



PDHonline Course G238 (4 PDH)

Introduction to Reliability Engineering

Instructor: Robert P. Jackson, PE

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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Introduction to Reliability Engineering

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INTRODUCTION:

One of the most difficult issues when designing a product is determining how long it **will** last and how long it **should** last. If the product is robust to the point of lasting “forever” the price of purchase will probably be prohibitive compared with competition. If it “dies” the first week, you will eventually lose all sales momentum and your previous marketing efforts will be for naught. It is absolutely amazing to me as to how many products are dead on arrival. They don’t work, right out of the box. This is an indication of slipshod design, manufacturing, assembly or all of the above. It is definitely possible to design and build quality and reliability into a product so that the end user is very satisfied and feels as though he got his money’s worth. The medical, automotive, aerospace and weapons industries are certainly dependent upon reliability methods to insure safe and usable products so premature failure is not an issue. The same thing can be said for consumer products if reliability methods are applied during the design phase of the development program. Reliability methodology will provide products that “**fail safe**”, if they fail at all. Component failures are not uncommon to any assembly of parts but how that component fails can mean the difference between a product that just won’t work and one that can cause significant injury or even death to the user. It is very interesting to note that German and Japanese companies have put more effort into designing in quality at the product development stage. U.S. companies seem to place a greater emphasis on solving problems after a product has been developed. [5] Engineers in the United States do an excellent job when cost reducing a product through part elimination, standardization, material substitution, etc but sometimes those efforts relegate reliability to the “back burner”. **Producibility, reliability, and quality start with design, at the beginning of the process, and should remain the primary concern throughout product development, testing and manufacturing.**

QUALITY VS RELIABILITY:

There seems to be general confusion between quality and reliability. Quality is the “totality of features and characteristics of a product that bear on its ability to satisfy given needs; fitness for use”. “Reliability is a **design parameter** associated with the ability or inability of a product to perform as expected over a period of time”. [5] It is definitely possible to have a product of considerable quality but one with questionable reliability. Quality **AND** reliability are crucial today with the degree of technological sophistication, even in consumer products. As you well know, the incorporation of computer driven and / or computer-controlled products has exploded over the past two decades. There is now an engineering discipline called **MECHATRONICS** that focuses solely on the combining of mechanics, electronics, control engineering and computing. Mr. Tetsuro Mori, a senior engineer working for a Japanese company called Yaskawa, first coined this term. The discipline is also alternately referred to as electromechanical systems. With added complexity comes the very real need to “design in” quality and reliability and to **quantify** the characteristics of operation, including the failure rate, the “mean time between failure” (MTBF) and the “mean time to failure” (MTTF). Adequate testing will also indicate what components and subsystems are susceptible to failure under given conditions of use. This information is critical to marketing, sales, engineering, manufacturing, quality and, of course, the VP of Finance who pays the bills.

Every engineer involved with the design and manufacture of a product should have a basic knowledge of quality and reliability methods and practices.

PURPOSE:

The purpose of this course is to provide an introductory body of information that will allow the engineer, engineering manager or corporate manager the resources to start the process of organizing a reliability department within the company he or she works for. We wish to illustrate those key design practices that ensure high levels of reliability. This course will also provide references for further study so that the concepts of reliability and reliability engineering, as applied to commercial and consumer products, are not overlooked or taken for granted. Successfully completing this course will not make you an expert or a specialist but certainly will provide you with an understanding of the basics so further study will be less confusing. There is no doubt about the fact that the design process is one involving many disciplines and even though we explore only one; i.e. reliability, we touch on several others. The last portion of this course will address reliability methodology as applied to computer programming. The study of how to improve the reliability of computer codes is a huge industry and one that garners significant awareness. The interaction of various program packages remains critical to many systems and subsystems. Reliability can provide the understanding, through testing, to insure no issues when two, three or more companies contribute code that will drive systems as found in the “Airbus”, Boeing “Dreamliner, MEGLEV, NASA’s shuttlecraft, top-of-the-line automotive products, etc.

DISCUSSION:

The main goal of reliability engineering is to **minimize** failure rate by **maximizing** MTTF . The two main goals of design for reliability are:

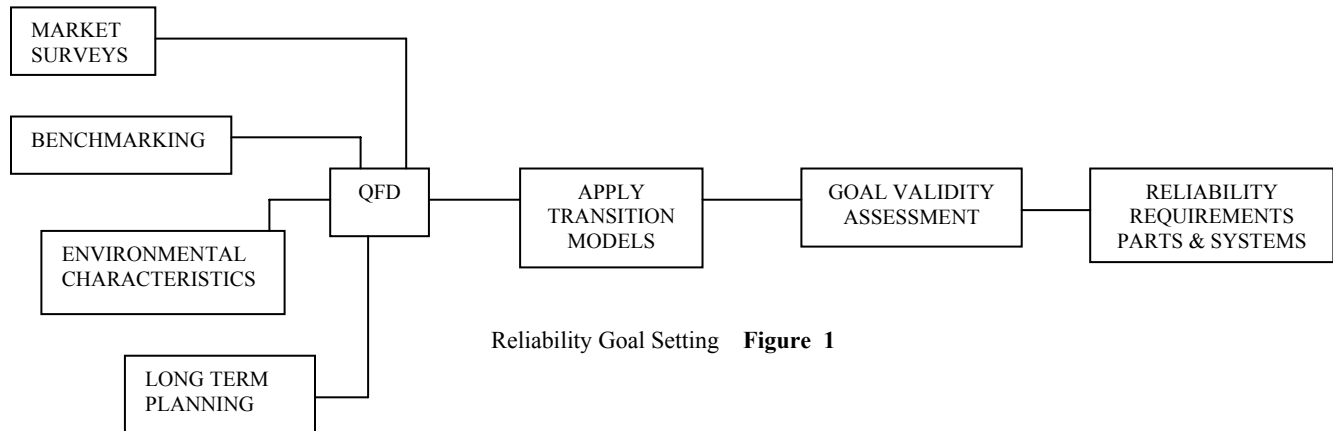
- 1.) Predict the reliability of an item; i.e. component, subsystem and system (fit the life model and/or estimate the MTTF or MTBF)
- 2.) Design for environments that promote failure. [10] To do this, we must understand the KNP’s and the KCP’s of the entire system or at least the mission critical subassemblies of the system.

The overall effort is concerned with eliminating early failures by observing their distribution and determining, accordingly, the length of time necessary for debugging and methods used to debug a system or subsystem. Further, it is concerned with preventing wearout failures by observing the statistical distribution of wearout and determining the **preventative replacement periods** for the various parts. This equates to knowing the MTTF and MTBF. Finally, its main attention is focused on chance failures and their prevention, reduction or complete elimination because it is the chance failures that most affect equipment reliability in actual operation. One method of accomplishing the above two goals is by the development and refinement of **mathematical models**. These models, properly structured, define and quantify the operation and usage of components and systems.

QFD

The very first step in this process is to determine what our customers want and translate those wants into “usable” engineering specifications that detail all elements relating to **form, fit and function**. This must be accomplished prior to formulating any mathematical models of the system. If consumers indicate they would like a range “this wide” and “this deep” with five burners, the engineer must translate this information into width and depth and specify the input of each burner and the appropriate burner type to do the job. This process is accomplished by using a technique called Quality Functional Deployment or QFD. Identification of a need or deficiency triggers conceptual design. The first step in conceptual design is to analyze and translate the need or deficiency into specific qualitative and quantitative customer and design requirements. [13] Well-defined and unambiguous requirements are absolutely

necessary and will lessen the probability of “false starts” and “detours” in the development process. We wish to minimize the inconsistencies between articulation of functional requirements and the definition of system requirement and parameter target values. [13] A matrix of features is developed and rated for desirability so engineering can translate those features into “hard” specifications. The following sketch will indicate one possible approach for doing just that.



DEFINITIONS

I think it's appropriate at this time to define Reliability and Reliability Engineering. As you will see, there are several definitions, all basically saying the same thing, but important to mention, thereby grounding us for the course to follow.

“Reliability is, after all, engineering in its most practical form.”

James R. Schlesinger
Former Secretary of Defense

“Reliability is a projection of performance over periods of time and is usually defined as a quantifiable design parameter. Reliability can be formally defined as the probability or likelihood that a product will perform its intended function for a specified interval under stated conditions of use.”

John W. Priest
Engineering Design for Producibility and
Reliability

“Reliability engineering provides the tools whereby the probability and capability of an item performing intended functions for specified intervals in specified environments without failure can be specified, predicted, designed-in, tested, demonstrated, packaged, transported, stored installed, and started up; and their performance monitored and fed back to all organizations.”

Unknown

“Reliability is the science aimed at predicting, analyzing, preventing and mitigating failures over time.”

John D. Healy, PhD

“Reliability is ---blood, sweat, and tears engineering to find out what could go wrong ---, to organize that knowledge so it is useful to engineers and managers, and then to act on that knowledge”

Ralph A. Evans

“The conditional probability, at a given confidence level, that the equipment will perform its intended function for a specified mission time when operating under the specified application and environmental stresses. “

The General Electric Company

“By its most primitive definition, reliability is the probability that no failures will occur in a given time interval of operation. This time interval may be a single operation, such as a mission, or a number of consecutive operations or missions. The opposite of reliability is unreliability, which is defined as the probability of failure in the same time interval “.

Igor Bazovsky

“Reliability Theory and Practice”

Personally, I like the definition given by Dr. Healy although the phrase “performing intended functions for specified intervals in specified environments “ adds a reality to the definition that really should be there. Also, there is generally associated with reliability data a confidence level. We will definitely discuss confidence level later on and how that factors into the reliability process. **I would recommend now that you take a look at the glossary of terms and vocabulary given with this document.** Reliability, like all other disciplines, has its own specific vocabulary and understanding “the words” is absolutely critical to the overall process we wish to follow.

PROCESS:

No mechanical or electromechanical product will last forever without preventative maintenance and / or replacing critical components. Reliability engineering seeks to discover the **weakest link** in the system or subsystem so any eventual product failure may be predicted and consequently forestalled. Any operational interruption may be eliminated by periodically replacing a part or an assembly of parts prior

to failure. This predictive ability is achieved by knowing the meantime to failure (MTTF) and the meantime between failures (MTBF) for “**mission critical**” components and assemblies. With this knowledge, we can provide for continuous and safe operation, relative to a given set of environmental conditions and proper usage of the equipment itself. The **test, find, fix (TAAF of TAAR)** approach is used throughout reliability testing to discover what components are candidates for continuous “preventative maintenance” and possibly ultimate replacement. Sometimes designing redundancy into a system can prolong the operational life of a subsystem or system but that is generally costly for consumer products. Usually, this is only done when the product absolutely must survive the most rigorous environmental conditions and circumstances. Most consumer products do not have redundant systems. Airplanes, medical equipment and aerospace equipment represent products that must have redundant systems for the sake of continued safety for those using the equipment. As mentioned earlier, at the very worst, we **ALWAYS** want our mechanism to “fail safe” with absolutely no harm to the end-user or other equipment. This can be accomplished through engineering design and a strong adherence to accepted reliability practices. With this in mind, we start this process by recommending the following steps:

- 1.) Establish reliability goals and allocate reliability targets.
- 2.) Develop functional block diagrams for all critical systems
- 3.) Construct P-diagrams to identify and define KCPs and KNPs
- 4.) Benchmark current designs
- 5.) Identify the mission critical subsystems and components
- 6.) Conduct FMEAs
- 7.) Define and execute pre-production life tests; i.e. growth testing
- 8.) Conduct life predictions
- 9.) Develop and execute reliability audit plans

These steps will fit into the reliability process and “weave” themselves into the flowchart as given:

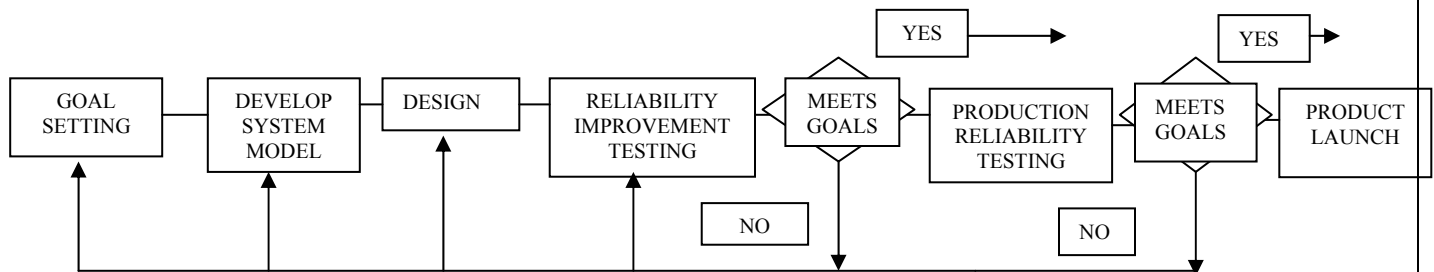


Figure 2

It is appropriate to mention now that this document assumes the product design is, at least, in the design confirmation phase of the development cycle and we have been given approval to proceed. Most NPI methodologies carry a product through design guidance, design confirmation, pre-pilot, pilot and production phases. Generally, at the pre-pilot point, the design is solidified so that evaluation and reliability testing can be conducted with assurance that any and all changes will be fairly minor and will not involve a “wholesale” redesign of any component or subassembly. This is not to say that when “mission critical components” fail we do not make all efforts to correct the failure(s) and put the product back into reliability testing. At the pre-pilot phase, the market surveys, consumer focus studies and all of the QFD work have been accomplished and we have tentative specifications for our product. Initial prototypes have been constructed and upper management has “signed off” and given approval to proceed into the next development cycles of the project. **ONE CAUTION:** Any issues involving safety

of use must be addressed regardless of any changes becoming necessary for an adequate “fix”. This is imperative and must occur if failures arise, no matter what phase of the program is in progress.

Critical to these efforts will be conducting HALT and HAST testing to “make the product fail”. This will involve DOE (Design of Experiments) planning to quantify **AND** verify FMEA estimates. Significant time may be saved by carefully structuring a reliability evaluation plan to be accomplished at the component, subsystem and system levels. If you couple these tests with appropriate field-testing, you will develop a product that will “go the distance” relative to your goals and stay well within your SCR (Service Call Rate) requirements. Reliability testing must be an integral part of the basic design process and time must be given to this effort. The NPI process always includes reliability testing and the assessment of those results from that testing. Invariability, some degree of component or subsystem redesign results from HALT or HAST because weaknesses are made known that can and will be eliminated by redesign. In times past, engineering effort has always been to assign a “safety factor” to any design process. This safety factor takes into consideration “unknowns” that may affect the basic design. Unfortunately, this may produce a design that is structurally robust but fails due to Key Noise Parameters (KNPs) or Key Control Parameters (KCPs).

KNPs

Key noise parameters represent a list of all potential factors the design must be **insensitive** to, such as temperature, mechanical stresses, voltage spikes, humidity, EMI, dust, contaminants, access cover damage, shipping processes etc. Every engineer must specify the range of operating conditions the product may see and these products must be able to operate successfully within this range of conditions. These specifications are called the **limits of acceptability** and are generally uncontrollable. The limits of acceptability are thought to be external factors acting upon the product.

KCPs

Key control parameters represent a list of all **design variables** specified by the design engineer. Motor windings, laminations, air gap, torque requirements, blade features, orifice sizes, shaft dimensions, wiring specifications, PC board layout are all examples of KCPs. These variables are **controllable**.

KCP and KNP parameters are detailed on our “P”- Diagram(s) or parameter diagram and describe the inputs and outputs of the overall system or subsystem. It is critical to understand these influences so we can apply them during our reliability growth testing. The one factor we fail to test for will be the one that creates the greatest issues with mission critical parts. Once we know the KCPs, we can structure our DOE, using those KCPs as independent factors, to see what affect they have on the product as a whole. We then use an optimization approach with these factors to see what might be the predicted performance of the overall product. To illustrate the approach, let’s assume we have three design factors or three KCPs (A,B and C) and the designer has two options as far as the final setting for each. Our DOE matrix would look something like this:

2 Level Full Factorial Design for 3 Factors
Table

	Factor		
	A	B	C
Run			
1	1	1	1
2	1	1	2
3	1	2	1
4	1	2	2
5	2	1	1
6	2	1	2
7	2	2	1
8	2	2	2

Table 1

Let's take a look at one more example. Assume we have three ranges and three oven doors and we wish to provide statistical data from a test matrix in which the three doors are rotated between all three ranges. We therefore will be getting data from nine (9) different platforms as follows:

Ranges			
	1	2	3
Doors	1	2	3
	3	1	2
	2	3	1

Table 2

We may be testing for surface temperatures, cycle testing door hinges, cycle testing door springs, measuring pull forces on a new door handle mechanism, etc. This DOE matrix will provide useful design data for overall evaluation of a component or system of components.

We will now take a look at each step in this process and describe how these steps factor into the overall effort. As always, we cut the cloth to fit the pattern. All companies are different and careful evaluations must be made during the planning phase for establishing reliability engineering processes.

ESTABLISH RELIABILITY GOALS AND ALLOCATE RELIABILITY TARGETS:

Reliability goals should be thought of as one (1) year goals (SCR) **AND** long term goals. Long-term goals are dependent upon the product and the industry, although they are generally no less than ten (10) years in duration. This length of time is very common for consumer products, especially durable goods. Engineering management and marketing management will have to determine what goals are realistic. This is always dependent upon the industry and competition within the industry. We want to start

formulating those goals at the **product level**. Then, taking the complete bill of materials for the product, we structure system, subsystem and component reliability goals for **mission critical parts and assemblies**. A proper reliability goal consists of a failure rate at a particular time with a confidence level that is required to validate that reliability goal; i.e. 10% failure in ten (10) years at a 90% confidence level or 5% SCR with a 90% confidence level. Please remember that SCR is service call rate and is generally understood to be the failure rate during the first year of product operation. [6] In considering the confidence level, we know that statistical estimates are more likely to be close to the true value as the **sample size increases**. There is a very close correlation between the accuracy of an estimate and the size of the sample from which it is obtained. Only an infinitely large sample size could give us a 100 percent confidence or certainty that a measured statistical parameter coincides with the true value. In this context, confidence level is a mathematical probability relating the mutual positions of the true value of a parameter with its estimate. [4] This is the reason that, when running growth-testing programs, sample size is important. A test program with only one sample or one product will not suffice and will not provide the statistical assurance of problems found and fixed. Some companies will factor in “customer education”, issues with literature and other “non-hardware” related items into the SCR rate. This is fine but it does tend to slant the overall SCR.

FAILURE RATE:

There are two basic formulas that define failure rate, the well-known **exponential** formula:

$$R(t) = e^{-(\lambda t)} \quad (\text{Formula 1})$$

In this formula, e is the base of the natural logarithm (2.71828), λ is a constant we call the failure rate, t is the operating time for which we want to know the reliability of the device. **NOTE: the failure rate must be expressed in the same units as the time “t”, usually in operating hours.** The reliability R is then the probability that the device, which has a constant failure rate λ , **will not fail** in the given operating time t . Reliability is the probability of success.

The second formula is:

$$R(t) = e^{-[t/\mu]^\theta} \quad (\text{Formula 2})$$

This is the formula for a Weibull distribution and is frequently used for describing mechanical parts. Again, t is the operating time for which we want to know the reliability of the device, μ is known as the scale parameter, or slope of the curve depicting the time vs. failure rate plot and θ is the shape parameter. The scale parameter determines when, in time, a given portion of the population will fail. The shape parameter is the key feature of the Weibull distribution that enables it to be applied to any phase of a “bathtub” curve. A shape parameter < 1 models a failure rate that decreases with time, $\theta = 1$ models a constant failure rate and $\theta > 1$ models an increasing failure rate, as during wearout.

There is one other relationship that is very important and frequently used as follows:

$$MTBF = 1/\lambda \quad (\text{Formula 3})$$

From these formulas, we see that $R(t) = e^{-(t/MTBF)}$ (Formula 4)

NOTE: When you are calculating reliability using the formulas above, be sure to include the minus (-) sign in the exponential expression.

From these expressions we see that **reliability** is expressed as a fraction between 0 and 1 and we hope much closer to 1 than 0. The only controlling factor, from an engineering standpoint, is the failure rate λ and we always strive for that value to be as low as possible consistent with other design restraints. In looking at the useful life of a product, the reliability of the last 10 hours of life is the same as for the first 10 hours of life. Let us assume that a “debugged” device has a 1,000 hour useful life with a failure rate $\lambda = 0.0001$ per hour operating in a given environment. Its reliability for any 10 hours of operation within these 1,000 hours of useful life is:

$$R(t) = e^{-[(0.0001)(10)]} = 0.9990 \text{ or } 99.9 \%$$

The probability that the device will not fail within its entire useful life is as follows:

$$R(t) = e^{-[(0.0001)(1000)]} = 0.9048 \text{ or } 90.48 \%$$

It has a 90% chance of operating 1,000 hours or its predicted life but, if it survives up to 990 hours, the probability of it surviving another 10 hours is 99.9%. Now, let's say the device survives past the 1,000 predicted life, wearout will begin to play a roll and the reliability will decrease for each subsequent 10 hours of operation until failure UNLESS we understand that a certain component is “mission critical” and needs replacement at the 1,000th hour of operation. When the part is replaced, the projection changes. In all probability, this knowledge was gained through reliability growth testing.

THE BATHTUB CURVE:

Exponential distribution or constant failure rate usually takes the shape of a “bathtub” curve where the failure rate, λ is plotted on the “y” axis and time “t” is plotted on the “x” axis. The bathtub curve does not indicate the failure of a single item or component but seeks to describe the failure characteristics of a specific population over time. When we talk about the **life predictions** of a product, we do so knowing the three areas of the curve define that product. These areas are as follows:

- 1.) Early failures or “**infant mortality**” failure, which usually represent quality, issues with manufacturing or design. These can show up quickly, usually during “burn-in” or initial running of the equipment. From $t = 0$, these failures diminish in frequency and number until the curve levels off or develops a slope equal to zero. We definitely wish to minimize the occurrence of infant mortality and to do so means a.) Appropriate specifications, b.) Adequate design, c.) Realistic tolerances and d.) Sufficient component **derating** relative to operating conditions. In addition to all of the above, stress testing; i.e. HALT and HAST, should be started at the earliest phase of the product design to discover what failure will occur. All failures must be investigated and components redesigned to improve the probability of life cycle usefulness. Another process to identify components that may experience infant mortality is “burn-in”. When failure is absolutely unacceptable initial burn-in certainly may be warranted.
- 2.) The second phase of the curve represents “**useful life**” in which random failures may occur due to over-stressing of the equipment. These stresses may exceed the design strength. One fact that is very important: MTBF applies when the underlying distribution has a constant failure rate. In other words, during the useful life of the product. **MTBF IS NOT SERVICE LIFE !!!** They do not equate.
- 3.) The last part of the curve represents “**wear out**” failures where the product reaches or exceeds its useful life. The parts begin to wear and degenerate to the point of system failure. Everything, eventually, wears out. **The job of the design engineer is to insure that the component with the shortest useful life lasts longer than the stated useful life of the product.** If the “weakest

component” can be easily replaced, doing so will not degrade the consumer’s opinion of the product but, if it cannot be easily replaced and not expected to fail, difficulties arise.

Please note: “ The actual time periods for these three characteristic failure distributions can vary greatly. Infant mortality does not mean that products fail within 90 days or any other defined time period. Infant mortality is the time over which the failure rate of a product is decreasing, and may last for years. Conversely, wearout will not always happen long after the expected product life. It is a period when the failure rate is increasing, and has been observed in products after just a few months of use. This, of course, is a disaster from a warranty standpoint! [18]

THE BATHTUB CURVE HYPOTHETICAL FAILURE RATE VERSUS TIME

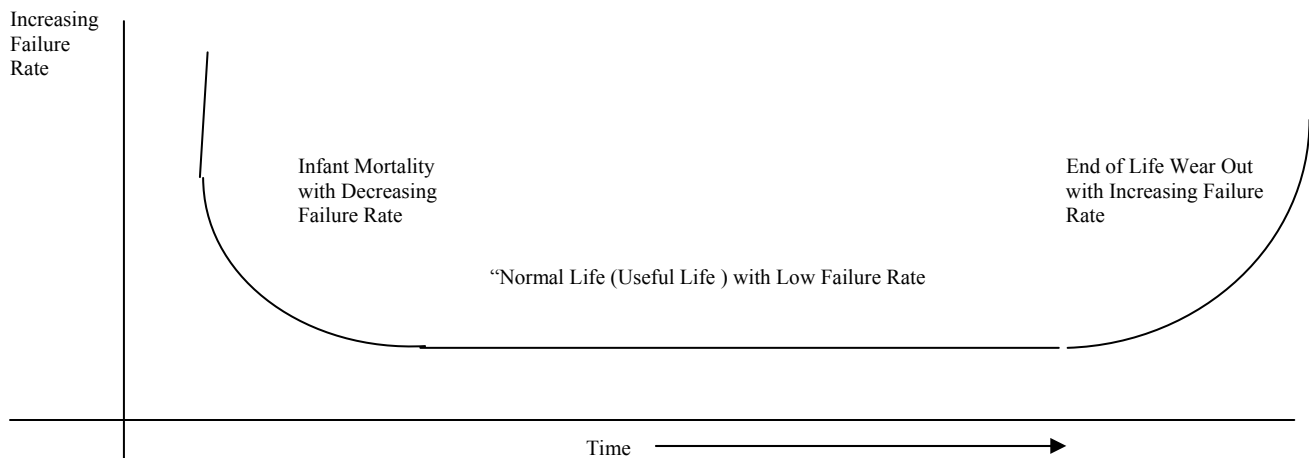


Figure 3

It is important to note as long as the population is kept constant by replacement of failures, approximately the same number of failures will occur in periods of equal length. If we do not replace the failed components, the population will decay exponentially and the number of failures in periods of equal length will also decay exponentially. This is due to the fact that there will be fewer and fewer components alive with each failure. The often stated rule of reliability is to replace components as they fail within their useful life and replace each component preventively, even if it has not failed, but not later than the end of its useful life or life cycle. Of course, to do this, we must know the useful life cycle or life expectancy.

SERIES AND PARALLEL:

We now wish to look at the reliability for two types of systems; i.e. series and parallel. The majority of devices may be modeled as series with one component, assembly or subassembly dependent upon another. Proper operation of a device such as this is dependent upon each subassembly or “block”. That type of arrangement may be modeled as follows:

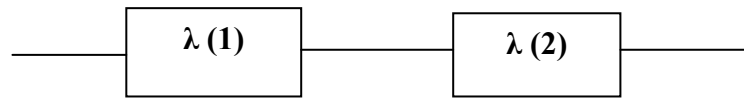
**SERIES MODEL**

Figure 4

With a series, $R = R(1) \times R(2)$ or using failure rates, $\lambda = \lambda(1) + \lambda(2)$. From this, we can see the following:

$$R(s) = R(1) \times R(2) \times R(3) \dots \quad R(s) = \prod_{i=1}^n R_i \quad (\text{Formula 5})$$

$$R(s) = e^{-(\lambda(1) + \lambda(2) + \lambda(3) + \dots)t} \quad R(s) = e^{-(\sum_{i=1}^n \lambda_i t)} \quad (\text{Formula 6})$$

A parallel mathematical model would look as follows:

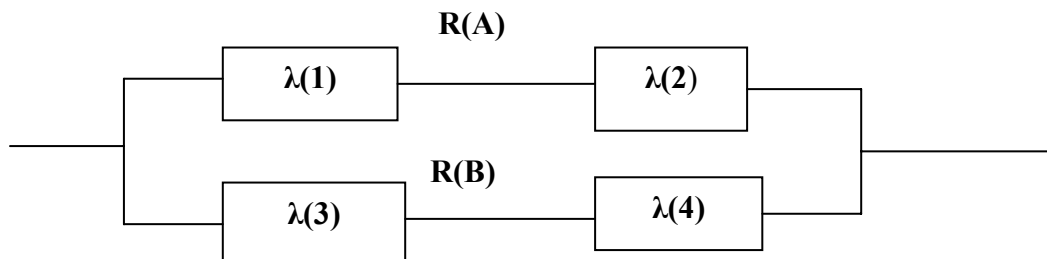
**PARALLEL MODEL**

Figure 5

The formula for reliability in a parallel model is as follows:

$$R = R(A) + R(B) - [R(A) \times R(B)] \quad (\text{Formula 7})$$

If the elements are identical, the formula becomes, $R = 2R(A) - R(A)^2$ (Formula 8)

I would like now to take an example from the text “Reliability Theory and Practice” by Igor Bazovsky which will demonstrate the calculations necessary to determine the reliability of an assembled device. We will look at a printed circuit board with the following characteristics:

10 Silicon Diodes	$\lambda(d) = 0.000002$
4 Silicon Transistors	$\lambda(t) = 0.00001$
20 Composition Resistors	$\lambda(r) = 0.000001$
10 Ceramic Capacitors	$\lambda(c) = 0.000002$

NOTE: For our example here all failure rates are in hours.

These “on-board” components represent a series arrangement so that any component failure will shut down the entire board. Ultimate “success” requires proper operation of each component. To estimate the reliability of the entire circuit, we first add up all of the expected failure rates; i.e.

$$\Sigma \lambda = 10\lambda(d) + 4\lambda(t) + 20\lambda(r) + 10\lambda(c) = 0.0001$$

The estimated reliability is $R(s) = e^{-(0.0001)t}$ where “t” is the operating time in question. If “t” = 10 hours, the reliability or probability that the circuit will **NOT** fail is 99.9%. As given above, the expected failure rate is 0.0001 per hour which gives us MTBF of $1/\lambda$ or $1/0.0001$ or 10,000 hours. Please note that the circuit board is expected to operate within the environment it was designed for. If that environment is changed for extended periods of time, the reliability calculations may not adequately define expectations. That’s why, when specifying operating characteristics for electronic devices, we sometimes see “limits of acceptability to be 85 degrees C with 1 hour excursions to 105 degrees C”. This type of specification is not uncommon at all.

FBDs or Functional Block Diagrams become very important in capturing those influences upon a system of components. They can certainly aid the engineering effort in assigning and understanding the “dependent blocks” and those influences; i.e. KNPs and KCPs upon the system of parts. I definitely recommend engineering personnel structure FBDs to facilitate this process.

ALLOCATION SPREADSHEET:

We now wish to portray the method used for the allocation of failure rate data for mission critical systems and subsystem. A typical “flowdown” reliability spreadsheet would look something similar to the one given below.

ELECTRIC RANGE	TODAY	TARGET	PREDICTED
λ	0.0652	0.0404	0
MTBF (years)	15	25	N/A
SUBSYSTEM	λ		
	Today	Target	Predicted
Backsplash & Cooktop	0.0228	0.0164	0
Controls	0.025	0.0147	0
Structure & Oven	0.0048	0.0028	0
Door & Drawer Asm	0.0126	0.0065	
COMPONENT	λ		
	Today	Target	Predicted
Backsplash, High	0.0007	0.0005	
Backsplash, Low-Mid	0.0012	0.0006	
Cooktop, Coil	0.0056	0.0038	
Element, Radiant	0.0061	0.0049	
Electronic Control	0.0137	0.0068	
Sensors	0.0013	0.0008	
Range Body	0.0012	0.0007	
Oven Cavity	0.0017	0.0009	
Door	0.0056	0.0034	
Door Hinge	0.0041	0.0016	

Table 3

You basically take the bill of materials that make up the subsystems and structure a detailed list of those mission critical areas that warrant defining failure rates for. You then do the very same for those components within each subsystem. Generally, at this time, you decide upon what components are

replaceable and which ones you will supply repair part or replacement kits for. **This is called reliability allocation.** The first “look” will be an estimate but as the growth testing and field service data becomes available, more accurate information will populate the spreadsheet.

DEVELOP FUNCTIONAL BLOCK DIAGRAMS FOR ALL MISSION CRITICAL SYSTEMS:

The act of structuring a functional block diagram grounds the design team so that all members will understand how the various subsystems interface and affect each other. It provides the structure for the product and will form the basis of understanding for the reliability allocation matrix. Basically, an FBD will do the following:

- Define the system function
- Define the operational modes of the system
- List the subsystems and show the boundary limits of the respective subassemblies
- List the functions of the subsystems (active and passive)
- Define the inputs and outputs of the systems, subsystems and components
- Define the failure critical or mission critical parts and interdependences

FBDs were introduced by IEC 61131-3 to overcome the weaknesses associated with textual programming and ladder diagrams. The primary purpose is to graphically represent interconnected subsystems to express system behavior. [15]. FBDs can, in some ways, be compared with integrated circuits where one of the best features is the relative ease in representing changes when those changes become necessary.

Given below is a typical FBD for a refrigeration system. This will illustrate the methodology used and the basic structure of the diagram. Software does exist to facilitate creating FBDs but, unless the systems are extremely complex, the process can be done by hand or by using PowerPoint® or some other graphics software.

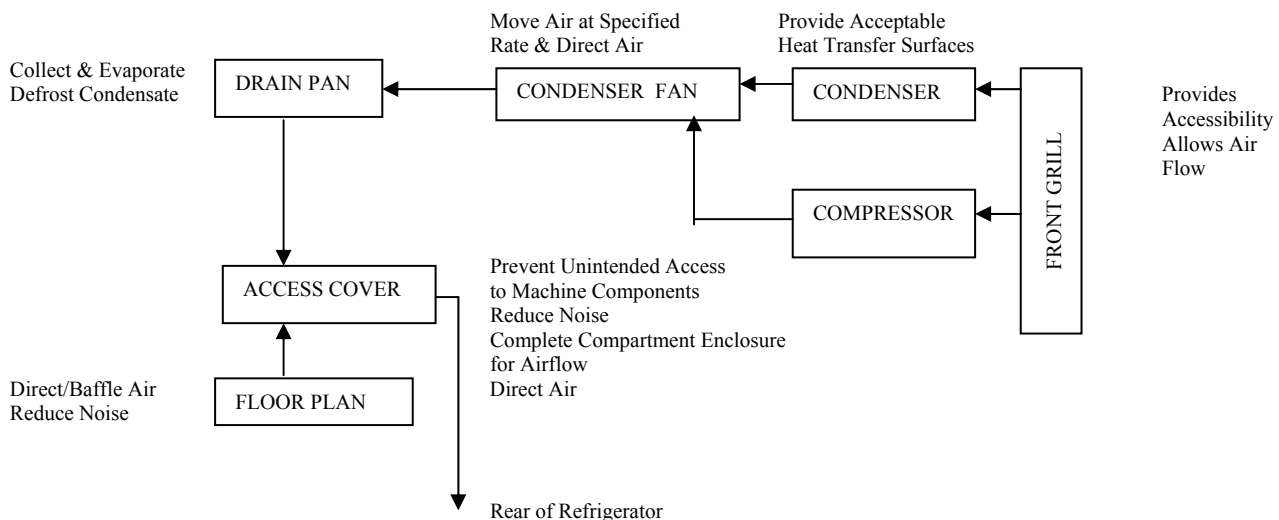


Figure 6

CONSTRUCT “P”-DIAGRAMS TO DEFINE KNPs AND KCPs:

A “P”-diagram is a parameter diagram and is an excellent technique for planning an effective evaluation and reliability test program. All of the correct environmental conditions must be factored into the test plans in order that the appropriate stresses and influences may be applied to the product during reliability testing. The basic structure or template for a “P”-diagram is as follows:

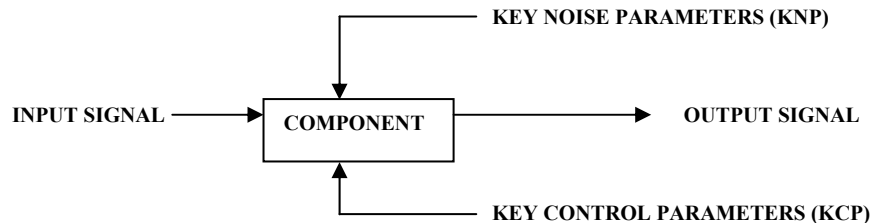


Figure 7

A diagram for a condenser fan motor and blade assembly would look as follows:

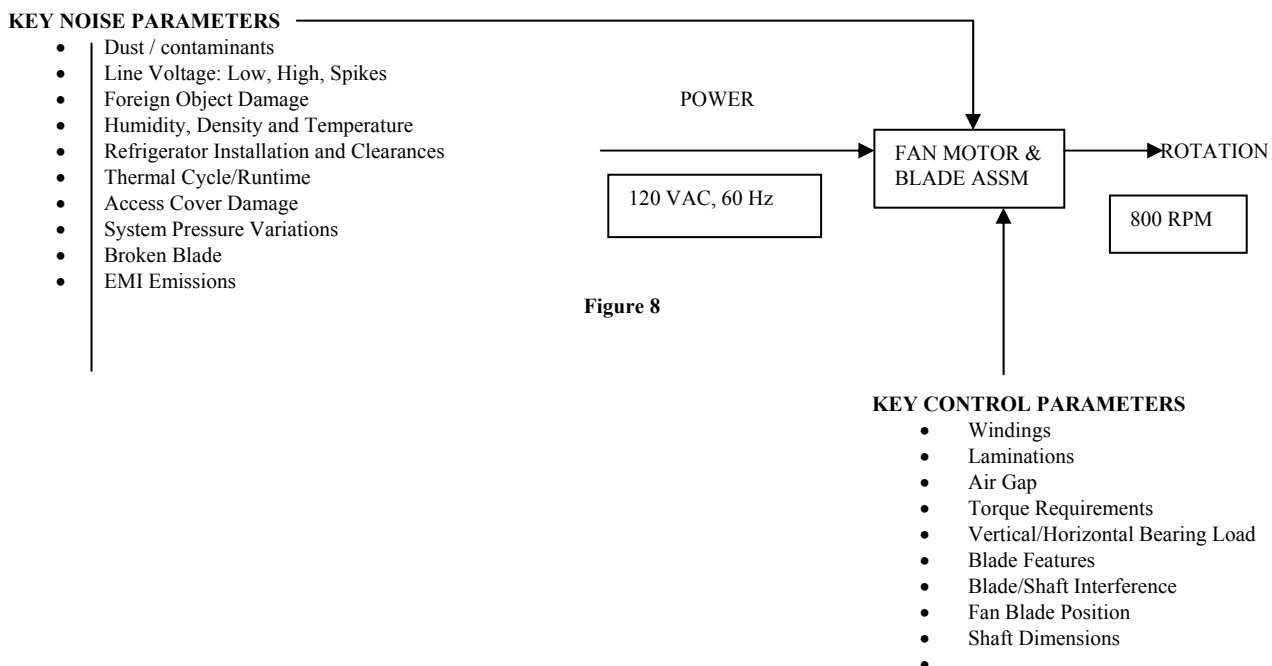


Figure 8

We wish to structure this type of diagram for all components we feel are “mission critical”.

BENCHMARKING:

If you look at the allocation spreadsheet above you will notice a column labeled “today”. This tabulation is for known failure rates that exist for products in production. The data is derived from experience with the products, subassemblies and components we have and the field service they give to “paying” customers. With any new product, we wish to start our allocation spreadsheet by tabulating failure rates for components similar to the ones we have specified previously. It’s a method of extrapolating; thereby allowing us to generate an estimate of the overall SCR and failure rate for a given

product. It's a great technique and gives us a very good method to "calibrate" the product level failure rate of our new product. Granted, the first rendition is an estimate but it does give us a place to start.

IDENTIFY THE MISSION CRITICAL SUBSYSTEMS AND COMPONENTS:

Mission critical components, when failure occurs, will interrupt or completely disable the product. It is very important to identify those components very early in the process so adequate testing and redesign, if needed, may be accomplished. This becomes somewhat difficult if a product represents a new concept for the company. HALT and HAST can provide excellent estimates of which components will fail. It is less difficult if the product is a redesign or an "off-shoot" of an existing product now being offered. The very best method to determine mission critical components is by looking at service call rates and discussing those rates with the service men and women having to interface with customers in the field. As described above, this is called benchmarking. Most companies will have tracking systems dedicated to noting and dealing with service calls generated from customers who have bought the product and who have had difficulties with its use. I have used a system that details SCR for:

- Gas burner ignition systems; i.e. igniters, spark ignition electrodes, standing pilots, ignition wiring
- Burner grates
- Electronic range controllers
- Porcelain enamel maintops
- Control panel graphics
- Control panel end caps
- Oven racks
- Gas burners
- Door lock mechanisms

For each category, total year-to-date and annual records are kept that allow identification of the "top ten". Those components and subsystems that create the top ten problem categories for the product in question. A "fault code" is assigned to each problem area so that a field service individual only has to use the appropriate code to designate the classification of the problem. A "sort" is then performed by service call managers to quantify those fault codes presenting the greatest number of "hits". These failures receive the most visibility and consequently the most engineering effort relative to redesign. Effective field repair costs upwards to \$100.00 per service call, plus parts, so if we define SCR as being the number of defective products / the number of products in operation, you can see there is a huge effort made to minimize and reduce field service repairs. I have association with high volume companies in which one percentage point of SCR reduction can create \$1,000,000 added to the bottom line. Some companies form a committee for the sole purpose of identifying mission critical parts. The members of this committee are generally people with considerable experience and a complete understanding of how the product is designed and its intended use.

CONDUCT FMEAs:

Failure Mode and Effect Analysis is the cornerstone of the reliability engineering process. It is a methodology for analyzing potential reliability problems early in the development cycle. It is a technique to identify potential failure modes, determine their effect on the operation of the product and identify actions to mitigate the failures. [8] With this being the case, an engineer can "design out" components or modify those components to make them more robust relative to the operational

conditions that will be encountered during use. Please note that FMEAs are always conducted after critical subassemblies are identified. There are several types of FMEAs, as follows:

- System—focuses on global system functions
- Design—focuses on components and subsystems
- Process—focuses on manufacturing and assembly processes
- Service—focuses on service functions
- Software—focuses on software functions

We look at, and rate, three areas: severity, probability of occurrence and the ability to detect the specific failure. There is a very simple template that will capture the possible failure modes and designate actions to be taken at a later date. An example of that template is as follows:

ITEM PART NUMBER OR NAME	POT FAILURE MODE	POT EFFECT OF FAILURE	POSSIBLE CAUSE	SEVERITY	OCCURENCE	DETECTION	ACTIONS TAKEN	RESPONSIBILITY

Table 4

The “header” for the template would show the Product Name, the Date, the System or Subsystem Name, the Name of the Design Leader and the Revision Number.

The process of conducting a FMEA for any product is as follows:

1. Assemble a team of individuals who have product knowledge. These people should come from the following disciplines: a.) design engineering, b.) manufacturing, c.) service, d.) quality, e.) repair.
2. Make sure the FBDs and “P”-Diagrams are available to adequately represent the system, subsystem or component.
3. Construct the FMEA template or work sheet.
4. Convene the team to identify the possible failure modes and assign importance to the severity, probability of occurrence and the probability of detecting the failure. Generally, the rating system goes from one (1) to ten (10) with ten being the most severe and creating the greatest operational issues. A recommendation from Mr. Stephen Curtis posted on the Six Sigma.com web site recommends the following classifications for the three line items:

SEVERITY			
Hazardous without warning	Very high severity ranking when potential failure mode effects safe operation		10
Hazardous WITH warning	Very high when a potential failure mode affects safe system operation WITH warning		9
Very High	System inoperable with destructive failure WITHOUT compromising safety		8
High	System inoperable with equipment damage		7
Moderate	System operable with minor damage		6
Low	System inoperable without damage		5
Very low	System operable with significant degradation of performance		4
Minor	System operable with some degradation of performance		3
Very minor	System operable with minimal interference		2
None	No effect		1

PROBABILITY			
Very high	Failure is almost inevitable	> 1 in 2	10
		> 1 in 3	9
High	Repeated failures	1 in 8	8
		1 in 20	7
Moderate	Occasional failures	1 in 80	6
		1 in 400	5
		1 in 2000	4
Low	Relatively few failures	1 in 15,000	3
		1 in 150,000	2
Remote	Failure is unlikely	< 1,500,000	1

DETECTABILITY			
Absolute uncertainty	Design control cannot detect potential cause and subsequent failure mode		10
Very remote	Very remote chance the design will detect potential cause.		9
Remote	Remote chance of detection		8
Very low	Very low chance the design control will detect potential and subsequent failure		7
Low	Low chance the design control will detect potential and subsequent failure		6
Moderate	Moderate chance the design control will detect potential and subsequent failure		5
Moderately high	Moderately high chance the design control will detect potential and subsequent failure		4
High	High chance the design control will detect potential and subsequent failure		3
Very high	Very high chance the design control will detect potential and subsequent failure		2
Almost certain	Design control will detect cause and subsequent failure mode		1

Table 5

5. Multiply the assigned numbers for severity, occurrence and detection together for a final score and record that score for later use. A score of 1,000 would indicate a failure that should definitely be addressed and one that would be coded as a “red” item. Red items must be fixed before pre-pilot builds occur and certainly before pilot runs occur. Some companies designate any score above 600 as a “red” item.
6. For each failure mode, identify what you feel to be the “root cause” of the failure. This will take experience and you may wish to consult the services of field technicians for their comments relative to product use and problem areas.
7. Describe the effects of those failure modes; i.e. injury to user, inoperability of product, improper appearance of product, degraded performance, noise, etc.
8. Determine what must be the initial recommended action. This is done for each failure mode.
9. Assign responsibility for addressing the “fix”.
10. Assign a “get well” date.
11. Before adjourning, establish a time to reconvene for a status on the failures and the “fixes”.

FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION SYSTEM (FRACUS):

FRACUS is an organized system for reporting failures encountered in testing, tracking failure investigations and then assuring implementation of corrective actions. FRACUS is frequently used in conjunction with reliability testing but is also applied to categorizing field failures. Unlike other reliability activities, FRACUS promotes reliability improvement throughout the life cycle of the equipment. [12] According to MIL-STD-2155:

“ Corrective action options and flexibility are greatest during design evolution, when even major design changes can be considered to eliminate or significantly reduce susceptibility to known failure causes. These options and flexibility become more limited and expensive to implement as a design becomes firm. The earlier the failure cause is identified and positive corrective action implemented, the sooner both the producer and the user realize the benefits of reduced failure occurrences in the factory and in the field. Early implementation of corrective action also has the advantage of providing visibility of the adequacy of the corrective action in the event more effort is required.”

FRACUS can provide control and management visibility for improving the reliability and maintainability of product level systems and individual components. All failures are noted and those failures are **consolidated into a central database**. The mechanism for doing this is an **“event record”** and contains the following information.

- Product level or component level serial number. (Each product tested must have a tracking number in order to insure the proper data is associated with the product or part being tested. Some companies will designate a component or product as DG-1, DG-2, DC-1, P-1, etc for design confirmation, design guidance, pilot, etc.) Regardless of the system used, some method is needed for differentiation.
- Date. This is the date of the recorded failure.
- Time. This is the time of the recorded failure.
- Downtime category. Is this a scheduled stop in testing or an unscheduled stop in testing?
- Duration of work stoppage.
- Life cycle phase. This would be DG, DC, pre-pilot, pilot or production
- System. The **product** model number from which the component or subsystem is taken.
- Part number. The part number of the component that failed.
- Operator or technician
- A description of the failure. I would use digital photographs to enhance the documentation of the failure.
- Corrective action. Was it replaced, reworked, etc.
- Root cause of failure
- Engineer assigned to “fix”
- Targeted “get-well” date.

The analysis process is structured to do the following:

1. Review in detail the event record.
2. Capture and review all historical data and records relating to any similar failures.
3. Assign owners for all action items.
4. Do a root cause analysis
5. Develop corrective actions

6. Obtain the failed items for root cause analysis. I certainly recommend keeping the component until all participants of the design team have agreed upon an acceptable redesign.
7. Test failed product as needed and detail a problem analysis report giving a suggested fix.

You may wish to accomplish this with a committee of experienced individuals. If this is the case, I recommend the following functions be included:

1. Design engineering
2. Reliability
3. Field service
4. Quality assurance
5. Manufacturing
6. Evaluations lab

If FRACUS is used during reliability testing, it is imperative the proper maintenance of the failure records be made and frequent report-outs forthcoming. FRACUS is a high visibility activity and one that will insure timely problem solutions. **ALL FRACUS ITEMS NEED TO BE ADDRESSED AND REPAIRS MADE PRIOR TO PILOT BUILDS.**

DEFINE AND EXECUTE PRE-PRODUCTION LIFE TESTS:

Reliability testing will fall into three basic categories. These classifications are given below with timing and the objectives of each test phase.

TESTING TYPE	WHEN IT OCCURS	TESTING OBJECTIVES
Growth Testing	NPI Feasibility Phase Design is immature	1.) Identify and remove root causes of premature failures. 2.) Identify and remove latent defects 3.) Provide early reliability assessments
Qualification Testing	NPI Pilot Readiness Design is mature	Validate reliability predictions for design
Audit Testing	After Start of Production	1.) Detect degradation over course of production 2.) Provide early warning of production variation 3.) Assurance of continued reliability

Table 6

Every product, especially every new product, has a “set” of known and unknown failures modes. The very first prototypes will almost certainly contain designs and / or manufacturing deficiencies that prevent the overall product from reaching reliability and quality goals. The very best method of discovering those potential failure modes, for an immature design, is through rigorous reliability growth testing. The purpose of growth testing is to identify those failure modes and allow for initial approximations of the failure rates so that projected SCR may be determined. Please keep in mind that all growth testing should occur **AFTER** FMEA exercises are held and potential root causes are considered. Generally, reliability growth testing is tracked by using a “Duane” model, which plots cumulative test years on the “X-axis (ordinate) and cumulative MTBF on the “Y” axis (abscissa). This is a log / log plot and will indicate an improving condition, by virtue of a positive (+) slope. A negative or flat slope will indicate that corrective action is not working. Mr. Duane’s model derives from the premise that as long as a successful reliability improvement effort continues on the design, the design’s reliability growth, as reflected by an increase in an index, such as MTBF for the system, is

approximately proportional to the square root of the cumulative test time. When plotted, the slope of the line is a measure of the growth rate. These rates typically vary from 0.10 to 0.60, with 0.40 to 0.50 suggesting an aggressive, well-planned, and fully executed test program. These test programs are structured to find failures and to spot trends relative to the design of components. The reason for the term “growth” is the reliability of products always improves over time due to the design, find, fix (or repair) methodology used. There are three basic approaches to corrective action **AFTER** failure occurs. These are:

- 1.) Test-Find-Test
- 2.) Test-Fix-Test (TAAF)
- 3.) Test-Fix-Test with Delayed Fixes.

The most accepted approach is the Test-Fix-Test approach and the one we will recommend here.

The **TAAF** or **TAAR** concept continues until the entire product meets or exceeds the reliability goals initially agreed upon by engineering and management. A comprehensive reliability growth program is developed based on three important factors, as follows:

- 1.) Management, where the decisions are made to keep the program moving.
- 2.) Testing, where all the weaknesses and failure modes are found in the design and manufacturing process.
- 3.) Failure identification, analysis and fix (TAAF), where the cause of failure is isolated, analyzed and then fixed by virtue of redesign.

During this test phase, it is imperative that careful notes be taken to detail the precise “fixes” that occur to make sure that the root cause of the failure is addressed and not a symptom of the failure. There will come a time in the test program when all of the products on test will be the recipients of the “fix” to verify a true solution to the problem. It is important to note also that this type of reliability testing is accomplished under the **same conditions** that will be found during normal operation of the product. Real problems result from compressed time frames due to the need for product launch. Sometimes it’s just not practical to test to failure because that first failure (MTTF) may be months downstream of the launch date, and yet, it is very important to identify time to failure and MTBF for mission critical components and subassemblies. How do we do this? We use HALT (Highly Accelerated Life Testing) and HAST (Highly Accelerated Stress Testing.) HALT exposes the product to a step-by-step cycling with environmental variables such as temperature, temperature change, power on/power off, shock, humidity, vibration, etc. By increasing the stresses and their rate of application, we discover in reduced time period, what components are the most susceptible to premature failure.

An example of this type of testing may be found with HALT of a spark ignition system for a gas-fired cooking product. In actual use, the ignition module is activated six or seven times per day during normal cooking periods. Generally, the spark module is expected to last for six million “sparks”. Continuous cycle testing, twenty-four hours per day, seven days per week, will certainly get us there much quicker and surface any real problems with hardware, wire routing and EMI. HASS testing is generally used on products for auditing continued reliability and not improving that reliability.

Another example of HALT is actuation of cooling fan motors when normal, low and elevated voltages are impressed on the windings. Fluxations in voltage create changes in shaft rotation; consequently, fan blade speeds. By impressing these changing voltages, any failures will be noted over time.

When running these tests, it is very important to choose a sample size no fewer than thirty models and part numbers. This will allow for enough data to satisfy all statistical requirements. There are tables that will allow for the proper selection of sample size and those should be consulted if any questions arise relative to “numbers”.

CONDUCT LIFE PREDICTIONS:

After we perform our HALT, HASS and reliability growth testing we are in a position to make corrections to our “allocation spreadsheet”; i.e. flowdown model and redraw our “bathtub” curve. We now have data that will allow us to make our **product life predictions**. Granted, this may be a “best guess” but we have hard data to substantiate our estimates, and as we launch the product we continue reliability testing but on an audit basis to verify the numbers. We constantly monitor the SCR and discuss with the field service personnel the usability of the product. It is very important to “tweak” the product life prediction so that warranty allowances may be modified on an as-needed basis. Our life predictions will construct a “bathtub” curve, which represents 1.) infant mortality, 2.) useful life and 3.) wearout.

DEVELOP AND EXECUTE RELIABILITY AUDIT TESTING (HASS):

As long as we manufacture the product, we conduct audit testing. Products should be pulled into the evaluations lab and “run through” evaluation to make sure there are no issues remaining with compliance to existing standards and all in-house requirements. This should be done, at least, on a quarterly basis, if not monthly. These same products should be audited in the reliability lab and cycle tested at least twice per year. This testing will indicate if there has been any degradation in component quality coming from the vendors of choice. This data must be kept on file and made available to management. We are looking for trends in performance so any issues may be found and corrected.

RELIABILITY ENGINEERING AND SOFTWARE DEVELOPMENT:

For years, reliability methods have been applied to hardware, for obvious reasons. Only within the last fifteen years have those same methods, somewhat modified, been used for validating software. As you know, capable software is absolutely critical to the proper performance of complex systems. In a modern world, software design teams may be working in the United States, India, Ireland, etc. all providing code that will be “mated” to produce desired results. With this being the case, reliability testing is an absolute must.

According to Dr. Duane Dietrich, [2]“ A software fault is an existing defect in a program that, when executed under particular conditions, causes software failures. A fault could exist for the life of the software without ever causing a failure. The program has to be executing in order for a failure to occur.”

We now need to take a look at the differences between hardware and software failures relative to reliability. The following table will show several of these differences.

SOFTWARE	HARDWARE
Failures driven by design errors. No wearout phenomenon. Only repair is with reprogramming. Reprogramming must remove errors and create none. Failure related to execution path. Operating environment does not affect reliability. Errors likely to exist in a random fashion Failures without warning.	Failures caused by deficiencies in design, production, use and manufacturing Failures can be due to wear. Sometimes warnings do exist. Preventative maintenance can improve reliability. Failure related to passage of operating or storage time. Reliability related to environment. Reliability can be predicted from knowledge of design and usage. Redundancy can improve reliability.

Table 7

There are several reliability models that are available to us. These models aid our efforts in finding and correcting problems. They are:

- 4.) Time between failure model
- 5.) Fault count model
- 6.) Fault seeding model
- 4.) Input domain-based model.

Time between failure models are characterized by noting these general assumptions:

- Independent times between failures.
- Equal probability of exposure for each fault.
- Embedded faults are independent of one another.
- Faults are removed after each occurrence.
- No new faults are introduced during correction

Examples of mathematical models addressing TBF are: 1.) Schick-Wolverton, 2.) Goal-Okumoto imperfect debugging, 3.) Jelinski-Moranda and 4.) Aggarwal. The Jelinski-Moranda model is the most popular and classical model to determine the reliability of the TBF process.

Fault count models assume that 1.) Testing intervals are independent of each other, 2.) Testing during intervals is reasonably homogenous and 3.) The number of faults detected during non-overlapping intervals are independent of each other. The best model for this classification is the Goal-Okumoto NHPP model. Another interesting type of NHPP model, with graphical interpretation, stems from the Duane model.

Fault seeding models actually introduce errors into the software at known locations to establish estimates for the number of indigenous faults.

The last model type is the **input domain** based model in which the input profile distribution is known. The most popular model of this type is the Nelson model.

Programming is just like any other technical endeavor. You don't sit down and start without a "game-plan". Stated goals are agreed upon and a plan of action developed. With this being the case, the best programming results from the following actions taken by the program management team:

- Top down design
- Structured design and coding
- Programming teams
- Design and code walk through
- Incremental releases
- Use of higher order languages that are object oriented.

The developments in software reliability are numerous and new approaches are employed frequently by companies marketing their “wares”. It has become a very specialized market and one that requires a specific background to execute.

CONCLUSIONS

I hope you have found this writeup useful and will continue to increase your knowledge of reliability and reliability engineering. It’s a remarkably useful technology and one that will continue to provide significant “value added” to the engineering profession.

END

GLOSSARY AND DEFINITION OF TERMS

DFR **Design for Reliability**

Design for Reliability is a methodology that involves 1.) Reliability goal setting, 2.) System model development, 3.) Product design, 4.) Reliability growth testing, 5.) Production reliability testing and 6.) Product launch. The main tenant of DFR is reliability growth testing in order to test, find, fix and retest. With this method, we make components and subassemblies impervious to KNPs.

FMEA **Failure Mode and Effect Analysis**

A method by which a component, subsystem or system is evaluated to determine the possible types of failure and if those failures could cause catastrophic consequences. It is used to determine those elements that are “mission critical” to the overall assembly of components. Generally, a scoring scheme is associated with the process so that the probability of failure, the severity of failure and the ability to detect a failure may be assessed and quantified. It is a process by which the cause / effect of a is investigated.

KCP **Key Control Parameters**

An example of KCPs are a.) Motor windings, b.) Number of laminations, c.) Air gap design, d.) Cooling Fan blade design, e.) Shaft dimensions.) f.) Insulation thickness, g.) EMI, etc. These parameters are specified by the design engineer and are considered to be controllable.

KNP **Key Noise Parameters**

The external influences, that cannot be controlled and which are impressed upon a component, subsystem and system. These parameters are sources of external variation relative to a system. Examples of KNP are a.) Dust and airborne contaminants, b.) Voltage spikes, c.) Foreign object damage, d.) Humidity, e.) System pressure variations, f.) Temperature variations.

HALT **Highly Accelerated Life Testing**

A method of testing a component, subsystem or system to accelerate the failure rate. An example would be accelerated cycle testing where the number of cycles might be 10 times the anticipated cycles per week, month or year. The theory being an accelerated cycle test, at specified stress levels, will produce no more failures than normal usage over the life cycle of the product. For this to be viable, the stress levels during HALT must be no greater than the stress levels found during normal usage.

HAST **Highly Accelerated Stress Testing**

A method of testing where the appropriate stress levels are well beyond those levels seen during normal qualification testing. With this testing, we are trying to produce failures. Please note that when we mention normal qualification testing, we are talking about evaluation testing that will prove adherence to some existing standard for the product in question; i.e. ANSI, IEC, etc.

HASS **Highly Accelerated Stress Testing**

Generally used for post-production audit testing. Elevated stress levels will be employed for specific factors to investigate any suspected deviations in component quality. This type of testing is used to verify vendor compliance with given component specifications AND to discover any issues with manufacturing and assembly.

MTTF Mean Time To Failure

An estimate of the average, or mean time, to a component's FIRST failure. MTTF assumes that a product cannot resume any of its normal operations.

MTBF Mean Time Between Failure

The MTBF is defined as the cumulative test time divided by the cumulative number of failures. It is considered to be the average time between failures of a system and is often contributed to the "useful life" of that device. MTBF does not include infant mortality or wearout failures.

QFD Quality Functional Deployment

The QFD process takes the wishes of the marketplace and the environmental characteristics of the marketplace and translates those into quantifiable specifications for use by engineering. This process involves: 1.) Market surveys 2.) Benchmarking existing products, 3.) Considering environmental characteristics, 4.) Total costs of operation and warranty, 5.) Consumer surveys and 6.) Examination of competitive products.

DOE Design of Experiments

Design of experiments is a test method to discover which KNP will contribute the greatest influence upon a component or system. It is also a method of evaluation or reliability testing that will provide adequate data for determining various parameters and settings when options are possible.

CTQ Critical To Quality

Critical to quality parameters are those factors that MUST be specified on a drawing representing component, subassembly or assembly. A CTQ is a parameter examined during first piece inspections for compliance. These specifications are considered to be paramount to the product and must be met for acceptance.

P-DIAGRAMS Parameter Diagrams

P-diagrams are used to characterize and note the external influences upon a component or assembly of components. These diagrams would indicate the KNPs and the KCPs AND the input and output impressed upon the product.

DFSS Design For Six Sigma

Design for Six Sigma is a methodology for designing parts that addresses statistacial concepts such as the mean and standard deviation of critical to quality dimensions. Six Sigma is a failure rate of no more than 3.4 parts per million samples.

FBD Functional Block Diagrams

An FBD provides the structure for the system, subsystem and component breakdown required for completion of the reliability allocation matrix. The FBD facilitates: 1.) Allocation of the SCR and reliability goals, 2.) Completion of accurate FMEAs, 3.) Development of the P-diagrams for test planning and 4.) Simplification of the design. An FBD basically defines the system function and captures the key elements of the system and the functions they perform.

SCR Service Call Rate

Service call rate is defined as the number of service calls in one year divided by the total product exposure in that same year. You simply divide the number of invoices for a twelve (12) month period of time by the number of products in usage for the same period of time. It generally takes nine to fifteen months to feel the effects of a product or process change when looking at SCR.

FRACAS Failure Reporting Analysis And Corrective Action System

An organized system for reporting failures encountered in testing, tracking failure investigations and then assuring implementation of corrections actions. It is a proactive process that starts with failure data, organizes it and then assures follow-up.

 λ Failure Rate

The total number of failures within a population divided by the total number of life units expended by that population during a particular measurement interval under stated conditions.

NPI New Product Introduction

A methodology that provides an inclusive check lists for implementing and launching new products. Generally, NPI includes design guidance models, design confirmation models, pre-pilot builds, pilot builds and production launch. It is also used to redesign and modify products already in production.

ANSI American National Standards Institute

The American National Standards Institute is an independent body that oversees the development of product standards and prescribes those tests deemed necessary to insure the safety of those products.

IEC International Electrical Code

The International Electric Code was formulated and is maintained by the European Union for the purposes of providing products that are inherently safe for use.

A.Q.L. Acceptance Quality Level

Acceptance quality level is usually defined as the “worst case” quality of a component and assembly of components that is still considered acceptable. The AQL is expressed as a percentage and should be high. Typical values for Six Sigma are between 92.74% and 99.99%.

Growth Testing

Growth testing involves putting products on test to discover at what point failures will occur. At this time, those products are modified to address the failures and then put back on test to continue the evaluation program as initially formulated. The is called the TEST, FIND, FIX, and TEST methodology.

Allocation Spreadsheet

An allocation spreadsheet provides design targets and acceptable failure rate targets for each subsystem based upon predictions of the individual elements. It represents a list, by subassembly for mission critical parts, of individual failure rates.

EMI Electromagnetic Interference

Also called radio frequency interference and is a disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source.

Limits of Acceptability

The range of specifications of a component or assembly of components. The “not to exceed” design guideline used during operation of the parts.

DG Design Guidance Models

The very first workable prototype in the NPI process. This model may be the first of its kind and is used for demonstrating the design concepts relative to marketing objectives of the product. It may or may not be a functioning model.

DC Design Confirmation Models

Design confirmation models serve to solidify all of the design concepts including form, fit and function. They are working models that allow for evaluation and reliability testing on a limited basis. At this point in the process, engineering drawings and specifications are solidified and considered to meet the intent of marketing and product demands.

PP Pre-Pilot

Pre-pilot models are those models from which most of the evaluation, reliability and ship testing work is accomplished. Also, most field test models come from the PP build. PP models are NOT generally considered to be saleable models but do represent culmination of engineering effort.

Test,Find,Fix

The most accepted methodology for the HALT and HAST reliability process. A component, once failed, will be examined for the root cause of the problem, modified accordingly and put back on test to verify the proposed fix.

Mathematical Models

Mathematical models portray the failure rate of the component or product during its useful life. It gives us an estimate of failure rate. Actual testing will allow us to modify that model, as needed, to reflect the actual failure rates resulting from usage.

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