RELIABLE ELECTRONIC EQUIPMENT

by

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ABSTRACT

The reliability aspect of electronic equipments is discussed. To obtain optimum results, close cooperation between the components engineer, the design engineer and the production engineer is suggested.

"In another war superior electronics would be decisive. As speeds cross thro' the sonic barrier and approach 1000 miles an hour, human and mechanical impulses are too slow to be adequate for control. Having battered the speed of sound, Man will have outstripped himself. How well a fighter or a bomber is used will depend upon the efficiency of its electronic-control devices" said General Spaatz. This almost prophetic statement of General Spaatz is now not only true of aviation electronics, but also of the entire field of military electronics. The extreme rapidity with which electronic gadgetry is replacing the human manipulation, has enlarged the field of application of electronics in military operations. In this era of pilotless aircraft and guided missiles, when the human operator has been relegated to a secondary position, the success or failure of an operation depends to a great extent on the proper functioning or otherwise of every individual electronic component that goes to make up the larger units. It becomes, therefore, extremely important to ensure that all military electronic equipments function without even minor breakdowns at all times. But this is easier said than done, as any person who has worked with electronic equipment can recall a few occasions when the equipment which was badly needed developed some last minute trouble. And everyone realises how difficult it is to forestall these last minute faults, as they seem to develop all by themselves. It requires great deal of imagination to realize that the roots of the trouble may be actually in the defective manufacture of a particular component or an imperfect solder point or inadequate maintenance. If a piece of electronic equipment is to function without giving trouble at awkward moments it is imperative that we should exercise extreme care from the stage of manufacture of each of its components to the stage when it is actually required for use.

"A chain", the old saying says, "is as strong as its weakest link." An electronic equipment is as useful as its reliability factor. According to Webster the word "reliable" is amplified as follows: "That may be relied upon, worthy of confidence, trustworthy". An example given was "we can speak of a railroad train as reliable when it can be depended upon to arrive on time." From the above, therefore, it appears that the concept of reliability may take several different forms. For the purposes of the office of Naval Research Programme (America) 'reliability' is defined as x/y, when y is the total time the equipment is required for use and x is the time out of this total time y that the equipment is in an acceptable operating condition. Ideally this ratio should be unity and it is towards this end that a great amount of work is to be done.

A direct approach to the problem is to the reliability into the equipment. This can be done by using quality components, having quality design and quality production.

Quality Components

The basic building blocks for reliable electronic equipments are the individual components that go into the design. Now the reliability of a given system is the product of the individual reliabilities of the various series components in that system. A "series" component is one which if it fails will cause system failure. It is evident that the individual components of the electronic equipment must have an individual reliability several orders of magnitude greater than the reliability which is acceptable for the equipment as a whole. Military electronic equipment is subject to dry heat, low temperature, low temperature high altitude, vibration and shock, moisture absorption and condensation and mould growth as it is meant for world-wide operation. So the responsibility of achieving greater reliability of individual components rests upon the component parts engineer who should be able to provide data concerning the reliability of parts and materials in the specific environments and thus serve as consultant or "common denominator" to all design groups. To be effective he must be able to determine the characteristics and performance of components and materials in various environments and from this establish the performance specifications and the conditions under which the performance is to be measured. In addition he must aid in system of planning. He must organise tests to collect and evaluate test data and disseminate the results and conclusions to design engineers.

The component faults which occur in any electronic equipment can be divided into three classes:

(1) Faults due to poor manufacture or the use of unsuitable materials.

(2) Faults due to bad design such as thermal overloading of components and valves.

(3) Fundamental faults into the cause of which research is needed.

A rough analysis has shown that about 60% of the total faults are in the first class, 35% in the second class and 5% in the third class.

The components engineer can well play his part directly in minimizing the faults of class 1, partly in minimizing the faults of class 3, and in co-operation with the design engineer in minimizing the faults of class 2.

Quality Design

Any new electronic equipment has to pass through three stages before it comes out of the factory—

(1) The laboratory model stage.

(2) The engineering model stage.

(3) The production stage.

In the laboratory stage the idea which has germinated in the mind of the inventor takes the physical shape. So, in order to have a lead to the goal of reliable, soldier-usable, military electronic equipment the laboratory mode should go through the engineering transition stage. Since the laboratory models are merely embodiments of new idea, taking them as production scale prototypes result in a large number of units promising much but incapable of performing reliably.

Quality design plays an important part in making the equipment reliable. For, during the production every component and piece of material used in the assembly may be thoroughly tested, every connection and solder joint may be perfect, every individual product on its completion may meet all the operating specifications but if the basic design itself is weak the product is just another product. So the design engineer should know where to use which component. That does not mean that he should have an extensive knowledge of all the components. A successful taxi driver need not know the names of all the roads. He should know at least to read the road sign boards. So also a successful design engineer should know to ask right questions at the right moments to the component engineer. Thereby he not only contributes towards reliability by himself but also makes the components engineer to contribute his share towards reliability by making him answer the difficult problems of components needed for new complex uses. For even the best components will fail if they are used in the applications for which they are not intended. So the design engineer should make specifications as complete as possible and components should be included therein only after thorough investigation and test to determine their suitability.

Secondly, the design engineer should try to minimize the number of components used thereby leading to a simpler design. He should avoid unnecessary complexity as in particular there is a dangerous trend towards complexity which is characteristic of the thinking done by some designers who become interested in the theoretical function of a complex component. Otherwise the price of complexity has to be paid in terms of reliability. No doubt he should strike a compromise between simplicity, performance, operational suitability, reliability and size and weight. But the compromise should not be at the cost of reliability. Regarding the cost of production, he can try to bring it down by other means such as designing towards complete interchangeability of parts, so that quite unskilled labour which is cheaper can be utilized in the production and at the same time quality of the product also will be better as a whole since the degree of accuracy of any adjustment, to be made during production will vary from person to person. This will also help for the product to smoothly run on the production line.

Once the engineering model comes out successfully after all the necessary tests, it can be taken as the prototype for production. Any difficulties in production due to any fault in design has to be communicated to the design engineer so as to make improvements in future designs.

Maintenance

Another approach to reliability in electronic equipment is to effect preventive maintenance and repairs as necessary. Combination of good design with the best available components will help to approach good reliability; yet utilization of preventive maintenance techniques will act as an additional aid. Preventive maintenance techniques called marginal checking, use performance margins to establish life expectancy of components so that those with low margin can be removed during testing period. The three features of this marginal checking scheme which make it very practical for use in large electronic systems such as electronic digital computors are:

(1) The checking system can detect imminent failures before they become real failures and cause computational error.

(2) This detection can isolate the failing component to a specific tube, crystal or resistor.

(3) Such isolation can be so rapid that it consumes only a small percentage of total machine time.

It should be borne in mind that marginal checking differs from ordinary checking by not only answering the question "Are all circuits functioning" but also "How much longer will the circuits function". Good equipment starts with wide safety margins, but age and wear reduce these safety margins leading to a total eventual failure. Marginal checking assures adequate safety by testing the system frequently enough so that only slight deterioration can occur between the tests. Semi automatic fault locators may locate the faults once they are developed and plug-in-assemblies may reduce the repair time but marginal checking will prevent to a great extent the faults occurring.

In conclusion it may be said that a close working harmony between the components engineer, the design engineer and the production engineer coupled with techniques like marginal checking as an additional aid together with a trend towards plug-in-assembly construction and semi-automatic fault locators will help to approach a reliability factor of unity.

Bibliography

1. Baker, W.R.G.—"Electronics for Defence" Pro N.E. Vol. 7, pp. 1—6, 1951.

2. Babcock, Col. John F.—"Air craft Fire Control", Ordnance Vol XXXVI, pp. 581-582, Jan-Feb 1952.

3. Devy, G.B.—"Reliability in Electronic Equipment" Proc. I.R.E. Vol. 38, pp. 344-345 April 1950.

4. Blake, Brig Gen Gordon A.—"Aircraft Armament", Ordnance XXXVI, pp. 570-572, Jan-Feb 1952.

5. Lel, L.K. and Paul, F.A.—"A New Profession, Components parts Engineering"—P.G.C.P.I.—I.R.E. pp. 152, March 1954.

6. Dummer, G.W.A.—"The Eng of Radar Equipments designed for the R.A.F." Electronic Engineering 24, pp. 348, (1952).

7. Joseph Manuele "Practical Design for effective production and high quality" Proc. I.R.E. Vol. 38, pp. 1385-1387, December 1950.

8. Harold Goldberg—"An Engineering Incentive Problem" P.G.E.M.I.—I.R.E. pp. 7-9, Feb 1954.

9. Dumont, Allen B.—"Quality Control in Engineering" Proc. I.R.E. Vol. 38 pp. 1251, Nov. 1950.

10. Deby, G.B.—"Reliable Electronic Equipment—A progress report" Proc. N.E.C., Vol. 6, 1950.

11. Taylor, Norman M.—"Marginal checking as an aid to computor reliability" Proc I.R.E. Vol. 38, pp. 1418-1421, Dec 1950.

12. "Circuitary packages for electronic computors" N.B.S. Bulletin pp. 36, March 1953.