

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

Ever since the concept of HALT was first invented, HALT practitioners have been looking for a way to calculate a Field MTBF from the results of HALT. Several people have tried but did 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 the problem.

The first approach is using a physics of failure approach in which we attempt to model the failure behavior of each component in each environment. The problem with this approach is that there are way too many variables and the model becomes too unwieldy.

The second approach is using existing Weibull models and making general assumptions about acceleration factors or plotting best fit curves. The problem with this approach is that, a) the acceleration factors are usually not correct and cannot be generalized, and b) most models are set up for constant stressing and not step stressing and there are typically not enough failures that occur to make the data statistically significant, so when you attempt to use it, the model blows up and the confidence intervals become unrealistically wide (e.g. we once tried using one of the more popular Weibull models on HALT results and achieved the result of an MTBF of 100,000 hours with a lower confidence of 1000 hours and an upper confidence of 10,000,000 hours).

The third approach is to collect a lot of data on products that have gone through HALT and then their subsequent failure history in the field. The problem with this approach is that it requires a lot of data from many different types of products in many different industries to develop an accurate model. In the past, no one had this type of data. Not until now. We have collected data from HALT and subsequent field results for the past 15 years on over 50 different products from 20 different industries and built our model based on this. And we continue to collect data and add to the model, making it more accurate over time.

Benefits of Calculator

Here are a few reasons for why and when this model should be used:

- As HALT takes only a few days to run and to implement its corrective action(s), and even if it took a bit longer, this time would be far less than waiting for a life or accelerated life test to be run and to implement its corrective action(s). The application of this model can be a huge time and cost saver.
- As higher HALT operating limits (OL) equate to lower AFR, you now have a tool that can accurately estimate the field AFR before launching the product. Stress levels that are depicted in the table in Section E are highly recommended for HALT. These levels can assure the producer that the product will exceed customer expectations and allow the producer to accurately forecast warranty expenditures.

- By not performing life tests and simply doing HALT, time and money will be saved. This is not to say that life testing isn't important. It should be considered for new technologies and for an existing part/design with a different application but not as a process to accurately estimate AFR.
- With seven to ten simple data entry points and most of them coming from the HALT effort, the *AFR Estimator* will provide an accurate field AFR instantaneously with its associated 90% statistical confidence limits. The inputs for HASS and HASA are: will you perform HASS or HASA, the daily sample size, and the detectable shift in the AFR you wish to detect.
- The *AFR Estimator* has been validated on over twenty-five products from diverse manufacturers and design environments.
- The model can accommodate HALT samples sizes from one to six with the optimum size being four. This quantity of units means that there should be four units in each environment and preferably, the same ones. Sample sizes of greater than four will default to four.
- 90% upper and lower confidence limits are calculated based on the HALT AFR and the HALT Sample Size.

Recommendations for Your Future HALTs

The *AFR Estimator* allows for the accurate estimating of the field AFR or MTBF from the results of HALT. An effective HALT needs to be done with at least three units and highly preferable four although the model can accommodate sample sizes from one 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. In addition to the highly recommended four units, here are a few additional requirements for consideration on future HALT efforts:

- 1- Each of the issues encountered needs to have root cause analysis understood, corrective action implemented and then verified 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. Issues encountered beyond these levels are to have root cause analysis performed but corrective action implemented as a business decision based on timeliness, cost, and program delays.
- 2- 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.
- 3- For the maximum benefit of a low field AFR or a high MTBF, it is suggested that the product achieve at least the levels shown under the Guard Band Limits in Section E below. These are 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 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 lowered to about 8Grms 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.

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 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 following Section H. Please note that the *AFR Estimator* will recommend an MTBF of 40,000 when a value to less than 40,000 is used.
- 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 following 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 following 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 following 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 below, i.e., a high-end consumer product equates to a Level 2. If the product does not meet the selected Category with its associated Guard Band Limits, it will have a higher estimated AFR. Enter the corresponding **Level** number from the table below. Enter the value in the table in Section H. Note: The **Category** column description may not exactly match your company's description for the product's field application. 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 following 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- 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 AFR Estimator
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	
HASS or HASA (Yes=1) or (No=0)	G	
If HASS or HASA, Daily Sample Size	G	
If HASS or HASA, Detectable Shift in AFR	G	

- 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.
- I- Please be aware that the model cannot estimate wear out modes. These types of failures will need to be addressed through reliability testing not covered herein.

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

Field Failure Rate Estimate - % of Failures/Year

	Input Matrix	Data Verifiy	
MTBF (in Hrs) =	200,000	OK	Key User input Calculated Selection Data Validity
Product Thermal (Hot in °C) =	110	OK	
Product Thermal (Cold in °C) =	-50	OK	
Product Vibration (in Grms) =	18	OK	
Prod Published Spec Level (see below) =	4	OK	
Vibration Table Technology =	3	OK	
Number of HALT Samples =	3	OK	
HASS or HASA (yes = 1, no = 0) =	1	OK	
If HASS or HASA, Daily Sample Size =	96	OK	
If HASS or HASA, Detectable Shift in AFR (in %) =	6	OK	
Steady State AFR, % (HALT Only) =	1.83		
Steady State Field MTBF, Hrs (HALT Only) =	478,685		
Lower 90% HALT Confidence Limit =	258,060		
Upper 90% HALT Confidence Limit =	983,900		
Days to Detect Shift w/ HALT/HASS/HASA (Max) =	17.1		

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