

## Field Failure Rate Estimate from HALT Results

### Overview of AFR Estimator

The *AFR Estimator* is a patent pending mathematical model that, when provided with the appropriate HALT and product information, will accurately estimate the product's field inherent AFR or Actual Failure Rate. This methodology has been used on a number of products with significant positive financial results. This model will also provide HASS or HASA data for the detection of an outgoing quality process shift in time from a stated AFR.

### Background of Calculator

Since HALT was first invented, its practitioners have been looking for a way to calculate a field MTBF from the results of HALT. Many have tried but could not produce meaningful results either because the approach was incorrect or because there was not enough data to substantiate the model. There are three ways to approach this problem.

The first approach is using a physics of failure (POF) approach to model the failure behavior of each component in each environment. The problem with this approach is that there are too many variables and the POF model becomes too complex.

The second approach is using existing acceleration models and making general assumptions about acceleration factors or plotting best fit curves. The problems with this approach are:

- The acceleration factors are usually not correct and cannot be generalized.
- Current acceleration most models are set up for constant stressing and not step stressing. With step stressing (as used in HALT), the dwells are not usually long enough at each dwell to be able to accurately extrapolate the reliability.
- Typically, not enough failures that occur to make the data statistically significant, so when attempting to use current acceleration models, the confidence intervals (the upper and lower values of the confidence levels) become unrealistically wide, and the conclusions of the data become erroneous. An attempt was made using one of the more popular Weibull models on HALT results and it achieved 100,000 hours MTBF with a lower confidence of 1,000 hours and an upper confidence of 10,000,000 hours. Because the confidence intervals were so wide, the data was not useful.

The third approach is to collect a lot of data on products that have gone through HALT and their subsequent failure history in the field then, build a mathematical model to correlate the HALT results with the field results. The problem with this approach is that it requires a lot of data from many different types of products from varied industries to develop an accurate model. In the past, no one had this type of data to build this model.

Fortunately, data has been collected from HALT and subsequent field results for the same products for the past fifteen years for over fifty different products from twenty different industries and the model is based on this data. Data continues to be collected and used to further improve its accuracy and capabilities.

## Benefits of Calculator

The main benefits of the *AFR Estimator* are:

- Performing HALT followed by running the calculator takes significantly less time and money to run than a Reliability Demonstration Test (RDT). The application of this calculator can be a huge time and cost saver.
- The calculator provides recommended minimum stress levels for HALT. These levels can provide assurance that the product will exceed the customers' expectations and allow for accurately forecast warranty expenditures.
- The model can accommodate HALT samples sizes from one to six, with the optimum size being four. This sample size means that there should be four samples in each HALT environment.
- The model can calculate ninety percent upper and lower confidence limits. These limits are derived from SEMI E10-0304 (point estimate).
- When provided with the product's field duty cycle, the model will provide the product's AFR and MTBF with confidence limits based on that stated duty cycle.
- The inputs for HASS and HASA will provide the daily sample size and the detectable shift in the AFR you wish to detect.

## How to Increase the Accuracy of Your HALT to AFR Calculation

Here are a few ways you can increase the accuracy of your HALT to AFR calculation:

- The corrective actions for the issues encountered within the Guard Band Limits on all of the products must have root cause understood and corrective action(s) implemented. These Guard Band Limits are strongly recommended as a minimum for the product. Products that meet or exceed the Guard Band Limits have significantly better reliability than those that do not. Pushing the product in HALT to the Fundamental Limit of the Technology (FLT) is highly recommended, whenever possible.

The Guard Band Limits are statistically derived values that can assure that the product when achieving these limits can maintain the product's specifications following time-related product degradation and unanticipated field stresses.

- It is important to verify that any thermal or product protection cutouts first work as intended. They will next be defeated in the case of a known destruction of the product, i.e., a hard disk drive, which is to be either located external to the chamber or suspended away from the vibration table. By doing this, the HALT can continue to verify the true robustness of the product or, the estimated AFR may be artificially inflated. Please note that the cutoffs may not be physical and may be embedded in the firmware.
- Prior to the starting HALT, it may be necessary to build extender cables to separate stress sensitive assemblies (like the hard drive above) or an LCD display and mount them possibly outside the chamber. If this is not done, the testing will be limited by these early failures and other potential failure mechanisms will not be discovered. Once the stress sensitive assemblies are discovered and the HALT is allowed to continue, the Guard Band Limits can be sought to determine whether the product meets or exceeds them. With these Guard Band Limits, the calculated AFR from the model will reflect the new expanded HALT limits or be limited by the stress sensitive assemblies encountered in the HALT if their limits are not improved.

- The units in each of the HALT stress environments needs to be tested with a protocol that sufficiently tests the product in each stress environment. A recommended starting point is 75% test coverage. Less test coverage may compromise the results of the model but more important, there will be a higher than anticipated field failure rate as customers will detect the failure modes that escaped during the HALT.

### Limitations of the Calculator

The calculator has many benefits, but there are a few limitations:

- The model can't estimate wear-out mechanisms. These will need to be addressed using Accelerated Life Testing (ALT).
- At this time, the calculator can only take into account the stresses of temperature and vibration. HALT should not be limited to just these stresses, but use of any stresses deemed appropriate for finding product weaknesses. In the future, other stresses will be added to the model as data is collected.
- You need to perform HALT using a protocol that sufficiently tests the product in each stress environment. If the test coverage can't find an issue, that issue (limitation) can't be included in the model.
- The calculator does not have data from all types of products. If your product type is significantly different than the types of products used to build the model, your results may not be as accurate as products that are more similar to those used to build the model.

### How to use the estimator

In order to run the *AFR Estimator*, you will need to gather the following information and complete the data entry table in Section H:

- A- The MTBF estimate in kHours or mHours can be from Telcordia, Relex, or a similar tool. If this estimate is not available, use 40,000 as a default value for the *AFR Estimator*. This parameter has very little effect on the final field AFR or MTBF estimate due to the highly variable processes followed by the many assumptions used in estimating an MTBF. Enter this value in the table at the end of Section H.
- B- The final Hot operating limit (HOL) achieved in HALT as measured on the product and not the chamber setpoint. Enter this value in the table at the end of Section H.
- C- The final Cold operating limit (COL) achieved in HALT as measured on the product and not the chamber setpoint. Enter this value in the table at the end of Section H.
- D- The final Vibration operating limit (VOL) achieved in HALT as measured on the product and not the chamber setpoint. Enter this value in the table at the end of Section H.
- E- The product's published thermal operating specifications, in °C. Try to match your product's **Published Specifications** to a corresponding **Level** number listed in the table in this section, i.e., a high-end consumer product equates to a Level 2. Enter the corresponding **Level** number from the table in Section H into the table in Section H. Note: The **Category** column description may not exactly match your company's description for the product's field application. In this case, select a **Category** that most closely lines up with your product. This is a very important factor in estimating the AFR. Also, observe that if you did not HALT the product beyond its published specifications, select the cell for which the **Product's Published Specs** most closely matches the levels achieved in HALT and then select the value in the **Level** for the table at the end of Section H.

Product's Published Specs	Category	Guard Band Limits	Level
0°C to 40°C	Consumer	-30°C to +80°C	1
0°C to +50°C	Hi-end Consumer	-30°C to +100°C	2
-10°C to +50°C	Hi Performance	-40°C to +110°C	3
-20°C to +50°C	Critical Application	-50°C to +110°C	4
-25°C to +65°C	Sheltered	-50°C to +110°C	5
-40°C to +85°C	All Outdoor	-65°C to +110°C	6

- F- The number of units used in the final HALT only. This is not the total quantity used in all of the HALT efforts.
- G- The product's field duty cycle. If not known, use 100.
- H- Is HASS or HASA being or going to be performed on the product? If yes, enter 1. Note: If 1 is selected (with HASS or HASA), two additional data inputs are needed namely, the Daily Sample Size and the Detectable Shift in AFR. The Daily Sample Size is the number of units that will be subjected to the HASS or HASA process in a twenty-four hour shift. If the HASS or HASA process control chart varies dramatically from shift to shift, then use an eight hour shift sample size until the control variables are under statistical control.

The Detectable Shift in AFR is the delta between the outgoing AFR and the detectable shift in outgoing quality (from HASS or HASA) that you wish to detect. For example, if the product baseline AFR is 4% and the worst case AFR is 10%, the Detectable Shift value is to be 6 (6%).

Parameter	Note	Value for <i>AFR Estimator</i>
MTBF Estimate, kHours	A	
Hot Operating Limit (HOL)	B	
Cold Operating Limit (COL)	C	
Vibration Operating Limit (VOL)	D	
Prod Published Spec Level Factor	E	
Number of HALT Samples	F	
Field Duty Cycle (in Percentage)	G	
HASS or HASA (Yes=1) or (No=0)	H	
If HASS or HASA, Daily Sample Size	H	
If HASS or HASA, Detectable Shift in AFR	H	

Once the Value for *AFR Estimator* column is completed, you are ready to run the *AFR Estimator* and determine the product's AFR, MTBF, Confidence Limits, and days to detect shift in AFR if HASS or HASA is being used. Enter these values in the green column on the *AFR Estimator*.

**Here is an example of what the AFR Calculator output looks like.**

Actual Field Failure Rate Estimate - % of Failures/Year			
	Input Matrix	Data Verify	Key
Calculated MTBF (in Hrs) =	40,000	OK	User input
Product Thermal (Hot in °C) =	130	OK	Calculated
Product Thermal (Cold in °C) =	-80	OK	Selection
Product Vibration (in Grms) =	28	OK	Data Validity
<b>Prod Published Spec Level (see below) =</b>	4	OK	
Number of HALT Samples =	4	OK	
Field Duty Cycle (in Percentage) =	100	OK	
HASS or HASA (yes = 1, no = 0) =	1	OK	
If HASS or HASA, Daily Sample Size =	26	OK	
If HASS or HASA, Detectable Shift in AFR (in %) =	5	OK	
Steady State AFR, % (HALT Only) =	0.31		
Steady State Field MTBF, Hrs (HALT Only) =	2,795,624		
Lower 90% HALT Confidence Limit =	1,507,128		
Upper 90% HALT Confidence Limit =	5,746,186		
Days to Detect Shift w/ HALT/HASS/HASA (Max) =	15.8		

  

Published Spec	Level #	Guard Band Limits	
0 to +40	1	Consumer	-30 to +80
0 to +50	2	Hi-end Consumer	-30 to +100
-10 to +50	3	Hi Performance	-40 to +110
-20 to +50	4	Critical Application	-50 to +110
-25 to +65	5	Sheltered	-50 to +110
-40 to +85	6	All Outdoor	-65 to +110

**The AFR Estimator allows for the accurate estimating of the field AFR or MTBF from the results of HALT.**

Here are a few tips on how to improve future HALTs, thereby improving the product's AFR.

- 1) An effective HALT needs to be done with at least three units and highly preferable four although the model can accommodate sample sizes up to six. Please realize that HALT sample sizes of three or less will dramatically affect the ability to detect product defects and hence, the statistical confidence is likewise impacted.
- 2) Each of the issues encountered needs to have root cause analysis completed, corrective action implemented and then verified on all units in HALT under the same stress conditions in which the defect was detected. Exceptions to this would be limitations that occur beyond the Guard Band Limits in the table following Section E. For issues encountered beyond these levels, perform root cause analysis but implement corrective action only after weighing the cost and schedule impact.
- 3) For the maximum benefit of a low AFR or a high MTBF, the product should achieve at least the levels shown under the Guard Band Limits shown in the table in Section E. These are usually very achievable with time and

understanding within the organization without having to use extended (more costly) temperature range components.

- 4) If HASS or HASA are being considered, the chamber vibration tables need to be normalized or you will need to make the HASS vibration level be equivalent to the HALT levels. In other words, if HALT was performed on a rigid table and HASS or HASA are planned on a non-rigid table one cannot correctly assume that 15Grms on the rigid table is equal to the same level on the non-rigid table as they are not. The HASS or HASA level for this example will need to be changed for equivalency.
- 5) When the *AFR Estimator* is run, it is assumed that the input factors cover the entire product to be shipped, i.e., if an option or interface board will be shipped with the product, HALT must have been done on it as well as the entire unit.
- 6) It is highly recommended that you have a copy of, "HALT, HASS, & HASA Explained", by Harry McLean and use it as a reference when performing HALT, HASS, or HASA (see [www.asq.org](http://www.asq.org)).

Future enhancements to the AFR Estimator, including improvements to the model's accuracy and additions of stresses beyond temperature and vibration, are accomplished through the addition of data to the model. If you have HALT data along with corresponding field data that you can provide for the developer, please contact Ops A La Carte and they will place you in contact with the developer.