the minimum power required, adding K additional branches to ensure, with a high reliability, of having at least N branches operate is considered. A procedure for estimating values for K as a function of the reliability of the individual solar cell is outlined. (Author)

REVIEW: The results here are reasonably standard and probably appear elsewhere in the literature. The methods of calculation are standard.

For other papers on the reliability of solar arrays see Abstracts and Reviews Serial Numbers 651 and 775. The first of these deals with the degradation and complete failure of solar cells due to radiation and meteoroid impact. The second is a theoretical analysis of the reliability of solar arrays. ##

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Serial Number 744
Code 836

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability design review techniques

AUTHOR: K. A. Frederiksen, Skybolt Systems Subdivision, Douglas Aircraft Company, Inc., Santa Monica, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 75-78, April, 1962

PURPOSE: To illustrate how design review can uncover weak points in the system.

ABSTRACT: Reliability starts with design. There are several types of design reviews: they can be formal or informal and can occur at various stages in the design. In early design, each subsystem is allocated a reliability goal. Then the reliability of each subsystem is predicted by simple parts count. Those which fall short of the goal are improved by redesign. This can take the form of parts elimination, environment severity reduction, derating, etc. An example is given.

REVIEW: This is a short example of the role of a design review activity in the upgrading of a design so that its estimated reliability is adequate. It should be noted that no comparison of actual reliability was made with the prediction. While it may be a minor point, reliability can actually be said to start further back than design--in the proposal/specification stage. It is interesting to compare this paper with others from this symposium (such as those covered by Abstracts and Reviews Serial Numbers 741 and 742) which cast doubt on the reliability estimation process. ##

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Serial Number 745
Codes 771;813;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability test optimization

AUTHORS: Charles A. Locurto, W. Thomas Weir, and John S. Youtcheff, General Electric Company, Missile and Space Vehicle Department

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 87-97, April, 1962

PURPOSE: To present the elements of a test program model and associated methodology for the demonstration of system performance and reliability.

ABSTRACT: In the development of modern defense and space-exploration systems, attention must be given to the planning and evaluation of environmental tests which yield a maximum amount of reliability information at a minimum cost. A test program model which provides for the development of an integrated environmental test program, and for the analysis and evaluation of test results is presented. The model also provides a means of formally qualifying equipment which has demonstrated design capability to meet its operational requirements. The integration of test activities through this model permits sufficiently comprehensive test planning at all equipment levels. This results in the optimum utilization of all test data in the demonstration of system reliability and performance requirements.

Topics discussed in the paper include: test considerations, integrated test program model, and analysis and evaluation of test results. Several illustrations are given. The requirements and responsibilities for department qualification of equipment at G-E MSVD, as well as some pertinent mathematical formulae are presented in two appendices. (Authors in part)

REVIEW: This is an outline of a test program for system reliability demonstration which one company has found to be effective. As such, it could be of value to others involved with the setting up and/or operating of similar programs. In keeping with the PURPOSE, the paper deals with general aspects rather than specific details. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Vendor data--fact or fiction?

AUTHORS: Marvin R. Carpenter and Leonard G. Rado, Reliability Department, General Precision, Inc., Librascope Division, Glendale 1, California

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 103-110, April, 1962

PURPOSE: To show how the test data on component behavior presented by vendors have improved in recent years, and how they may be of help to users.

ABSTRACT: In this paper, we have raised several questions about the dependability and usefulness of vendor data and have attempted to provide admittedly tentative answers. A truer, more complete picture might emerge if an actual case study of a system designed and built with the help of vendor data were performed. In the absence of such a study, we must rely on our own experience, which leads us to believe that vendor data can be of significant help to the user of high-reliability electronic components. Our judgment is based on the following considerations:

1. Vendor data gives user test-lab personnel much preliminary information about components. Thus the user can immediately eliminate many components and tests which do not pertain to his requirements; he can then concentrate his test efforts where they will do the most good.

2. In general, vendors can afford to test larger samples than users can; it is practical for vendors to test units from many production lots on a nearly continuous basis, while users can seldom afford to test units from more than one or two lots. Thus vendor data usually reveals more about a component's over-all application capabilities.

3. For the two reasons just mentioned, vendor data provides an excellent starting point, or reference, from which component users can begin to write procurement and application specifications to detail their own unique needs.

Again, a word of caution. The component user should not rely blindly on vendor information in preparing his own specifications, nor should he overgeneralize on it. We feel, however, that most vendors are sincerely trying to make their data presentations as useful--and as accurate--as possible. Component users can help by telling vendors as much as possible about the details of the application. Vendors are now asking: "What kind of information do you want? How do you want it presented? What are the shortcomings of our present data?"

It is hoped that this paper will stimulate consideration of vendor data and accelerate the trend toward better vendor presentations. The user pays for this data every time he buys a component. Econom-

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ics dictate that he should use it. (Authors)

REVIEW: The problem of separating fact from fiction in vendor advertising has undoubtedly plagued most users of components from time to time. While the authors of this paper make no claim that they have solved the problem, they have presented a very worthwhile piece of work. They are to be commended for addressing themselves to these questions in a manner which appears to be both competent and reasonable. ##

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Serial Number 747
Codes 782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Space environments and the reliability of hydraulic controls

AUTHOR: A. B. Billet, Aerospace Hydraulics Division, Vickers Incorporated

SOURCE: Proceedings of the IAS Aerospace Systems Reliability Symposium, Salt Lake City, Utah, pp. 111-119, April, 1962

PURPOSE: To outline the effects of space environments on the reliability of hydraulic controls, and to indicate some ways of improving that reliability.

ABSTRACT: The effects of space environments on hydraulic controls are discussed briefly under the following headings: high temperature and temperature shocks, low ambient pressure, ozone content, radiation and cosmic rays, and disassociated atomic oxygen. Some of the ways of minimizing the effects of these environments are outlined. Reference is made to some of the special procedures for the hydraulic components used in such vehicles as the Minuteman, Polaris, Atlas, and Skybolt missiles. The presentation includes a number of pictures and figures.

REVIEW: This paper indicates that considerable success has been achieved in the reliability of the control systems of space vehicles, in spite of the fact that initially there was little, if any, past experience on which to base design decisions. Papers such as this serve a useful purpose in summarizing the results of the experience which has accumulated. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Graphic sampling plans for consumer acceptance of electronic components

AUTHOR: L. Danziger, IBM Corporation, Poughkeepsie, New York

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 127-141, May, 1962

PURPOSE: To provide sampling plans graphically, whereby the consumer can be assured that the minimum mean life (or maximum failure rate) is no worse than a specified value with a given confidence.

ABSTRACT: Sampling plans are presented graphically whereby the consumer can be assured that the minimum mean life (or maximum failure rate) is no worse than a specified value with a given confidence. It is assumed that the time to failure of the units is exponential (constant failure rate) and that the populations are infinite in size. Samples of n units are placed on life tests which may be run "with replacement" or "without replacement" of the failed units. In either case, the test is stopped if c + 1 units fail before the assigned test duration, or if no more than c units fail by the time the specified time is reached. The first outcome leads to rejection and the latter to acceptance.

Values of (test duration/mean life) are presented graphically for sampling plans "without replacement" for n = 1 - 1000 at several confidence levels from .75 through .99 and acceptance numbers 0 through 10. For any given choice of consumer plan, tables are given from which an approximate operating characteristic curve can be quickly obtained so that the producer's protection can also be assessed. These tables can be used to define a plan which most nearly satisfies producer and consumer interests.

Values of the expected number of failures are given for sampling plans "with replacement" at several confidence levels from .75 to .99 and acceptance numbers 0 through 15.

In general, for the same initial sample sizes, the replacement plans require shorter test duration at the expense of the potential use of more units. If the test durations are equated, then the replacement plans require smaller initial sample sizes but one must have additional units available to replace failed units.

REVIEW: This paper constitutes a useful addition to the literature on acceptance sampling plans for testing for a minimum mean life with a guaranteed consumer protection. The material is clearly presented, and a number of numerical examples are given. Five relevant references are cited. ##

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Serial Number 749
Codes 552;822;824;
840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction of failure rates by the Weibull method

AUTHOR: John W. Webb, Marathon Electric, Wausau, Wisconsin

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 271-285, May, 1962

PURPOSE: To explain to engineers and technicians the use of Weibull graph paper in the analysis of life test data.

ABSTRACT: This paper is concerned with the graphical fitting of life test data to known statistical distributions in order to determine the mean time between failures. Plots of four distributions of percent failed versus time or steps are shown. Some typical data giving percent failed in terms of age in steps are cited. These data are plotted on exponential paper, on normal probability paper, and on Weibull paper. In each case the goodness of the fit is judged in terms of the linearity of the plot. The calculation of the mean time between failures is illustrated. Brief reference is made to median ranks, delay factor, separate populations or bi-modal distributions, confidence limits, truncation, and computer programming for the calculation of mean time between failures. Four references are cited.

REVIEW: In keeping with its purpose, this paper does not go into the theory underlying the graphical approach which is discussed. Presumably this theory is found in the four references which are cited, and the reader interested in fully understanding what was done will probably wish to refer to these.

Certain aspects of the paper are rather confusing. Examples follow. The author presents plots of "four typical life curves," but makes the remark that at least one of them is "highly idealized." In the situation to which the remark applies, a period of initial failures is followed by a period of no failures. In two of the plots, rising portions of the curves are represented by negative exponential functions, which clearly must decrease as the independent variable increases. In Figure 3 the horizontal scale is not identified, but it would seem that it represents age in millions of steps, whereas the vertical scale apparently represents percent failed. These points mar the clarity and readability of the paper.
##

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Serial Number 750
Codes 836;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Testing and analysis for marginal design

AUTHORS: Martin W. Joseph and John Massey, Elgin National Watch Company, Elgin, Illinois, and Louis Zboran, ITT Kellogg, C. S. D., Chicago, Illinois

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 287-302, May, 1962

PURPOSE: To discuss the features of a testing and analysis program for the evaluation of the reliability of a new design.

ABSTRACT: Any successful reliability program must embody clear-cut definitions of the system's performance requirements, and of failure criteria for the system, its subsystems and components. It must include a detailed engineering description of the system, its expected outputs and operating conditions, as well as appropriate part specifications. While catastrophic failures are fairly straightforward, degradation failures are generally difficult to define, predict, and recognize. A fixed criterion must be agreed upon, and must reflect the assumptions made by the designer in developing the circuit. Such assumptions must be defined before a program of reliability for marginal analysis can proceed.

An example of the end-of-life limits and reliability considerations in the design of a monostable triggering circuit is cited. The methodologies and philosophies pertaining to testing and analysis for marginal design are discussed under the following headings: Analysis of Tolerance Designs, Implementation of Findings, and an Empirical Approach to Worst Case Analysis.

REVIEW: This paper is a discussion and illustration of some facets of the evaluation of the reliability of a new design, with particular reference to design reviews and the worst case technique. As such it could be of interest and value to designers. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Practical applications of the Weibull distribution

AUTHOR: J. N. Berrettoni, Department of Statistics, Western Reserve University, Cleveland, Ohio

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 303-323, May, 1962

PURPOSE: To show the widespread applicability of the Weibull distribution.

ABSTRACT: In many cases of analyzing data, one is confronted with finding the appropriate distribution to describe the pattern of variation of the empirical data. The usual approach to this problem is to plot the data on normal probability paper and then to accept the normal distribution as a representation of the underlying distribution of the empirical data if the data plot as a straight line.

Another approach to this problem, and a more general one, is to plot the data on Weibull Probability Paper (WPP). And, if the data plot as a straight line, then we may accept the Weibull distribution as a representation of the empirical data. This approach is more general because other distributions, such as the exponential and the normal are related to or approximated by the Weibull and because the Weibull plot is very sensitive in showing heterogeneous and/or mixed distributions.

This paper shows the widespread applicability of the Weibull distribution in describing empirical data. The diversified applications used for this purpose are

1. Corrosion resistance of magnesium alloy plates
2. Return goods classified by number of weeks after shipment
3. Number of down times per shift
4. Leakage failure of dry batteries
5. Life expectancy of ethical drugs
6. Reliability of step motors
7. Reliability of solid tantalum capacitors. (Author)

REVIEW: This paper accomplishes its purpose, as the Weibull distribution seems to provide a very good fit for the data in the examples cited. Such a paper is useful because of the importance of the Weibull distribution in reliability analyses. The mathematical basis for the estimation of the parameters of the distribution by means of Weibull probability paper is given in an appendix. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Planning for reliability optimization

AUTHOR: Alexander Sternberg, General Electric Company, Missile and Space Vehicle Department

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 325-338, May, 1962

PURPOSE: To discuss the planning stage in the control and maintenance of the reliability of a missile system.

ABSTRACT: Trade-off analysis is an essential part of the planning effort associated with a reliability program. The prime considerations to be taken into account in this analysis are the limitations imposed by statistical analysis, time, equipment, and reliability goals. These limitations have to be evaluated in order to determine optimum testing programs. Reliability and confidence estimates, program and test schedules, and equipment and testing costs must be explored. Reliability trade-off analysis begins with the development of the time limitations imposed by the program schedule. Maximum testing times are established early. The amount of testing is further limited by available funding. Thus program schedules and funding restrict the trade-off parameters to those of reliability objectives, sample sizes, and confidence estimates.

Curves have been established to illustrate how reliability, confidence, sample size, and costs are functions of each other. Testing programs are designed to meet all the criteria imposed by the development program. For simplicity it has been assumed throughout the analysis that equal stresses are applied to components in both component and system testing. This assumption can be modified if the system test data warrants it. A method has been developed, and is illustrated in graphical form, to estimate the confidence that can be placed on system reliability using component test data. The individual failure rates of the components are summed to form an estimate of the system failure rate. In conjunction with this, an estimate of the confidence in the system reliability has been established. Figures are used to illustrate how this method can serve as a guide in developing levels of testing programs. (Author in part)

REVIEW: The ideas and results in this paper are presented largely in the form of graphs, tables, and charts accompanied by a rather brief discussion. On some points the reader may desire more detail than is given. In particular, this is likely to be true in connection with the estimation of the confidence to be placed on system reliability using component test data. Other papers addressed to the problem of confidence limits on system reliability have been covered by Abstracts and Reviews Serial Numbers 152 and 227. ##

Serial Number 753
Codes 512;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability demonstration

AUTHOR: Frank M. Gryna, Jr., Space Systems Division, Martin Company, Baltimore 3, Maryland (current affiliation: Associate Professor of Industrial Engineering, Bradley University, Peoria, Illinois)

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 339-352, May, 1962

PURPOSE: To review the statistical aspects of reliability demonstration tests, to discuss the sources of reliability demonstration data, and to present an approach for combining the engineering and statistical aspects of demonstration.

ABSTRACT: Reliability demonstration is considered as a series of tests of a product to determine whether or not a numerical reliability requirement has been met. Three of the important objectives of such a demonstration are: (1) to obtain proof of compliance with a contractual reliability requirement, (2) to provide data for evaluating progress toward meeting the requirement, and (3) to obtain data on current hardware to provide application information for use in future products. A reliability demonstration plan should provide for achieving these objectives.

The statistical aspects of reliability demonstration are discussed under the headings of two statistical concepts--confidence level and the operating characteristic curve. Two basic practical problems in demonstration are briefly considered, viz. cost and late detection of non-compliance and/or equipment problem areas. In considering solutions to these problems, reference is made to two areas: (1) the use of part and component test data to simulate system tests and (2) the use of a statistical risk concept which makes maximum use of all past test data. An approach called "effective confidence level" is described. (Author in part)

REVIEW: This is a useful paper for those who are concerned with both the engineering and the statistical aspects of reliability demonstration. The author presents these in a reasonable perspective. His emphasis on the combining of engineering and statistical judgment to use all valid data and to develop better demonstration techniques is very worthwhile. Eight pertinent references are cited and two appendices provide help in the design of a reliability demonstration plan. ##

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Serial Number 754
Codes 844;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure modes in high reliability components

AUTHOR: George P. Anderson, Reliability Engineering Department, Remington Rand UNIVAC, Division of Sperry Rand Corporation, St. Paul 16, Minnesota

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 353-362, May, 1962

PURPOSE: To review some failure studies made on high reliability components, to indicate the need for feeding back good failure data to suppliers, and to discuss the over-all value of failure analysis in reliability engineering.

ABSTRACT: The reliability of equipment or systems depends primarily on their design. An important aspect of reliable design is that of reliable component selection. Even given reasonable success in these areas, failures must still be expected. It must be recognized that every failure has a cause, and the important consideration is that of learning from the failures. The major reliability problem observed during the development, assembly, and operation of high reliability hardware at UNIVAC has been the catastrophic failure of components selected for their reliability. Semiconductor devices are the biggest offenders. This paper reviews some of the failure studies made on premium priced components procured to carefully formulated specifications and purchased from qualified, reputable suppliers.

The major headings in the discussion are Diode Failure Modes and Transistor Failure Modes. The discussion is illustrated with 36 pictures. Instances are shown where increased reliability of a device resulted from the feedback of failure mode information to a supplier. Some doubt is cast on claims of "inherent reliability" for semiconductor devices.

REVIEW: This paper represents a realistic approach to the problem of failures in electronic equipment. The premise that every failure has a cause is the natural foundation for a program which seeks, insofar as possible, to identify those causes, and to feed the resulting information back to those who should be able to take at least some preventive action against failures due to such causes in the future. It would seem that at least part of this preventive action would involve the exercise of greater care and attention to detail on the part of the human element. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Computer generation of Poisson integers

AUTHOR: Edward C. Varnum, Barber-Colman Company, Rockford, Illinois

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 363-370, May, 1962

PURPOSE: To describe a computer method for generating Poisson integers.

ABSTRACT: By applying the von Neumann rejection method, a sequence of Poisson integers is obtained from a flow of random numbers. Code sheets for the generation of a series of pseudo-random numbers and the resultant Poisson integers are shown, along with numerical examples obtained on a computer at the author's company. The paper is introduced by a review of the Poisson distribution and its relationship to reliability studies. (Author)

REVIEW: Approximately one half of the text of the paper is devoted to the derivation of the mean and variance of the binomial and Poisson distributions. The von Neumann rejection method and the computer program are briefly described. The chief usefulness of the program, as the author has indicated, arises from the fact that a flow of Poisson integers may be used in simulating the operation of many types of equipment and systems. ##

Serial Number 756 -1
Codes 222;820;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Use of the military standard plans for hazard rate under the Weibull distribution

AUTHORS: Henry P. Goode and John H. K. Kao, Department of Industrial and Engineering Administration, Sibley School of Mechanical Engineering Cornell University, Ithaca, New York

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 371-389, May, 1962

PURPOSE: To present a procedure, together with necessary tables of products, for applying the MIL-STD-105B plans to acceptance sampling inspection when the quality of items in the lot is evaluated in terms of the instantaneous failure rate or hazard rate as a function of time.

ABSTRACT: A procedure is presented for applying the MIL-STD-105B plans to acceptance sampling inspection when the quality of items in the lot is evaluated in terms of the failure rate or hazard rate as a function of time. Inspection of sample items is by attributes with life testing curtailed at some pre-assigned time. The Weibull distribution is assumed as the underlying life length model. The location and shape parameters of the Weibull distribution must be known or estimated from theory or previous experience. For the application of the procedure the value of the scale parameters need not be known explicitly as the hazard rate contains information on its magnitude.

The selection of a suitable plan, the determination of its operating characteristic in terms of hazard rate for a specific plan, and the determination of an appropriate life testing time are all made through the use of 11 tables covering a range of Weibull shape parameters from 1/3 to 5. The probability of acceptance for a lot depends only on the probability of an item failing before the end of the test period, t. The actual life at which an item fails is not needed since inspection is on an attribute basis. The operating characteristic for any sampling plan specified by the acceptance number and sample size depends only on t and Z(t), the hazard rate. With t and Z(t) specified, a sampling plan can be selected.

Each table provides $t \cdot Z(t)$ for each combination of sample size code letter and the rejection numbers used for each Acceptable Quality Level of the 105B plans. From the procedure, plans may be evaluated in terms of either the producer's risk or the consumer's risk.

By simple modification, double or multiple sampling can be used.

REVIEW: The procedures and tables presented in this paper are based on the paper by the same authors covered by Abstract and Review Serial

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Number 202. The comments in that review apply also in this case. A corresponding paper prepared by the authors for use when lot quality is evaluated in terms of mean item life was covered by Abstract and Review Serial Number 208. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quality control for a total weapon system

AUTHORS: Eloise E. Bean* and Wilbur A. Steger, The RAND Corporation, Santa Monica, California (*current affiliation: Planning Research Corporation, 1333 Westwood Boulevard, Los Angeles 24, California)

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 391-399, May, 1962

PURPOSE: To describe a major facet of a three-year-old RAND Logistics Systems Laboratory study which could be of interest to those involved in the quality control of the reliability and overall performance of a total weapon system.

ABSTRACT: There are many contingencies involved in the planning and development of an entire weapon system. Throughout thousands of actions the ultimate goal of producing the most effective weapon system for a specified budget must be kept in mind. Weapon system quality control actions are those actions taken during the weapon planning and development cycle to help insure a high degree of confidence in the overall system. To achieve this, it is necessary to combine the anticipated results of the many individual quality control procedures into an estimated performance expectation for the overall system. This paper suggests one method of achieving this systematization.

The proposed technique is a detailed computer-assisted simulation experiment modelled on the entire system. It is suggested for use as a centralized control device to obtain weapon system oriented decisions about the allocation of quality control budgets between alternative uses in a given system. The paper consists of a description of the technique as developed and used in the RAND Logistics Systems Laboratory, and a discussion of its possible uses as an allocation device for quality control decisions regarding a weapon system.

REVIEW: This is essentially a brief description of a simulation model together with an indication of some areas in which it could be useful. The ideas may prove helpful to those who are concerned with assessing the reliability of complex systems. The implementation of such a model for any specific system will, of course, require careful study of all of the pertinent features and requirements of the system and the associated development and testing program. ##

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Serial Number 758
Code 822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Criteria for the identification of a probability distribution based on analysis of life test data

AUTHORS: Richard Meyers and Leonard Stern, International Electric Corporation, A Subsidiary of International Telephone and Telegraph Corporation, Paramus, New Jersey

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 401-425, May, 1962

PURPOSE: To outline a method of defining and isolating an underlying probability distribution for life test data.

ABSTRACT: This paper is concerned with criteria which an experimenter may use to make a decision regarding the most suitable probability distribution for a given set of life test data. The distributions considered are the exponential, Poisson, compound Poisson, incomplete gamma, incomplete beta, and Weibull. The methodology for fitting each distribution and testing for significant differences is discussed and illustrated. A comparison of the results is made.

REVIEW: This paper contributes nothing that is new since the methodology for fitting distributions, and that for assessing the goodness of the fit by the X^2 test, are covered by many standard references on statistical methodology. A considerable amount of space in the paper is devoted to derivations of results which are well known for the distributions considered. ##

Serial Number 759
Codes 720;841;844;
864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A case study of component failures

AUTHOR: Walter R. Kuzmin, Packard-Bell Electronics Corporation (Now with Aerospace Group, Hughes Aircraft Company, Culver City, California)

SOURCE: Transactions Sixteenth Annual Convention, American Society for Quality Control, Cincinnati, Ohio, pp. 427-437, May, 1962

PURPOSE: To present case histories of component failure investigations and to suggest a means of initiating corrective action by the use of appropriate check-off procedures.

ABSTRACT: Many investigations of the malfunctions of systems have indicated that failure to follow a good quality control program or to maintain adequate procedural documentation has permitted errors to be made repeatedly. It is important to understand the need for properly documented procedures such as specifications, drawings, test procedures, etc. Illustrative case histories are presented, consisting of the following: Key Switch, DC Amplifier, Time Delay Relay, and Capacitor. Some of the features of a reliability program, and the need for them as indicated by the case studies, are indicated.

The following conclusions are drawn. Failure to properly adhere to necessary documentary procedures for the design and development of a weapon system can be equally as serious as a physical failure of hardware, since loss of or failure to properly transmit pertinent information or data may result in inaccurate failure diagnosis or improper design and fabrication of a system. To minimize effects of inadequate documentation, check off lists are recommended. Proper orientation to technical requirements and the implications of statistical probabilities of all personnel, particularly vendors, must be done to create a better understanding as to needs of a program. Independent evaluations of all components and systems must be made, since any possible mode of failure must be detected early. Final explanation of the need for documentation is required to encourage recording of more accurate data, the use of formal test procedures and the like by all contractors concerned with reliable weapon systems. Constant and continuous evaluation of vendor's technical capability and quality control is needed to provide assurance that changes in personnel, facilities, and processes do not compromise reliability requirements. (Author in part)

REVIEW: The case studies presented in this paper should prove useful to those concerned with the specification, design, production, or testing of high-reliability equipment. The emphasis on the need for understanding why various reliability and quality control requirements are necessary is a commendable feature. ##

Serial Number 760
Codes 400;820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Applied statistics--an important phase in the development of experimental science

AUTHOR: H. C. Hamaker, N. V. Philips Gloeilampenfabriken, Eindhoven, The Netherlands

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 101-109, April-June, 1962 (Pergamon Press Limited, Headington Hill Hall, Oxford, England) (reproduced by permission of Philips Technical Review)

PURPOSE: To give a very general introduction to the uses of applied statistics.

ABSTRACT: In many fields of inquiry, especially those concerned with living beings, "exact" observations are not possible and it is necessary to investigate the effect of several factors at the same time. This has led to the design of experiments on a statistical basis, in which several factors may be varied simultaneously and which require an appropriate statistical analysis for their interpretation. The author advances the view that the introduction of statistical principles is bringing about a fundamental change in experimental science in general. Though the statistical principles are always the same, the methods adopted depend on the nature of the investigation. To illustrate the statistician's approach, the author inquires into the average length of words and sentences. Next, the principles are applied to problems of quality control of machine-made products. Though the problems are similar, the circumstances are different, particularly in regard to conditions, aims and experimentation possibilities. Finally, the author considers the marked differences between applied and theoretical statistics. The true value of statistical methods is that they provide universally accepted standards for the conduction and interpretation of investigations. It is of great value that with statistical procedures the inevitable risk of drawing a wrong conclusion is known. For the applied statistician, however, only the order of magnitude of this risk is of interest, while the mathematician requires that the risk shall be known exactly. Experimental science proceeds on the basis of experience and intuition, vague concepts that cannot be brought under the rules of precise mathematical formulae and constants. The applied statistician should take this fact as his point of departure and should not attempt to achieve a precision which does not correspond to the actual conditions of experimentation. (Adapted from Author's abstract)

REVIEW: This article is interesting to read and should be of value to the non-statistician; a design engineer might benefit appreciably from reading it. It is a general philosophical paper and has little technical content, but it serves to convey an appreciation for the value of the effective application of statistical techniques.

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Serial Number 761
Codes 720;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Increase of transistor reliability and life by improving the design and technological processes

AUTHOR: H. R. Baumgartner, Standard Telephones and Cables, Ltd., London, England

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 111-123, April-June, 1962 (Pergamon Press Limited, Headington Hill Hall, Oxford, England)

PURPOSE: To describe specific empirical procedures that have been successful in fabricating long-life industrial transistors.

ABSTRACT: Transistor failure is generally caused by physical or chemical changes occurring on the surface of the transistor, making the life of the transistor strongly dependent upon packaging and passivation. The most reliable passivating technique is the growth of an oxide layer on the surface of the transistor as is typical of the silicon planar technology. This technique is not applicable to germanium devices and the reliability of the transistor depends almost completely upon the packaging. Survival curves of germanium alloyed transistors are presented, which recommend the cold welded case containing molecular sieve material as the most reliable encapsulation.

REVIEW: The data presented here confirms the generally accepted thesis that water is the primary cause of transistor degradation and reports a practical means of maintaining a partial water vapor pressure in the transistor case of less than 0.008 Torr. This is useful information applicable to many packaging problems.

The implication (in one place in the paper) that "high reaction temperatures" prevent the use of a thermally grown oxide as a passivating layer on the surface of a germanium transistor is probably erroneous. Germanium oxidizes at a relatively low temperature but forms a white, powdery layer which does not possess the physical and chemical properties necessary for surface passivation. This fact, rather than the temperature of reaction, is more likely the reason that germanium devices are not passivated by thermally grown oxide layers. ##

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Serial Number 762
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Low-level redundancy as a means of improving digital computer reliability

AUTHOR: J. C. Cluley, Electrical Engineering Department, The University of Birmingham, Edgbaston, Birmingham 15, England

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 203-216, July-September, 1962 (Pergamon Press Limited, Headington Hill Hall, Oxford, England)

PURPOSE: To show how some forms of redundancy might improve reliability.

ABSTRACT: The expected fault rate in a large digital computer has been calculated from the published figures of typical component failure rates, and the resulting mean time between failures--less than a week--is clearly much too low for critical real-time applications such as air traffic control. The reliability of the installation can be improved by redundancy and the use of majority decision elements, but the most economical form of redundancy appears to be the provision of duplicate equipment with provision for eliminating the redundancy, a block at a time, while a test routine is being run. By interleaving the test programme with the main programme on a time-sharing basis, the normal working of the computer is unaffected, and, for the loss of a small fraction of the total available computing time, a continual check can be made on the functioning of the computer. By suitable design of the packaging of the components, a faulty unit can be detected and replaced without interrupting the main programme operation. Although there are practical difficulties associated with the duplication of equipment at the component level, this form of switching redundancy appears to offer the maximum increase in reliability for a given outlay in components, and the facility of matching the system reliability to the particular application by programme changes alone. (Author)

REVIEW: This is in part a general discussion of some forms of redundancy and in part a discussion in some depth of a few particular kinds. The paper is theoretical; therefore the results are applicable only when all of the assumptions (implicit as well as explicit) are satisfied. Some of the implicit assumptions may be difficult to ferret out. ##

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Serial Number 763
Codes 716;730;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of a silicon alloy transistor

AUTHORS: J. Honeychurch and O. M. Elkins, Quality Assurance Department, Texas Instruments Ltd., Bedford, England

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 217-225, July-September, 1962 (Pergamon Press Limited, Headington Hill Hall, Oxford, England)

PURPOSE: To describe the life tests and semiautomatic test equipment for some silicon alloy transistors.

ABSTRACT: The 2S300 series silicon alloy transistor was specifically designed to attain a high degree of stability during life. Substitution of welding techniques for soldering has eliminated the risk of contamination of the active surface by flux, and the use of a filler of good thermal conductivity has enabled high dissipation levels to be reached without excessive rise in junction temperature.

The results of this exercise have fully justified the expectations of the device designers, and show that the silicon alloy transistor is a stable and highly reliable device. The leakage currents, after a short time on test at 200 mW, 50°C ambient, approached values normally associated with planar transistors, while gain and saturation voltage remained remarkably constant with life. The investigation into the variation of the major parameters with temperature gave results which were in very close agreement with the values predicted by theory.

The use of automatic testing of large numbers of transistors under controlled conditions, in the assessment of device reliability, has proved to be a very necessary technique, and will be applied to a wide variety of transistors in future programmes. (Authors)

REVIEW: This is a good and rather comprehensive report of a series of life tests. The analysis seems to be well done. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effects of radiation damage in solar cells

AUTHOR: F. C. Treble, Royal Aircraft Establishment, Farnborough, Hants., England

SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 299-309, October-December, 1962 (Pergamon Press Limited, Headington Hill Hall, Oxford, England)

PURPOSE: To show and discuss the effects of proton irradiation damage on silicon and gallium arsenide solar cells.

ABSTRACT: The results confirm the qualitative deductions made from the theory of radiation damage in solar cells, namely:

(1) The principle cause of performance loss is current degradation, resulting from reduction of minority carrier lifetime.

(2) The reduction of output voltage is a secondary effect.

(3) Response to the shorter solar wavelengths (blue response) is less affected than response to the longer wavelengths (red response).

(4) The damage rate increases with decrease of proton energy.

(5) Gallium arsenide cells are considerably more resistant to radiation damage than silicon.

These studies have also established long-term solar cell damage rates in known proton environments at energies down to 25 MeV. The most damaging energies are probably lower than this, but a reasonable extrapolation can be made from the available data.

It is not yet possible to use this data to estimate accurately the degradation rates of solar cell power systems in particular orbits, as the particle intensities in the Van Allen belt, their energy spectra, spatial distribution and temporal fluctuations are not yet known with any degree of certainty. However, enough is known to show that the degradation of silicon cells is a serious problem when considering long-life satellites orbiting continually in a proton environment.

The n-on-p configuration in silicon does not appear to have any significant advantage over p-on-n, from the data presented in this paper. This may be because the better red response on the n-on-p cell resulting from higher carrier mobility in the base layer can only be achieved at the expense of lower mobility and therefore higher resistivity in the surface layer. With such a cell, the junction cannot be so shallow and, since this adversely affects blue response, the balance of advantage may lie with the p-on-n type.

However, the final word in this matter cannot be said until the

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potential advantages of both configurations have been exploited to the utmost. For instance, with n-type diffusants, such as phosphorus, it may be possible to achieve a higher surface impurity concentration to offset the disadvantage of lower carrier mobility.

The gallium arsenide results are very encouraging and show the advantage in this context of a material in which the collection efficiency is not so dependent on a high minority carrier lifetime. Other advantages of the gallium arsenide cell over silicon are that its output voltage is higher and it is less sensitive to temperature rise. (Author)

REVIEW: This experiment seems to have been well done and is reported clearly. As the author indicates, neither theory nor engineering is complete in this area and the optimum solution is probably yet to come. ##

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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 through controlled environments and microminiaturization

AUTHOR: G. W. A. Dummer, Royal Radar Establishment, Malvern, England

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TITLE: Aging studies on transformer insulating materials (Class A) by means of infrared spectroscopy

AUTHOR: G. Lengyel, Ontario Research Foundation, Toronto, Canada

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TITLE: The reliability and quality control field from its inception to the present

AUTHOR: C. M. Ryerson, Pan Technical Systems, Inc., Montrose, California

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TITLE: High-density tantalum-film microcircuits

AUTHOR: T. V. Sikina, Philco Scientific Laboratory, Blue Bell, Pennsylvania

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TITLE: Film circuit panel for space guidance computers

AUTHORS: A. E. Lessor, J. W. Skerritt, R. E. Thun, and D. S. Weed, International Business Machines Corporation, Components Division, Kingston, New York

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TITLE: Substrates for deposited-film passive components

AUTHOR: R. J. Settzo, Corning Glass Works, Bradford, Pennsylvania

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TITLE: Properties of tantalum sputtered films

AUTHORS: D. Gerstenberg and E. H. Mayer, Bell Telephone Laboratories, Inc., Murray Hill, New Jersey

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SOURCE: Electronics Reliability & Microminiaturization, vol. 1, pp. 189-201, 227-232, 275-298, 311-319, 333-338, 347-352, and 353-358, July-September and October-December, 1962 (Pergamon Press Limited, Headington Hill Hall, Oxford, England)

These papers are respectively the same as those covered by Abstracts and Reviews Serial Numbers 727, 733, 392, 599, 600, 606, and 604.
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Serial Number 766 -1
Codes 770;837;840;
850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Status report: Production engineering measure on micromodules

AUTHORS: (prepared by Surface Communications Division, Radio Corporation of America, Camden, New Jersey)

SOURCE: 69 pp., prepared for U.S. Army Electronics Materiel Agency, Philadelphia, Pennsylvania, Contract No. DA-36-039-SC-75968, September, 1962

PURPOSE: To present a status report on the micromodule program.

ABSTRACT: The main sections of this report are entitled Introduction, The Micromodule Concept, Micromodule Reliability, Micromodule Availability and Costs, Maintenance and Logistics, and Typical Micromodule Equipment Applications.

The reliability of the micromodule has been demonstrated by the accumulation thus far of approximately 95,000,000 element hours of test (approximately 50,000,000 hours of micromodule testing and 45,000,000 hours of microelement testing). Reliability calculations based on these data yield a failure rate of 0.036%/1000 hours (MTBF of 2,780,000 hours) for a 10-element average module, under normal stress conditions (20% electrical stress and 40°C thermal), and at a 60% confidence level. This degree of micromodule reliability which has been achieved is the result of: inherent characteristics of the micromodule configuration; full exploitation of the best materials and processes within the state-of-the-art; and a comprehensive reliability implementation program including rigid specifications, careful vendor selection and qualification, thorough production testing, and detailed failure analysis and control.

The chief reliability advantages inherent specifically in micromodule construction are: optimum utilization of machine processes, mechanical ruggedness, reduced supporting hardware, and component-module compatibility.

One of the basic decisions for insuring reliability was to retain the component identity, that is, to maintain a breakdown of circuitry into the conventional component types (resistors, capacitors, transistors, diodes, transformers, and inductors). This decision took advantage of the availability of years of experience in the existing component industry, the reservoir of circuit design experience, and the full range of component values. Circuits could be designed (for optimum performance with assured reliability) with minimum stress levels and optimum deratings. (Authors)

REVIEW: This is a rather comprehensive report covering many phases of the program besides reliability per se. The report is quite optimistic

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AND TECHNICAL REVIEWS

about the future of micromodules and their advantages over other systems. It should be noted that at a 60% confidence level, 40% of the estimates of mean life are expected to be too high. There are apparently no field life data presented here.

It certainly is to be hoped that the micromodule concept does live up to all the expectations for it.

(Another paper on this subject was covered by Abstract and Review Serial Number 734.) ##

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Serial Number 767
Codes 821;831;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the synthesis of reliable switching elements

AUTHOR: A. J. Bernstein, The RAND Corporation, Santa Monica, California

SOURCE: RAND Corporation Memorandum RM-3013-PR, 30 pp., March, 1962, prepared for United States Air Force Project RAND Contract No. AF 49(638)-700 (ASTIA Document No. 274989)

PURPOSE: To report on a study directed toward attaining more reliable performance from unmanned, space-borne systems where long-life computers may be mandatory.

ABSTRACT: The elements, of which networks of switches are made, operate properly with a given probability, and fail if they remain closed (shorted), or open, independent of the control signal.

Probability equations are used in the examination of reliability improvement for a simple (series-parallel) circuit. A theorem is presented and proved which gives a general rule for finding the probability that a given network will be shorted or opened, in terms of the probabilities in simpler networks.

The possibilities of failure due to a network shorting or opening are mutually exclusive. The probability that the network will operate properly can be given in terms of the probability that it will open and the probability that it will short (each of which is treated in the references).

Networks of fixed length or width are examined, the first in detail, the second by duality. A theorem is developed and proved which gives the probability of short circuit failure of fixed-length circuits, and another (again by duality) for the probability of open circuit failure of fixed-width circuits.

Finally, these theorems are used in the synthesis of networks having less than a given probability of each type of failure.

REVIEW: As a nice mathematical treatment of the subject, this paper should further the author's purpose in writing it. Following the synthesis procedure will produce a fixed-width or fixed-length network of the desired reliability. The bibliography of two entries is adequate for the author's purpose. ##

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Operating characteristic curves for reliability measurement

AUTHOR: Austin J. Bonis, AC Spark Plug, Electronics Division of General Motors, Milwaukee, Wisconsin

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 1-7

PURPOSE: To present several forms of operating characteristic curves that are useful in MTBF tests.

ABSTRACT: Five charts are presented for use in acceptance testing with regard to MTBF. Four of these are related. They are based on the true average (expected) number of failures during the test and give the probability of accepting the equipment as a function of the actual number of failures during the test. Several forms and parameters are provided so that the most convenient form can be used. A final chart concerns an entirely different circumstance. Here the parts are assumed to have a normal (Gaussian) distribution; the probabilities are given of about 2/3 of the observations falling within certain fractions of the true standard deviation.

REVIEW: This paper does present curves and examples that can be used in actual practice. Spot check shows that the charts are correct, although the formulas on which they are based are not given. While the author asserts that the charts may be used "cook-book" fashion without understanding them, it is a good idea if the restrictions and formulas on which they are based are given, at least in an appendix. In this way a person can check the validity of the graphs, or get more accurate answers if he wishes. Being able to check the validity of the graphs may not seem to be too important, except that some authors, some typists, and some printers do make mistakes.

Chart 3, the basic chart, is based on a Poisson distribution of observed failures when the true average (expected) number of failures is known. This will hold if (and only if) the times between (to) failures are exponentially distributed. The equation used is $2d = \chi_p^2(2a+2)$ where χ_p^2 is the value of χ^2 (Chi Square) that will be exceeded a fraction p of the time and (2a+2) is the degrees of freedom. (The notation is that of the text.) This chart will give the correct answers for the introductory examples only when the Poisson distribution is a suitable approximation to the binomial.

The term "probability of acceptance" is not explained correctly. It is actually just the average fraction of lots that will be accepted (if the true parameter is as stated). It says nothing at all about the probability that a lot has a particular true

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parameter. There are a few other inaccurate statements in the explanations of the charts, but they are fairly obvious and not critical. The last chart, it should be emphasized, is for an entirely different situation than the others. It requires a normal (Gaussian) distribution.

The statement "It is interesting to see that if your system has a standard deviation smaller (better) than required ... , then it does not make any difference to either you or to the customer if you take the two-out-of-three test in preference to the seven-out-of-ten test," is quite in error since the amounts of consumer's protection for the two tests are extremely different, unless, of course, both you and the consumer know the true value, in which case the test is superfluous. Specifications which permit the assumption to be made that the true value is known are therefore faulty. They result in neglect of the consumer's risk. ##

Serial Number 769
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Redundancy and the detection of first failures

AUTHORS: D. C. James, A. H. Kent, Jr., and J. A. Holloway, The Martin Company, Denver, Colorado

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 8-27

This paper was covered by Abstract and Review Serial Number 100. ##

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Serial Number 770
Codes 860;870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A field study of the maintainability and reliability of an interceptor squadron

AUTHORS: R. S. LaVallee, Technical Operations, Inc., Burlington, Massachusetts and D. S. Stoller, RAND Corporation, Santa Monica, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 28-34

PURPOSE: To analyze, in terms of flight operations, the maintenance and reliability data collected by RAND during a field study.

ABSTRACT: This study was made several years ago, but the limited availability of this type of information makes worthwhile its availability in an unclassified document, even though the aircraft is no longer in the Air Force inventory. The results are primarily useful in that they indicate the importance of certain parameters on maintenance and reliability. In particular, the validity of the Poisson distribution for predicting both the failures generated by system operation and the time required for repair was examined. The effect of periodic inspection on reliability was also of concern. This paper presents some highlights of the study. More detailed results are discussed in the authors' original RAND paper [1]. (Authors)

REFERENCE: [1] R. S. LaVallee, and D. S. Stoller, "The Effect of Maintenance and Reliability on the Operational Effectiveness of an Interceptor Squadron," RAND Corporation, Santa Monica, Calif., P-2053; October, 1960

REVIEW: It is worthwhile to have this type of information even though it is difficult to get and to interpret. Unfortunately, the details regarding the fit of the Poisson distribution were left out. In a private communication, the first author has indicated that these details were deleted when the paper was condensed by a referee, but are in the original P-2053 [1]. ##

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Serial Number 771
Codes 838;870;880

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction of command control system dependability and performance

AUTHOR: L. W. Sepmeyer, System Development Corporation, Santa Monica, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 35-42

PURPOSE: To discuss the prediction of duplex computer system availability as well as the expected number of failures and the system mean time to a lost time incident.

ABSTRACT: In command and control systems, of which the SAGE Air Defense System is one example, system performance and dependability are a function of a number of parameters in addition to the usual failure-time pattern associated with reliability. For duplex installations, especially where digital computers are concerned, maintenance characteristics of the machines, as well as maintenance and operating policies, can have a profound effect on system down time. Equations are derived for predicting duplex system down time and mean time to lost time incidents on the basis of machine characteristics and operating parameters. The results are illustrated by a numerical example. (Author)

REVIEW: This is essentially a mathematical paper, and the mathematics is in principle not complicated. However, the readability of the paper is marred, perhaps principally by the lack of development material and discussion in places where it would have been helpful to the reader who wishes to follow the material but is not initially familiar with it. In Section IIA the author defines Mode B operation as involving one computer (say computer A) performing the mission function and the other computer (computer B) performing some other task, and states that in this mode computer B is <u>not</u> available for immediate switchover. However, in the second paragraph of Section IIB, which deals with Mode B operation, he apparently ignores part of the above definition in obtaining the fractional time that computer B is not available for unscheduled switchover as given in Equation (1). Not all of the symbols are defined in the text the first time they are used. An example of this is the symbol F which first appears in Equation (8), without having been defined earlier in the text. The listing of symbols at the end of the paper takes care of this in a way, but requires the reader to flip pages as he reads. All in all, the reader interested in this topic would do well to obtain a familiarity with it from other sources before attempting to read this paper. ##

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Serial Number 772 -1
Codes 824;831;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Upper bounds on mean life of self-repairing systems

AUTHOR: Earl J. Kletsky, Department of Electrical Engineering, Syracuse University, Syracuse, New York

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 43-48 (presented at the AIEE Conference on Diagnosis of Failures in Switching Circuits, Michigan State University, East Lansing, Michigan, May, 1961)

PURPOSE: To determine upper bounds for the mean life of some types of systems.

ABSTRACT: Upper bounds on mean life of self-repairing systems are established on the basis of a very general system model. Expressions for system mean-life are obtained by formulating the problem as a two-dimensional difference equation in time and the number of nonfailed spare elements.

Results indicate that mean life of an isolated system cannot be expected to exceed roughly three times the mean life of the elements which make it up, regardless of how standby elements are employed. If the element failure rate in standby is substantially less than the failure rate in operation, then system mean life is essentially linearly proportional to the number of available standby elements. (Author)

Each particular process is considered to be a Poisson process and these are combined in several ways.

REVIEW: The results derived here can be of use to the design engineer who is after some quick numbers. It should be emphasized that the results are merely a ceiling; the practical case may have a lower mean life than this ceiling.

The type of system mentioned by the author in the introduction, "... having very high reliability during early life followed by a very rapid decrease in reliability at some future time" is not necessarily the type analyzed in the paper. All the processes used in the paper have a (piecewise) constant conditional rate. An implicit limitation in the analysis is that the failure rate of parts is independent of the number of failed redundant elements. Thus a group of resistors in parallel will not meet this assumption because as some fail the others are loaded more heavily.

The boundary conditions for the "Binomial" Systems (Eq. 10) are wrong, although they give the correct answers. Using the author's notation, the conditions should be

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

$$U(0,s) = 0; \; P_j(0+) = 0, \; j \neq 1,$$
$$P_1(0+) = L\lambda u,$$

rather than $U(0,s) = 1$, $P_j(0+) = 0$. In a private communication the author has acknowledged this transcription error, and has requested that the following additional corrections be indicated:

Eq. 24 should read:

$$U(m,s) = \frac{\alpha}{s+\alpha} U(m-1,s)$$
$$U(0,s) = 0 \quad P_j(0+) = 0, \; j \neq 1,$$
$$P_1(0+) = \alpha = L\lambda u.$$

Eq. 25a should read:

$$(s + \alpha + b) \; U(1,s) = bU(2,s) + \alpha \text{ for } j = 1,$$
$$(s + \alpha + b) \; U(j,s) = \alpha U(j-1,s) + bU(j + 1,s) \text{ for } 1 < j < m.$$

Eq. 25c should read:

$$U(0,s) = 0.$$

Page 43: The heading of the third section should read:

REDUNDANT SYSTEMS.

Eq. 23: First member of the right side should read: $\alpha U(j-1,s)$.

Page 47: Third line from bottom, right hand column: set open bracket before the word "replacement" and delete open bracket following the word "rate".

Eq. 26: Second line should read:

$$X = \frac{\alpha}{B} \neq 1, \; m = N-L + 1, \; \alpha = L\lambda u.$$

(The results of the "Binomial" System analysis could have been obtained much more simply and quickly by using the facts that (1) the sum of two Poisson variables is a Poisson variable, (2) the properly normalized times for n failures for a Poisson process have a Chi Square distribution, and (3) the mean of a Chi Square distribution is the degrees of freedom. Unfortunately, this method is not readily extended to the Open System case.) ##

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Serial Number 773
Code 811

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design reliability creation through management directives

AUTHOR: John W. Griswold, The Boeing Company, Seattle, Washington

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 49-55

This paper is essentially the same as the one covered by Abstract and Review Serial Number 247. ##

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Serial Number 774 -1
Codes 733;842

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A data reduction and failure correction system (COFEC)

AUTHOR: Aaron Fogel, Reliability Control Department, General Dynamics/Astronautics, San Diego, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 56-70

PURPOSE: To describe a system for failure recording and corrective action.

ABSTRACT: The COFEC system (Cause of Failure, Effect, and Corrective Action) provides an efficient means for reliability data reduction and presentation in a manner suitable for executive action. An appropriate information storage and retrieval system accepts a large quantity of data and provides periodic reports which delineate those areas most worthy of attention in efforts toward the improvement of future system reliability. Sample forms indicate the nature of the periodic readout. In addition, relevant data may be made available on short notice, as specific points of interest develop. (Author)

REVIEW: This is an excellent article for those setting up a failure reporting and corrective action system. However, it could have been made more useful by the inclusion of more detail on some points. For example, specific information on times to failure is not presented. The paper would also have been improved by the inclusion of more illustrations of the other types of reports mentioned as being available. At the same time, it must be recognized that the omission of much specific information is often dictated by the space available for publication.

It may be worth noting that the term "system" as used by the author might better be called "subsystem", since the reference is to such subsystems as instrumentation, propulsion, guidance, etc. It also appears that the term "part number" is in many cases equivalent to "drawing number", but the author has pointed out in a private communication that it is not necessary that this be so. The user may, of course, set up his own numbering system as a means of identification. The referenced AFBM Exhibit 58-10 has been superseded by Mil-R-27542, but this in no way invalidates the author's use of the former to indicate a basis for the "severity of failure" classification.

It might be thought that only major weapon systems and large operations could afford the sophistication of the system described. However, the author (private communication) has pointed out that the system is directly applicable to a product of any type or size. The sophistication of the system is built into COFEC. The method of recording and presentation is determined on an economic basis.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

For high reliability programs, the volume may not justify automated techniques. The author has emphasized that this data handling system is designed to accept failure information over a very wide range of items, to digest this information into meaningful terms for the purpose of obtaining corrective action, and to allow management follow-up for its effectiveness. ##

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844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of solar arrays

AUTHORS: W. A. Klein and S. N. Lehr, Space Technology Laboratories, Redondo Beach, California

SOURCE: IRE Transactions on Reliability and Quality Control, vol. RQC-11, October, 1962, pp. 71-80 (presented at the Second Annual Seminar on Reliability in Space Vehicles, Los Angeles, California, December, 1961)

PURPOSE: To discuss possible failure modes of solar arrays, to derive a formula for the calculation of the probability of occurrence of modules with a specific current output, and to obtain upper and lower bounds for the reliability of an interconnected array.

ABSTRACT: The predominant failure mode of solar arrays is considered to be an open circuit due to a mechanical break. The effect of various combinations of open-circuited cells on current output (at a fixed terminal voltage) from a series-parallel interconnected array of solar cells is examined using a typical solar cell I-V characteristic. It is found that for certain practical types of interconnected arrays, the degradation of the modular components of the array is most likely to result in specific current output values from a module rather than in a continuous distribution of output values. A formula for the calculation of the probability of occurrence of modules with a specific current output value is derived. The multinomial probability distribution then allows the approximate calculation of the probability that the current output of the entire array is greater than some minimum required value. Upper and lower bounds for the reliability of an interconnected array are obtained. (Author in part)

REVIEW: This is a theoretical analysis of the reliability of solar arrays. The underlying assumptions are clearly stated and arguments for their justification are given. As the authors have indicated, the practical application of such an analysis depends on the availability of good data on the failure rates of all components in all possible modes of failure. When data are available, the analysis can be used to ensure that design of the solar array includes enough extra array capacity to allow for its statistical degradation.

Other papers dealing with the reliability of solar cell arrays were covered by Abstracts and Reviews Serial Numbers 651 and 743. The first of these deals with the degradation and complete failure of solar cells due to radiation and meteoroid impact. The second outlines a procedure for conducting a tradeoff study of reliability versus weight for a solar cell array. ##

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