WHY HALT CANNOT PRODUCE A MEANINGFUL MTBF NUMBER AND WHY THIS SHOULD NOT BE A CONCERN

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BIOGRAPHY

Mike is an experienced leader in reliability improvement through analysis and testing. He has also led numerous quality system development programs and compliance programs, including Safety and EMC. He has 18 years of reliability, quality, and compliance experience, the majority in start-up companies. Mike is also an expert in accelerated reliability techniques, including HALT and HASS. He set up and ran an accelerated reliability test lab for 5 years, testing over 300 products for 100 companies in 40 different industries. Mike is co-founder and managing partner at Ops A La Carte, a Professional Business Operations Company that offers a broad array of expert services in support of new product development and production initiatives. Through Ops A La Carte, Mike has had extensive experience as a consultant to high-tech companies, and has consulted for over 50 companies including 3COM, Ciena, Intuitive Surgical, AeroGen, and Brooks-PRI Automation. He has consulted in a variety of different industries including telecommunications, networking, medical, semiconductor, semiconductor equipment, consumer electronics, and defense electronics. Mike has authored and published 7 papers on reliability techniques and has presented these around the world including China, Germany, and Canada. He has also developed and currently teaches 5 courses on reliability techniques. Mike has a BS degree from the University of Colorado at Boulder, and is both a Certified Reliability Engineer and a course instructor through the American Society for Quality (ASQ), IEEE, Effective Training Associates, and Hobbs Engineering.

ABSTRACT

HALT is a very powerful tool that can help manufacturers achieve high reliability quickly at the design phase by finding design-related problems with accelerated step stress techniques. However, due to the nature of the process, valid life data in the form of Mean Time Between Failure (MTBF) figures cannot be ascertained. The number of samples is low and the acceleration factors are not only high but varying, and this yields reliability figures with poor confidence bounds around the numbers.

This should not be considered a drawback of the HALT process because the goal of a good reliability program is to design a reliable product rather than to merely measure a product's reliability. For those customers who insist on reliability numbers, calculations using prediction methodology is usually acceptable, and for those instances where it is not acceptable, a Reliability Demonstration Test (RDT) is always available, and field data may be available, as well.

In addition, there are two methods of using the HALT results as aids in calculating MTBF. The first method is using the HALT data to choose aggressive acceleration factors

when running an RDT. There are good acceleration factor models for both elevated temperature tests as well as for fast temperature cycling tests. The second method is using a field database and, over the course of a number of HALTs on different products, comparing the HALT results on the new product to the field results from the products that have already gone through HALT to obtain reliability figures. This paper shall discuss these methods in further detail.

KEY WORDS

HALT	Acronym for Highly Accelerated Life Test. In HALT, stresses such as OmniAxial (6 degree-of freedom) random vibration, rapid temperature transitions, voltage margining, frequency margining, and any other stresses that are appropriate are used to find the weak links in the design and fabrication processes of a product. HALT is performed during the design phase.
HASS	Acronym for Highly Accelerated Stress Screen. In HASS, the highest possible stresses are used in order to reduce the time of the screen. The screen must be proven using the HASS Development process prior to using it in manufacturing. HASS is performed on 100% of the units being shipped for the product being screened.
RDT	Acronym for Reliability Demonstration Test. A test in which a product is run for an extended period of time and estimates of MTBF are obtained for comparison to the requirements. The test may be run in the prototype of development stage.
MTBF	Acronym for Mean Time Between Failure. A method of describing the reliability of a product, in hours. The MTBF for a product indicates, on average, how many hours a product is expected to operate between failures.
NTF	Acroynm for No Trouble Found. A failure that occurs but then cannot be reproduced at a later date.
Mil-HDBK-217	A reliability prediction handbook developed by the military. In the handbook, each component type is assigned a failure rate, in failures per million hours. When performing a prediction, failure rates for each part in the product is looked up and the handbook. Each of these failure rates are then multiplied by various factors (temperature, stress, quality, environment, and learning factors) to yield a total failure rate for each part. The failure rates for each part are then added together to give a total failure rate for the system. This can then be inverted to describe the MTBF of a system (MTBF = 1/failure rate).
Bellcore RPP332	Same concept as Mil-HDBK-217 except that the prediction handbook was developed by Bellcore, and failure rates are described in failures per billion hours.

INTRODUCTION

One of the most common question asked during HALT is how to derive MTBF numbers from HALT results. HALT in itself cannot product accurate MTBF results but it can help when setting up other, more suitable reliability measurement systems. This should not be considered a drawback of the HALT process because the goal of a good reliability program is to design a reliable product rather than to merely measure a product's reliability. For those customers who insist on reliability numbers, calculations using prediction methodology is usually acceptable, and for those instances where it is not acceptable, a Reliability Demonstration Test (RDT) or tracking field data is always available.

Present MTBF Tools

The three most popular methods today for producing MTBF numbers is calculations using prediction methodology, RDT's, and field data.

A reliability prediction can be a very useful tool in developing MTBF numbers because it is relatively quick and can yield results prior to shipping a product. However, reliability predictions are usually very inaccurate as well. A typical prediction on a board level product that uses a common reliability prediction handbook (i.e. Mil-HDBK-217 or Bellcore RPP-332) may take about 4-8 hours to perform (longer if other than nominal stresses are used), but these types of prediction handbooks derive their failure rate calculations by polling companies that use each specific type of component and requesting their field data. This can lead to very inaccurate data because the application of a specific component in the present product may be much different than that used by the companies being polled. Reliability predictions are often off by a factor of 10 or more as compared to field results that are obtained later in the product life cycle. Using actual rather than nominal stress factors for temperature, electrical, quality, environment, and manufacturing screening can make the prediction more accurate. However, accurate stress factors, especially factors for power and voltage, is often very difficult to determine.

A better method of developing an MTBF number is by means of an RDT. In this case, the HALT results will help to determine the appropriate stresses, and from these stresses, the acceleration factor is calculated. Choosing the appropriate stress is perhaps the most important part of setting up an RDT because too little stress will cause the test to be too long, or it will require too many units to be under test at one time, driving up the cost of the test. And too much stress is even worse because if the product is taken beyond the level where failures are being accelerated and is taken to the point that non-relevant failures are being introduced, the test results may be invalid and it may require that the entire test be repeated at lower stress levels. The major drawback of RDTs is that the correct amount of stress to apply can be very difficult to determine, and when this occurs, conservative stress values must be used, causing the test time to increase. A typical RDT using conservative stress values may take six months or more, depending on number of units used, the number of failures experienced, and the confidence bounds desired. Also, the test routines used to exercise the product during the RDT is often different from how the product is exercised in the end-use environment, which may lead to inaccurate MTBF numbers.

A better method still is to use field data because the data comes directly from customers using the product in the intended application. The MTBF is calculated by multiplying the number of units fielded and in use divided by the number of failures experienced. However, there are several drawbacks to this method. The first drawback is that many customers are not forthcoming with the data, leading to many "No Trouble Founds" or "NTFs" since the repair technician may not know what problem to look for. Also, many customers with spares on-site take weeks to fill out failure reports and send back the parts, thereby inflating the MTBF numbers. Finally, failure data from the field data is not timely. By the time a company determines that a product has a design problem after being released into manufacturing, hundreds and even thousands of systems may have already been shipped.

Why HALT Does Not Produce Good MTBF Numbers Either

The three most popular reliability prediction methods are not effective in producing timely and accurate MTBF numbers. Therefore, it should not be surprising that HALT does not either. Deriving life data from accelerated tests requires accurate acceleration factors and many failure points. The higher the accelerants, the less accurate the acceleration factor formulas will be. The fewer the failure points, the wider the confidence bounds will be about the final number. A HALT is a special form of accelerated life test that uses a step stress approach, stepping up the stress and then validating the functionality of the product prior to stepping up to the next level. This approach tends to produce results much quicker than most other types of accelerated tests, but one side effect of having this level of acceleration is that the acceleration factor formulas become, for the most part, invalid (or at least, very inaccurate). And since this is the factor that most greatly influences the time compression of an accelerated test, the MTBF calculation then becomes inaccurate.

Also, HALT is typically performed at the pre-production stage, and most often, very early in the design cycle so that failures can be properly analyzed and corrective actions made well before the product is released. However, the drawback of this is that there usually are very few samples available, and therefore, fewer failures are realized (typically between three and ten failures are found). The number of failures is one of the key factors in determining the confidence bounds. Confidence bounds indicate the range within which the MTBF figure may fall. The fewer the failures, the wider the confidence bounds. One particular HALT yielded a confidence limit of 100 hours and an upper confidence limit of 1,000,000 hours. Wide confidence bounds undermine the credibility of the reliability numbers.

Two Methods That Can Be Used to Develop MTBF Numbers from HALT Results

Even though HALT alone cannot produce accurate MTBF numbers, there exists two specific methods for which the HALT has been able to help in setting up other types of experiments that, in turn, have produced accurate MTBF numbers.

Method 1 – Using HALT to Develop an RDT

The first method is using the HALT data to choose aggressive acceleration factors when running an RDT. There are good acceleration factor models for both elevated temperature tests as well as for temperature cycling tests. Once the HALT is complete, the next step is to evaluate the limits and then to back off from these limits to give some margin between the product limits and the proposed RDT levels. Equally as important is to evaluate the failures that occur at each of these limits to determine if each of the failures found were accelerated to failure (thus, valid failures) or if there were any failures that were due wearout or overstress. If the latter is true, then the failure was one that could not be accelerated and care must be taken in choosing the reliability demonstration limits so as not to produce these types of failures because they do not give meaningful data relative to the life of the product.

One drawback of using HALT results to develop an RDT is that the RDT may take three to six months. A second drawback is that if there were wearout failures discovered during HALT, the RDT level must be backed off substantially from the HALT limits, and this, in turn, will lower the acceleration factors and thus increase the length of the RDT or require that more units be used, or both.

Method 2 – Using HALT Data in Conjunction with Field Data

After each HALT on a product is performed, the product is then tracked in the field for failure modes similar to those found in HALT. Once one is uncovered, the acceleration factor for that failure mode can easily be calculated because the amount of stress and time needed to uncover the failure during HALT is known, and the amount of field time to uncover the same failure is now known as well. After this is done for several different products, a database of information can be developed and now the HALT results can be used as a predictor. Then for new HALTs, failures can be looked up in the field database and appropriate MTBF numbers for each of these failure modes can be established.

One drawback of developing MTBF results from field data is that many products must be sent through HALT and then tracked in the field before an adequate database can be established. This may take a company several years to develop. Also, major changes in product type and technology used over time may render the database useless because the prediction method can only work with like failure modes from like parts' usage.

CONCLUSION

The three most popular methods of producing reliability data – predictions, RDT's, and field data – are not effective in producing timely and accurate MTBF numbers. Therefore, it should not be surprising that HALT does not either. However, this should not be considered a drawback of the HALT process because the goal of a good reliability program is to design a reliable product rather than to merely measure a product's reliability.

For those customers who absolutely need MTBF numbers and cannot rely on the inaccuracies of a prediction and need more timely results than those of an RDT or field data, there are two methods that can be used in conjunction with HALT that can produce relatively accurate data and in a more timely manner. The first method is to use the HALT data to choose aggressive acceleration factors when running an RDT. The major drawback of this method is that the RDT is still likely to take several months. The second method is to use HALT data in conjunction with field data. After each HALT on a product is performed, the product is then tracked in the field for failure modes similar to those found in HALT. The major drawback of this method is that many products must be sent through HALT and then tracked in the field before an adequate database can be established, and major changes in product type and technology used over time may render the database useless.