GTE Communications Transmission Systems

DEMODULATOR

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Also in this issue:
30th Anniversary

Most experts agree that improving quality is a basic requirement for a business striving to remain healthy and grow in today's economy. This issue of the Demodulator examines quality as it applies to the telecommunications industry in general and the manufacturing segment of that industry in particular.

In the public mind, the word "quality" generally denotes excellence or fineness and is frequently equated to expensive. For out purposes a more suitable definition of quality is "conforming to specifications." Extending this definition, a quality product is one which fulfills its design purpose. In other words, quality means fitness for use. A wheel barrow or a limousine can both be described as high quality items and quality equates to cost effective rather than expensive.

The "fitness for use" definition implies that the product is satisfactory to the end user. In the telecommunications industry, specifications define acceptable equipment performance so "conformance to specifications" and "fitness for use" have essentially the same meaning. The end user periodically measures the equipment performance to verify that it conforms to specifications and is therefore fit for use. While this is the ultimate determination of equipment quality — it is very late for a manufacturer to discover his product does not measure up. Generally, quality cannot be serviced in by simple parts replacement and field corrections of design or manufacturing deficiences are very expensive. To avoid this situation, manufacturers establish Quality Control and Product Assurance programs.

Quality Control

The major function of a Quality Control program is to inspect the workmanship of a product to make sure it meets the quality level required by the design.

A good Quality Control effort detects design and manufacturing errors early in the process. It is far less embarrassing and expensive to correct errors at that time than to correct failures that occur during actual operations, particularly in telecommunications systems, where quality and reliability have always been paramount considerations. For these reasons equipment manufacturers have developed stringent engineering standards and quality control procedures to assure reliable products.

Prediction and Evaluation

During the design phase of a product, quality control procedures are undertaken to predict the inherent reliability of a proposed design. During the manufacturing and early life of a product, quality control procedures are used to evaluate the degree of reliability.

Predicting reliability involves an analysis of statistical data to estimate the inherent reliability of a product design, before the product is manufactured. All pertinent engineering data are carefully examined, particularly the reliability ratings of recommended components and parts.

The designer's extrapolate and interpolate this data and use probability mathematics to estimate the reliability of a proposed design. Design deficiencies and improper part selection are frequently uncovered by this process.

Evaluation

Evaluating reliability involves measuring the performance of a product or components to determine what degree of reliability has been achieved. This is accomplished by subjecting the product to a variety of tests and by acquiring accurate reports of failures occuring during actual field use.

Such information is of considerable value in evaluating the product's performance under typical operating conditions. The ultimate reason for accumulating failure reports from the field is to effect product improvement. This is usually done by analyzing the failure reports to determine the nature of the failures, and then taking steps to prevent them from occurring in the future.

Inspection is another important aspect of quality control. Inspection assures that the workmanship in a product meets the levels of quality required.

Test programs are accomplished to provide concrete evidence of a product's performance. Tests range from environmental testing of individual components to field tests of entire systems. Data gathered from these tests are used to analyze component reliability as well as the overall product or system reliability.

Reliability Terminology

If not properly understood, mathematical expressions used to measure reliability can be misleading.

Three expressions of reliability are: the probability function, the failure rate, and the mean-time-between-failures or MTBF. (For products that are not repairable, the latter expression is referred to as the mean-time-before-failure.) Each of these expressions can be applied to a part, component, assembly or to an entire system. The probability function is expressed as a decimal or a percentage. It is an estimate of what the chances are that a particular device will perform its mission.

The failure rate is ordinarily expressed in terms of the number of failures per unit of time, usually 1 hour, 100 hours, or 1000 hours, or as a percentage of failures per 1000 hours. The MTBF is expressed in hours and is the ratio of the total test time (or operating time) of a device to the total number of failures that occur during the test period.

The probability function P can be expressed mathematically as:

$$P = \frac{a}{a + b}$$

Where

a = number of successes
b = number of failures

To illustrate how this expression is applied, consider the following example. If 100 components were tested for 1000 hours and there were no failures during the test period, the probability function would be 1.0 or 100 percent,

$$P = \frac{100}{100 + 0} = 1.0$$

If, however, 10 components failed during the test, the probability function would be 0.9 or 90 percent,

$$P = \frac{90}{90 + 10} = 0.9$$

Thus, stating that a product is 90 percent reliable does not mean that it will probably operate only 90 percent of the time, but that there is a 90 percent chance that it will successfully complete its mission.

The probability function must be qualified to be meaningful. Expressing reliability in terms of an abstract number is meaningless unless the physical conditions that prevailed when the reliability was assessed are included. It is also important to know the size of the sampling used to determine the probability function.

In the previous example, it can be seen that 10 failures represented a 10 percent decrease in reliability. If the 100 components were taken from a production run of 5000, the sampling may not be large enough to accurately predict the performance of the entire run.

The second expression is the failure rate f, which can be expressed mathematically as:

$$f = \frac{a}{b}$$

Where

a = number of failures
b = duration of test, in hours

As an example, if 100 components are tested for 1000 hours, and ten of them fail during the test, then the failure rate is:

$$f = \frac{10}{1000} = 0.01 \text{ per hour}$$

When calculating the failure rate, it is important to consider the age of the product. Failure rates of new electronic products are apt to be high because of such factors as production errors, defective parts, faulty installation, and improper alignment. After a normal break-in period however, failures become less frequent and failure rates tend to remain relatively constant during the useful life of the equipment. When the product begins to wear out, the failure rate may begin to increase steadily. A typical curve of electronic equipment failure rate versus age is shown in Figure 1.

Closely associated with the failure rate is the mean-time-between-failure (MTBF). This expression is the average time between failures and is

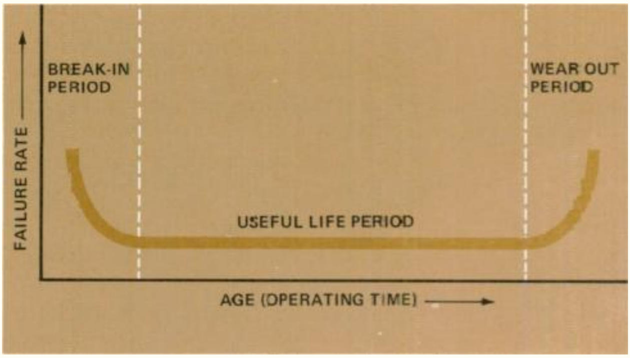


Figure 1. Curve showing typical failure pattern of electronic equipment.

the reciprocal of the failure rate. Using the previous example, the MTBF would be expressed as:

$$\text{MTBF} = \frac{1}{0.01} = 100 \text{ hours}$$

Therefore, the larger the value of MTBF the greater the reliability and, inversely, the smaller the value of the failure rate, the greater the reliability.

Users of communications equipment usually are most concerned with system or equipment reliability. However, the reliability of parts, components, and circuit design provides the basis for measuring the overall reliability of communications equipment or systems. Perhaps the most important factor affecting overall reliability is the increasing number of components required in single systems. Since most system failures are actually caused by the failure of a single component, the reliability of such components must be considerably better than the required overall system reliability. This fact becomes quite evident when considering how the overall system reliability is measured.

If all the components of a system are considered to be functionally in series, and if the failure of any component results in a system failure, then the overall system reliability R is:

$$R = r^n$$

Where

r = mean reliability (probability function) of each component

n = number of components in series

The formula for calculating the overall system reliability produces some rather interesting results as seen in the following table:

n	r	R
10	.99	0.90
100	.99	0.40
200	.99	0.19
500	.999	0.16
1000	.999	0.37

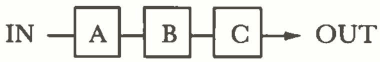
One means of improving reliability when designing a product is through redundancy — that is by providing an alternate means of accomplishing a given function. The probability function for redundant electronic circuits, arranged in parallel, is expressed as:

$$R = r_1 + r_2 - r_1 r_2$$

Where

R = Overall reliability
r_1 = Reliability of circuit 1
r_2 = Reliability of circuit 2

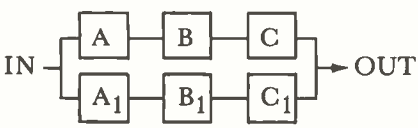
As an example of how redundancy works, consider a circuit with three components, A, B, C, connected in series:



If the reliability of each component is 0.95, then the overall reliability for the series circuit is:

$$R = 0.95 \times 0.95 \times 0.95$$
$$R = 0.86$$

When a redundant circuit is added in parallel, as shown in the following diagram, the overall reliability increases.



Using the formula for computing the probability function of a parallel (redundant) circuit, the overall reliability becomes:

$$R = 0.86 + 0.86 - 0.86 \times 0.86$$
$$R = 0.98$$

Thus, there is a 14 percent gain in the overall reliability as a result of adding the redundant circuit. However, redundancy often requires the use of additional components, such as a switching circuit, which may lower the overall system reliability.

The quality control procedures discussed so far are part of a formal discipline, Reliability Engineering. As a specialized engineering branch, reliability evolved in response to the very exacting reliability requirements of guided missiles and manned space vehicles.

Today, Quality Control has expanded its role to become a management tool for reducing costs and improving productivity, as well as assuring quality. The rest of this article discusses these new aspects of Quality.

Management And Quality

Engineering managers have long been aware that quality is as important a consideration of management as are time and costs. More recently, administrative managers have also become aware of the importance of quality. Today, these managers realize that quality does not cost, it pays. Conforming to quality standards saves time and money because it reduces the amount of scrapped material and rework requirements. Higher quality also means fewer field failures and greater customer satisfaction.

This is not to say that upgrading a product saves money. Higher grade products generally cost more to produce. This kind of upgrading is sometimes necessary even though a product conforms to specifications. For example, upgrading might be required if a competitor's product exhibits better performance. However, what we are talking about is reducing the occurrence of management and worker controllable defects. Many of these improvements result from the efforts of organized groups such as "Quality Circles" or "Work Simplification Teams."

In many companies, management is fostering and encouraging the formation of these groups because they provide an organized, systematic approach to increasing productivity and reducing costs. Worker participation is fundamental to this concept. The "Father of work simplification," Allen H. Mogonson says, "The person doing the job knows far more than anyone else about the best way of doing that job, and therefore is the one person best fitted to improve it."

Team Structure

The size and make-up of a team is dependent upon the scope of the work simplification project undertaken. Team members should be selected because they can make a useful contribution, without reference to their position in the company. Voluntary participation is probably best.

Every team should have a leader with a clear responsibility for directing the project. Whenever practical, the leader should be elected by the team members. Also an individual or individuals should be directly responsible for identifying the cause (diagnosing) the problem. People assigned to diagnoses must have the skills and time necessary to perform this function.

The size and formal organization of the team and the formality of the meetings are also dependent on the magnitude of the project. A small intra-departmental project could be handled on an informal basis. Large inter-departmental projects require formal treatment.

Another approach to Work Simplification programs is to have the program introduced through orientation meetings. Teams are formed from volunteers enlisted at these meetings. Each team identifies problems within its area and establishes a team project to solve a particular problem. The process from program introduction to problem solution is diagrammed in Figure 2.

The following paragraphs use Figure 2 in describing how a work simplification team solved an actual problem.

The problem was uncovered and solved by a work simplification team in GTE Lenkurt's Capacitor Department. The team was formed from department personnel who volunteered after learning about the program by watching video tapes and attending meetings sponsored by the Industrial Engineering Department. After the second meeting, the team was formed and elected a leader. These steps are represented by block 1 and 2 in Figure 2. Figure 3 is a photograph of the team members.

The first actual team meeting was a "brainstorming" session to identify and list problems. Once the list was completed, the problems were given priorities by team vote. Every effort was made to get a consensus particularly as to which problem should be addressed first. Table 1 shows a partial list.

The problem given the highest priority was to reduce the rework requirements resulting from bubbles in the epoxy used to seal the ends of one type of capacitor. Figure 4 illustrates the problem. The rework is required because the bubbles might break and allow moisture to enter. Specifically the bubbles violate prescribed electrical specifications.

The next step in the process was to describe the problem completely so that all of the team members understood it. Once the problem was adequately described, a list of its probable effects was prepared at another brainstorming session. It was during the description forming phase that

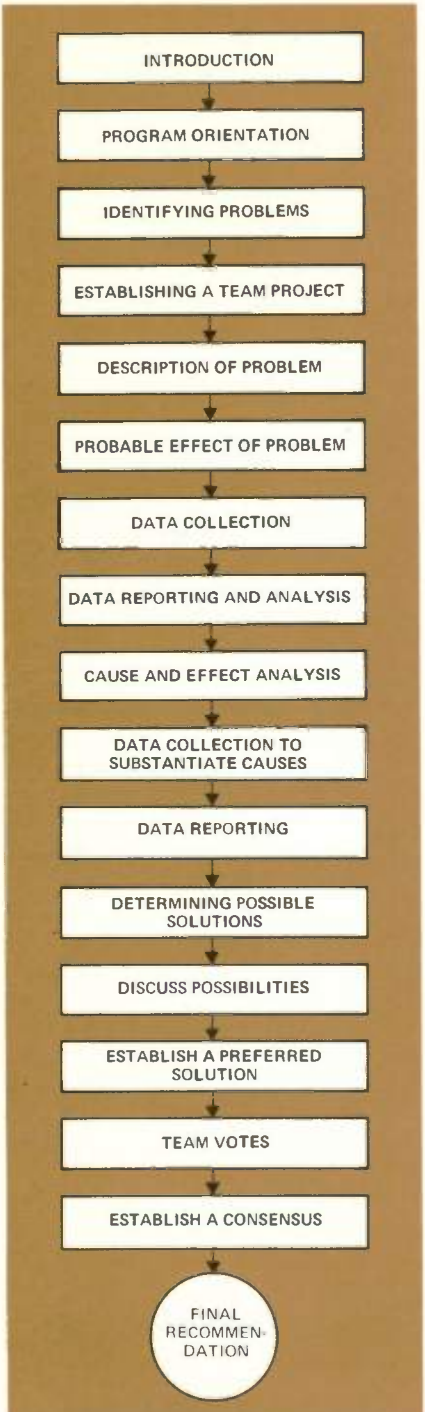


Figure 2. Work Simplification Process.

the bubble problem really came into focus.

The listing of probable effects helped establish the seriousness of the problem which was subsequently verified by cause and effect data gathered and analyzed during the data collection, reporting and analysis steps.

The first data collected and charted showed the total hours rework due to epoxy bubbles as a percentage of total work hours available. Figure 5 is a graph of the data from July 1979 to August 1981.

The most significant fact disclosed by this data was that the rework rate was higher during the warmer months. Armed with this information, the team asked a nearby weather station for day to day temperature information over the same time period. The results showed a close correlation between rework time and ambient temperature. In other words, on a warm day, a greater number of capacitors required rework because of bubbles in the epoxy. This is shown by referencing the rework curve to the temperature scale on the right of Figure 5.

At this point it was apparent that temperature was a major factor in the

Table 1. Problem List.

1. LEAD-ATTACH DIFFICULTIES
2. MORE CABINET SPACE
3. MACHINE DOWN TIME-GENERAL
4. YIELD EFFECT-VARIOUS SIZE CAPS
5. PROGRAMMING LEAD-ATTACH:
   Reduce set-up time
6. LOST TIME: WEIGHING MYLARS
7. LOST TIME: STOCK ROOM TRANSFERS
8. BENT LEADS
9. BUBBLES IN EPOXY

Figure 3. Work Simplification Team. Seated left to right are Ida Greene, Elsie Westfall, Joan Johnson and Sarah Consorti. Standing left to right are Martine Slife, Elaine Hilliard and Agnes Courchaine.

bubble problem. The following plan of attack was established, to verify the cause and investigate possible remedies.

1- Set up tests for improved environment at 60°F. Split a capacitor run and compare results. Repeat at 68°F and 85°F.
2- Add anti-foam additive to Epoxy.
3- Evacuate ("De-Air") Epoxy in a vacuum chamber after mixing.

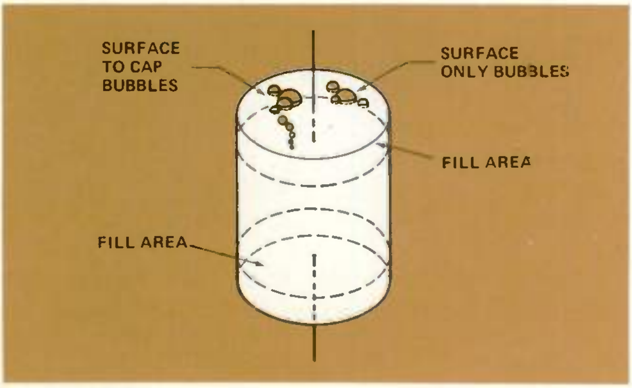


Figure 4. Bubbles in Epoxy.

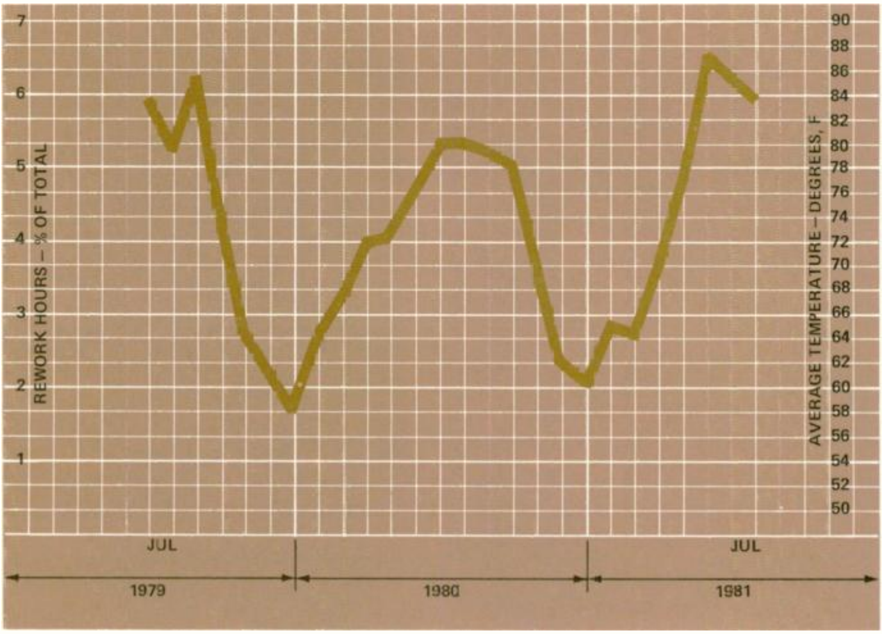


Figure 5. Rework Hours Due to Epoxy Bubbles.

It should be noted that whenever action items like these were formulated, responsibility for their completion was given to definite team members.

The temperature tests confirmed that the number of rejections varied directly with temperature. The use of anti-foam additives did not reduce the percentage of rejects nor did the evacuation procedure, so these remedies were deemed unsatisfactory.

The team met to consider other possible solutions. Two that emerged from this "brainstorming" session were:

1- Perform the work in a temperature controlled area.
2- Find an epoxy which did not bubble excessively at higher temperatures.

The first solution was held in abeyance because providing temperature control for the large area would be quite expensive.

The second possible solution was investigated by selecting four different epoxy's and subjecting them to the same temperature test previously described. The results of these tests are shown in Table 2.

Table 2. Epoxy Evaluation at 84°F.

BATCH	% DEFECTS
A	1.6%
B	8.7%
C	21.9%
D	24.4%

As shown in the Table, Epoxy A is superior to the other three insofar as bubbling is concerned. Epoxy A's 1.6% defect rate at 84 degrees

Farenheit is considered acceptable since the temperature seldom reaches that level and the failure rate decreases at lower temperatures.

While the results are still being evaluated, it is apparent that following the teams recommendation will substanstially reduce rework time. The time saved will be devoted to production — which is to say productivity will be increased. These are hard results which can be measured in dollars.

Another result of the program which cannot be easily quantized is the improvement in worker skills and enthusiasm. Although our discussion did not go into details, team members were encouraged to participate to the maximum extent. Training of team members went hand-in-hand with problem solving. Members learned how to collect and analyze data, how to present data graphically and to give oral presentations to management.

Today, the team is trained and eager to take on new assignments. They are confident of their ability to solve problems.

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30th Anniversary

Founded in March 1952, the Demodulator enters its thirty-first year of continuous publication with this issue. From the beginning, the Demodulator has been dedicated to telling people in the telecommunications industry about advances in technology. Our readers include managers, engineers, technicians and teachers in industry, education, government, the armed forces and the international telecommunications community.

In the early issues, the Demodulator explained basic telecommunications theory and described its applications. Over the years, information has been printed on open-wire carrier, cable carrier, signaling, frequency division multiplexing, microwave radio, pulse code modulation, data transmission, coaxial cable transmission, millimeter waveguide transmission, satellites, cable TV and Fiber Optics.

In May, 1952 the Demodulator discussed transmission losses in radio links. In those days, the microwave frequency was around 900 MHz and the channel capacity was up to 36 voice channels. The September/October 1981 issue describes the use of adaptive equalization to solve multipath problems for digital microwave systems. Between these extremes literally dozens of Demodulator articles are devoted to microwave radio.

Much of the information for the microwave articles was provided by Mr. Robert F. White, a Lenkurt Senior Staff Engineer. In 1970, Lenkurt published a book "Engineering Considerations for Microwave Communications Systems" written by Mr. White. He has since retired but the book is in its fourth printing and still going strong.

Pulse code modulation (PCM) was first discussed in the Demodulator in January 1959. By 1973, we had published enough material to warrant collecting it into one book, "Readings in Pulse Code Modulation." By 1978, enough additional material had appeared in the Demodulator to warrant a second edition.

The first Demodulator article about communications satellites was published in May 1962. The latest article, Satellite RTD (round trip delay) was published in July/August, 1981. Several other articles were published in the interval between these two.

The possibility of using lasers in communications systems was discussed by the Demodulator in July, 1961 and again in November 1965 and January 1970. In February 1972, the transmission of light through optical fibers was first discussed. Subsequent issues in November 1975, November/December 1978 and May/June 1981 discuss fiber optic transmission systems.

Demodulator articles are frequently reproduced in national trade publications such as Telephony, Telephone Engineer and Management and Communications News. Periodically, the more popular articles are reprinted and bound into a single volume. These "Selected Articles From the Demodulator" volumes are sold at cost.

In 1965, the Golden State Chapter of the Society of Technical Writers and Publishers gave the Demodulator a Certificate of Merit as the "Best in Category" of technical publications.

In 1982, the Energy Telecommunications and Electrical Association gave the Demodulator an award for "Excellence of Its Authors and Editors Publishing the Demodulator." This is the first time the association has given an award to any publication. In the interval between these two awards, the Demodulator received national recognition including awards for excellence in illustration from the Technical Illustrators Management Association and the Association of Technical Writers.

Perhaps the greatest recognition the Demodulator has received is its inclusion in the permanent telecommunications exhibit at the Smithsonion Institute, Washington, D.C. The awards and recognition would never have been won without the dedicated efforts of many people. We regret that it is impossible to acknowledge the efforts of each and every individual ever associated with the Demodulator. However, we can and do acknowledge the invaluable contributions of the current staff, whose pictures appear at the end of this article.

On the occasion of the Demodulator's 10th anniversary the then editor, Mr. A.R. Meier wrote: "Unlike many publications, the Demodulator's purpose is not to provide "catalog" information or advertise products, except incidentally. Instead, our aim is to provide a source of information and education about the fascinating, dynamic field of telecommunications which we serve. By stimulating interest and building good will, we think our interests are well served."

As a writer, I might state them differently but my thoughts about the Demodulator agree with those of Mr. Meier.

John B. Birge

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GTE Lenkurt Demodulator

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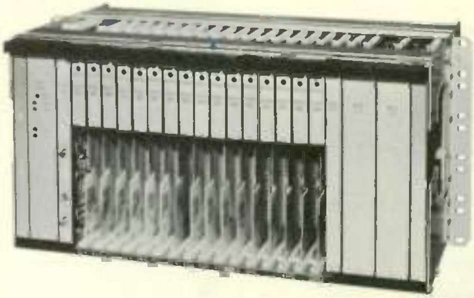

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