Introduction

MTBF stands for Mean Time Between Failures. It is a term that represents reliability of a given product. We will discuss history, concepts and misconceptions and how that may relate to true reliability and then how La Marche calculates MTBF.

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Overview

Reliability is the probability that a device will perform its expected function for a set time period. MTBF is the calculated average time it will take for a system to fail. As can be see by these definitions, reliability and MTBF are items that are very important when deciding which products or devices a customer may purchase. These numbers can be very deceiving and also very difficult to calculate.

History & Prediction Models

The first approach to a reliability calculation system happened in Germany during WWII (about 1940) [1] and involved the highly unreliable V-1 Rocket designed by Von Braun. German Mathematician, Eric Pieruschka, assisted Von Braun in coming up with the reliability calculation to describe the reasons for the failures. Prior to this time, mechanical reliability was approached as resolving the weakest link and that would solve the problem. That process did not work then, however, it only revealed more issues.

Mil-HDBK 217 – Military handbook published in 1965 defining a standard method to measure reliability used by the U.S. military. The two acceptable prediction processes under this standard are Parts Count prediction and Parts Stress prediction. The U.S. Military recommended discontinuation of this standard in 1996 due to prediction reliability issues with the standard. [2] "In particular, MIL HDBK 217, Reliability Prediction of Electronic Equipment, is not to appear in an RFP as it has been shown to be unreliable and its use can lead to erroneous and misleading reliability predictions." This standard can still be found in various active forms (software and hardware), the internet (in its last version – Mil- HDBK 217F) and by other organizations other than the military. Please note that newer devices etc may not be included in the tables outlining the expected failure rates etc.

The Telcordia (originally known as Bellcore) method is based on Mil-HDBK 217 but is tailored for the Telecom Industry [1]. The last revision was issued in January of 2011 and is known as SR-332 issue 3. As in the Mil-HDBK 217, this method utilizes part count and parts stress methods. Since this model is being updated it is more useful than the earlier model and also has software versions available online. We used this method in our early MTBF calculations.

RBD (Reliability Block Diagram) is a model that uses blocks to represent components that may fail within a complex unit [3]. Series blocks indicate that if one component fails within the unit, then the entire system fails. Parallel blocks illustrate redundant paths where one failure does NOT bring down the whole unit. A unit can be made up with parallel and series blocks representing the whole unit operation. This method helps to determine failure scenarios and understandings to define MTBF and reliability issues. Software is available that takes the defined blocks and calculates the MTBF and MTTF.

The Markov Model also known as the State Space Diagram. Instead of using blocks of components, this model uses failure states of the system as well as states that the system could function in [4]. Individual states are mapped out with arrows indicating the transition between states. Each state and path between states is given a function or variable. A system of equation is then created and used to solve for the reliability of the system.

FMEA/FMECA (Failure Mode and Effects Analysis / Failure Mode, Effects and Criticality Analysis) is an analysis of the possible ways that the product could fail and the consequence of such a failure [5]. FMECA includes information about how severe the problem may be. FMEA/FMECA is usually used in the design process, and is not used to calculate MTBF.

Fault Tree analysis is a technique where an undesired event (usually system failure) it specified and the system is analyzed to find all ways in which the system can arrive at this undesired event [6]. A "tree" is created with a variety of faults that lead to the failure. These events can be caused by component failures, human interaction or environmental events. The events at the bottom of a fault tree act as input to the logic gate leading to the next event. The gates that are most often used are and gates (Event A and Event B happen) and **or** gates (Event A or Event B happens). A fault tree is very similar to an RBD and reliability is calculated in the same way.

HALT (Highly Accelerated Life Testing) is a method of subjecting a product to certain stresses that are much higher that the expected environmental stresses that the product may encounter [7]. HALT greatly shortens the time necessary to observe a failure. Using this method the weak links of a product can be found and improved upon. HALT is not a way of calculating reliability but is, instead, used to increase reliability.

Basics on MTBF

MTBF and reliability are really all about failure. Every product ever made will eventually fail, but ideally, not within its service life. Reliability and MTBF calculations are used to determine the likelihood of failure. Many people will look at the MTBF of a product and make assumptions. For example, if an MTBF is 100000 hours, one may think they have a long time before having to replace their product. That is not the case. The customer must go one step further. Given the MTBF they should calculate the reliability or the probability that it will last for as long as they intend to keep it in service. This section will go over the basics of MTBF and reliability.

Bathtub Curve

The bathtub curve is a representation of product failure rate over time [7][8]. There are three sections to the bathtub curve. The early (infant mortality) failure rate is the failure of weak items. The early failure rate starts high but steadily decreases. The normal life failure rate is a low constant rate that represents the usable life of the product. Normal life failure is caused by external forces such as overload. The wearout failure rate is a steadily increasing rate indicating the end of the products life. The bathtub curve "does not depict the failure rate of a single item, but describes the relative failure rate of an entire population of products over time."
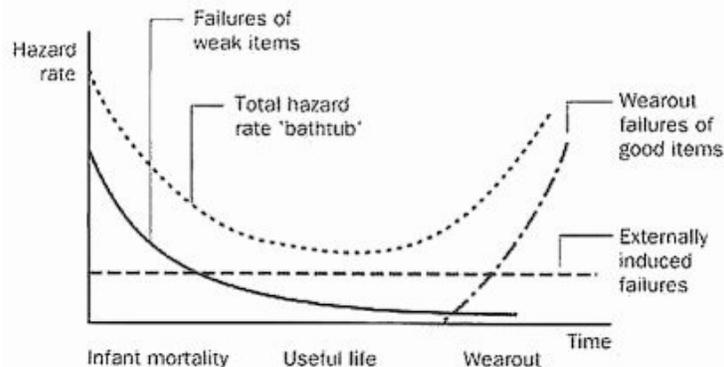
Service life is the time that a product is in service out in the field. The useful life of a product is the time after the device is broken-in/burned-in and before the device starts to wear out. In order to have the maximum service life, a customer would want to ensure that the service life matches the useful life. In other words, it is a good idea to have the product burned in before put into service. This can prevent failures due to defective parts.

Terms and Their Meanings [9][10]

To better understand the terms related to MTBF, here is an example used by APC of a sample human population [1][9][10].

> There are 500000 25-year-old humans in the sample population.
> Over the course of a year, data is collected on failures (deaths) for this population.
> Throughout the year, 625 people failed (died).

Total Time (operational life) for reliability and MTBF calculations is the defined time period multiplied by the number of units in the sample group. In the sample above the total time is 500000 years.

Failure Rate is the number of failures the sample group experiences over the total time. In regards to the sample, the failure rate is 625/500000 = 0.125%

MTBF (Mean Time between Failure) as stated earlier is the average time between system failures of the entire sample population. It is calculated as the total time over the number of failures. Using the sample above, the MTBF of this human population would be 800 years. MTBF is used for systems that can be repaired. Since death cannot be repaired, it might be more appropriate to use MTTF

MTTF (Mean Time to Failure) is similar to MTBF and is used for systems that are replaced upon failure. MTTF is calculated as total time divided by the number of units under test. The MTTF of this sample would be 1 year.

Service Life is the amount of time a device is service, or the expected length of operation before a device will fail. In terms of a human, this would be the age at which a person dies.

Mission Life is the period of time that data is collected for the use of reliability calculations. In the sample above the mission life would be one year.

Useful Life is the time after the device is broken-in/burned-in and before the device starts to wear out. A human would enter this as a young child and leave this stage as an aging adult. During the useful life stage, failures can still happen but is uncommon.

Reliability is the probability that a device will operate for a specified time period. It is calculated using an exponential function. In this sample the reliability of an 80 year service life is approximately 80%.

MTBF is often confused as being the actual service life of the device. One reason these numbers differ is because MTBF is generally calculated when the device is in its useful life and is, therefore, much less prone to failure. MTBF is usually calculated using a large sample group and a shorter mission life. For that reason, statistically fewer failures would also occur.

To properly use MTBF a customer should calculate the reliability of a product given the MTBF and the time they plan to keep it in service.

Simple Equations [11]

With all these different ways of calculating Reliability and MTBF, one might think that the equations used are very complicated. In order to get a more accurate MTBF, probabilities and complex systems of equations are used.

$$Reliability = e^{-Planned\ Service\ Life / MTBF}$$

$$Failure\ Rate = \frac{Failures\ within\ Mission\ Time}{Mission\ Time \times Sample\ Population}$$

$$MTBF = \frac{Mission\ Time \times Sample\ Population}{Failures\ within\ Mission\ Time} = \frac{1}{Failure\ Rate}$$

$$MTTF = \frac{Mission\ Time \times Sample\ Population}{Sample\ Population}$$

How does La Marche calculate MTBF?

La Marche calculates MTBF using a complex, yet widely used, probability distribution know as a Chi Squared Distribution. A computer procedure is used to report the Mean Time Between Failure for different products. Using the Chi Squared Distribution the procedure calculates the MTBF based upon data collected and summarized from RMAs and shipments.

The MTBF procedure used by La Marche offers more variables than the simple equation above. It also uses real world data from shipments, RMAs and service calls. The different variables used by the La Marche MTBF procedure are as follows:

Time Period – The mission life in number of months from historical shipment and return data used in the MTBF calculation.

Daily Operating Hours – The number of hours that is assumed as the amount of time the product is in operation for each 24 hour period.

Operating Offset – The number of months that are assumed to have passed from the time of shipment until the product is put into operation.

Number Shipped – The number of units shipped within the time period specified.

Operating Hours – The total number of operating hours calculated for the units shipped within the time period.

Failures – The number of units which failed within the time period.

Confidence Level – The number of hours that an individual unit can be assumed to operate before a failure occurs. Stated as a percentage, the confidence level is calculated based on a Lower, Mean, and Upper Confidence Level.

Lower Confidence Level – Worst case confidence level

Mean Confidence Level – Average confidence level

Upper Confidence Level – Best case confidence level

Conclusion

MTBF is a probability. When referring to Reliability and MTBF the customer needs to understand that even if a product has 90% reliability after 10 years, it is still possible for a failure to happen before or at 10 years.

We at La Marche are confident in the MTBF that is stated on our product datasheets. VANCE-ADD BY EXPLAINING WHY LA MARCHE IS CONFIDENT IN THE MTBF STATED ON THE DATA SHEETS. Again, failures are bound to happen, which is why La Marche offers a great warranty program on all products.

References

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