

## **1.0 INTRODUCTION**

### **1.1 Purpose**

This document is the worldwide test and reliability standard used to specify accelerated stress testing (AST) of electrical and electronic products.

### **1.2 Overview**

Background information, methodology, responsibilities, and detailed procedures for AST are contained in this document. AST consists of highly accelerated life test (HALT), screen verification, proof-of-screen (POS), and highly accelerated stress screening (HASS).

### **1.3 Definitions & Acronyms**

AST = accelerated stress testing  
HALT = highly accelerated life test  
HASS = highly accelerated stress screening  
POS = proof-of-screen  
UOTL = upper operating temperature limit  
LOTL = lower operating temperature limit  
UDTL = upper destruction temperature limit  
LDTL = lower destruction temperature limit  
OVL = operating vibration limit  
DVL = destruction vibration limit

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## 2.0 BACKGROUND

### 2.1 Purpose

The purpose of AST is to precipitate and detect (observe) defects in products during design and detect defects during manufacturing. Relevant defects, or those likely to occur in deployment, must have the root cause identified and the optimal solution must be determined, implemented, and *verified*. Section 4.3 contains more information on relevant defects.

### 2.2 Methodology

During AST, applied stresses will be increased above expected deployment levels to compensate for a relatively small sample size and to find defects quickly.

AST simulates the decrease in product strength over time (cumulative fatigue damage) or an absolute overstress condition.

AST uses a “test-to-failure” methodology during product design and a “screening” process during manufacturing. These are defined in more detail in sections 4 to 6 of this document.

The accelerated stress test methods for electronics and electrical products include:

1. HALT (or product ruggedization)
2. Screen verification and POS (preparation for HASS),
3. HASS

These methods can also be applied to *some* electromechanical products.

## **3.0 RESPONSIBILITIES**

### **3.1 Reliability Engineering**

Reliability Engineering is a functional group at Carrier Electronics, Huntington, Indiana. Reliability Engineering is responsible for:

1. Maintaining the AST (and other reliability test) standards, procedures, and methods.
2. Implementing, performing, and assisting other locations performing AST.
3. Assisting in developing the initial HASS/HASA profile.
4. Maintaining and analyzing the HASS/HASA data.

In addition, this group will have the primary responsibility for deciding which failures discovered during testing are relevant and critical (see section 4.3). Relevant defects require corrective action. Reliability Engineering will also assist in the corrective action process.

### **3.2 Product team/supplier**

A product team, located at any Carrier Electronics location <sup>1</sup>, or a supplier, is responsible for developing products and ensuring that all product requirements, including reliability, are achieved.

The product team or supplier will implement the corrective action required to address relevant failures discovered in AST.

### **3.3 Manufacturing AST**

Manufacturing AST, including the HASS/HASA profile generation, POS, screen verification, data evaluation, and failure analysis will be the responsibility of Reliability Engineering. Manufacturing personnel will run the actual HASS.

Corrective action determination and implementation will be the combined effort of both manufacturing and Reliability Engineering.

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<sup>1</sup> Engineering, contract and component factories, and regional technical centers, etc.

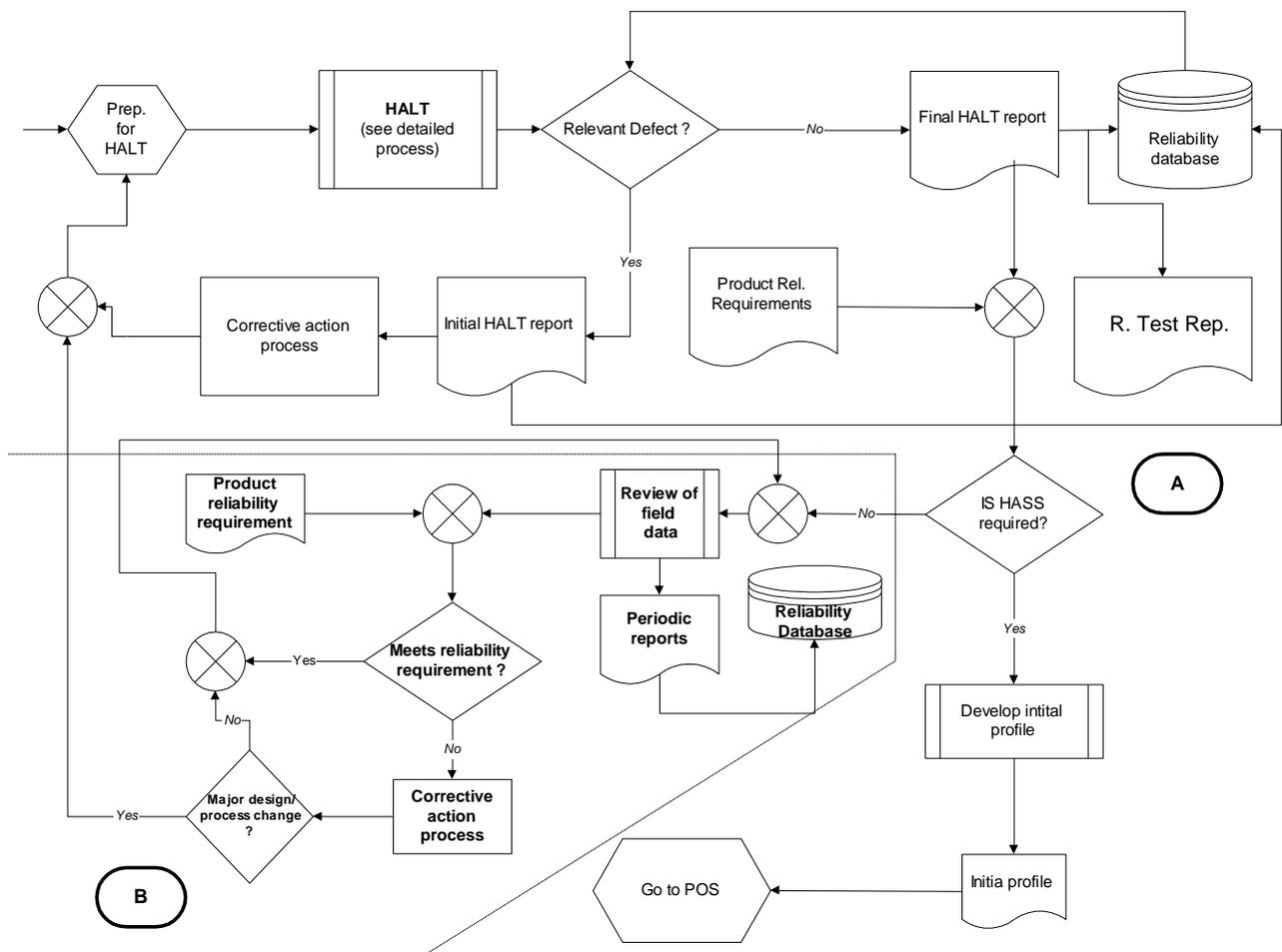
## 4.0 HIGHLY ACCELERATED LIFE TEST (HALT)

All electronics and electrical products will be subjected to the HALT process during design and manufacturing as required by Ref. [TBD]. HALT will be performed on some electromechanical products if deemed necessary by Reliability Engineering.

Figure 4-1 depicts the process.

Sections 4.1 to 4.8 shall be implemented during product design (or redesign) and sections 4.9 to 4.11 shall be implemented during product manufacturing and deployment. These phases of product development are defined in Ref. [TBD].

**Figure 4-1  
HALT Process**



A = Performed during product design

B = Performed during product manufacturing/deployment

## 4.1 HALT preparation

Preparation consists of the following:

#	Description
1	The HALT plan, which is a section of the reliability test plan, shall be created according to Ref. [TBD].
2	The product team shall obtain the required samples, according to Ref. [TBD], from the expected supplier of production versions.
3	<p>The product team, in conjunction with Reliability Engineering, shall develop a functional test and diagnostics set-up. <i>It is highly recommended that the expected manufacturing functional test/diagnostics be used during HALT.</i></p> <p>A “design-for-test” philosophy shall be utilized. All “major” product operations must be monitored during the functional test. All “critical” I/O signals and power sources must be loaded and activated.</p>
4	The product team shall provide to Reliability Engineering, schematics, drawings, and documents describing the product electrical/electronic operation, physical characteristics, and mechanical dimensions. These items are needed to define the mechanical and electrical connections between the samples and the AST chamber and functional test/diagnostics set-up.
5	The product team shall identify a staff member to coordinate all HALT activities with Reliability Engineering. This staff member shall have broad knowledge of all aspects of the product development and manufacturing. This staff member may be required to assist in the performance of HALT.
6	A location for the “product” thermocouple (used to control chamber operation) shall be chosen so that circuit electrical operation and power dissipation of nearby devices does not influence temperature measurement. In addition to the chamber “product” T/C, several other T/Cs may be used to characterize product temperatures during HALT and POS. The source of this information may be thermal analysis, measurement, or results of previous testing.
7	Location of “product” accelerometer(s). Initially, at least one accelerometer shall be placed in the center of printed circuit boards or near areas of the boards where

	significant deflection can occur. If a failure occurs during vibration, place additional accelerometers near the failed devices so that exact levels can be measured.
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## 4.2 Perform HALT

HALT consists of single environment and combined environment exposure as described below.

Use Ref. [TBD] for definitions of functional tests.

### 4.2.1 Single environment

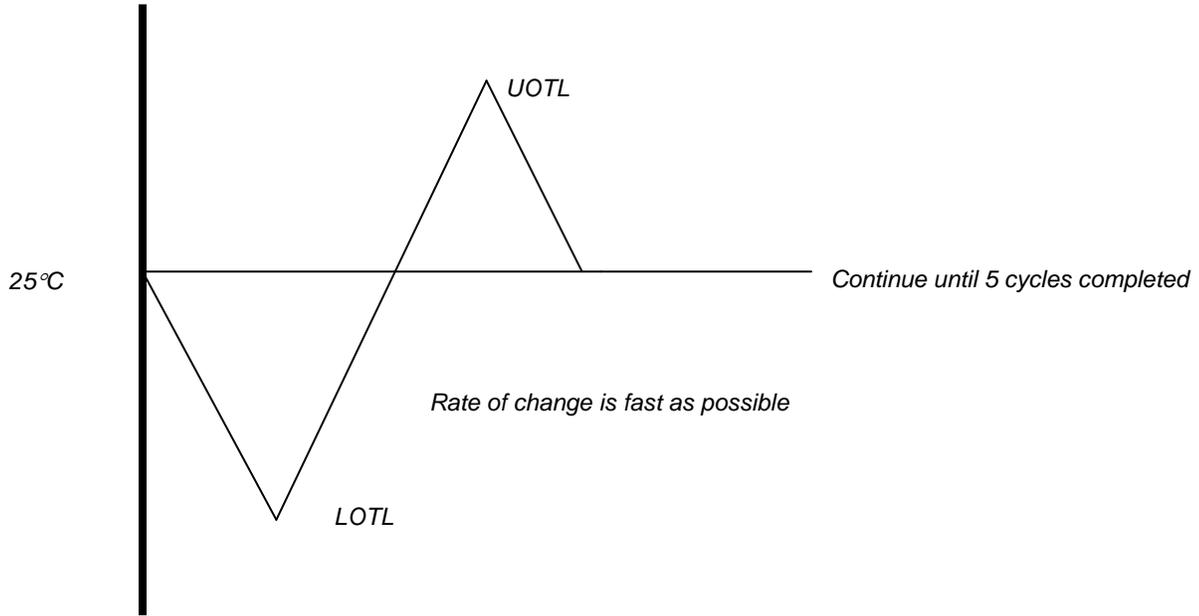
Single environment testing is performed as follows:

#	Description
1	<p><u>Step-stress</u>: On at least 1/2 of the samples: temperature <sup>2</sup> and vibration are “stepped” until operating and destruction limits are determined or chamber limits (or fundamental technology limits <sup>3</sup>) are reached. Perform functional tests before, during, and after stress exposure.</p> <p>The stresses shall be applied according to sections 4.2.1.1 and 4.2.1.2.</p>
2	<p><u>Temperature cycling</u>: On the same samples used in step-stress, cycle temperature using maximum rate of change possible between operating limits discovered in step-stress and perform limited functional tests. The temperature cycle profile is depicted in Figure 4-2. Five (5) temperature cycles are performed.</p>
3	<p>If a failure has occurred and the sample can be repaired, repeat step stress or temperature cycling from the point of failure. Determine new operating and/or destruction limits, or technology or chamber limits if possible. Perform a maximum of five (5) temperature cycles.</p>
4	<p>Remove all stresses and perform functional tests/diagnostics (while products are outside chamber, if necessary).</p>

<sup>2</sup> The “cold” step-stress includes performing cold start/operation on one of the first three samples.

<sup>3</sup> The “fundamental” limits of product technology are the stress values resulting in a rapid strength degradation, “exponential” increase in the number of failures, and/or changing of material properties. If the product operating and/or destruction limits and the fundamental limits are “too” low and/or not separated, the product can be expected to have poor reliability.

**Figure 4-2**  
**Temperature Cycle Profile**



**4.2.1.1 Stress types**

Perform single environment step-stress to each sample as shown below:

Sample # 1	Sample # 2	Sample # 3
1. Temperature "Cold"	1. Temperature "Hot"	1. Vibration
2. Temperature "Hot"	2. Temperature "Cold"	2. Temperature "Cold"
3. Vibration	3. Vibration	3. Temperature "Hot"

If more than three samples are to be tested, repeat columns from left to right on additional units.

**4.2.1.2 Stress values**

The step stress values are depicted below:

During the temperature "cold" step-stress on one sample, the duration is 5 minutes with power off, followed by at least 5 minutes or sufficient time to perform functional test and diagnostics with power on, at each stress value at and below -10°C.

During temperature "hot" step-stress, vibration, and on the remaining temperature "cold" step-stress samples, power is on and duration is at least 5 minutes for each step and stress type or sufficient time to perform functional test and diagnostics.

Step #	Temperature Cold" (°C)	Temperature "Hot" (°C)	Vibration (g <sub>RMS</sub> )
1	25	25	5
2	0	40	10
3	-10 (Cold Start/Op)	50	15
4	-20 (Cold Start/Op)	60	20 (5 "tickle" or modulated excitation)
....	....	....	....
....	Lower Operating and Destruction Limits (LOTL, LDTL) /Chamber Limits/Technology Limits	Upper Operating and Destruction Limits (UOTL, UDTL) /Chamber Limits/Technology Limits	Operating and Destruction Limits (OVL, DVL)/ /Chamber Limits/Technology Limits

### 4.2.2 Combined environment

The objective of combined environment exposure is to find additional failures and to confirm failures observed in single environment exposure.

On the available unused samples and on at least one non-failed or repaired sample from step stressing:

#	Description
1	<p>Apply the combined temperature/vibration environment depicted in Figure 4-3. Perform functional tests/diagnostics during exposure.</p> <p>The combined environment consists of precipitation <sup>4</sup> and detection <sup>5</sup> portions. The testing shall be continued until at least 2 profiles have been completed or more than ½ of the samples have failed (operationally or destructively), whichever occurs first.</p>
2	Repair failed samples and continue test from the point of failure, if possible.
3	Remove all stresses and perform functional tests/diagnostics (while products are outside chamber, if necessary).

### 4.3 Determine “relevancy” and “criticality” of defects

All failures observed in the testing must be categorized as being either “relevant” or “irrelevant”. Relevant failures are those HALT failures that are most likely to occur in normal field deployment. There may be different criteria for destructive and operational failures. Past product or technology reliability performance is a big factor in the determination of relevant failures.

The Reliability Engineering group will have primary authority to make the determination. The product team will also be consulted to assist in this determination.

The *reliability database* <sup>6</sup> will be examined to aid in the determination process. The database contains information from previous AST results on the same product or similar products, field and factory failures, reliability/physics-of-failure theory, and benchmarking.

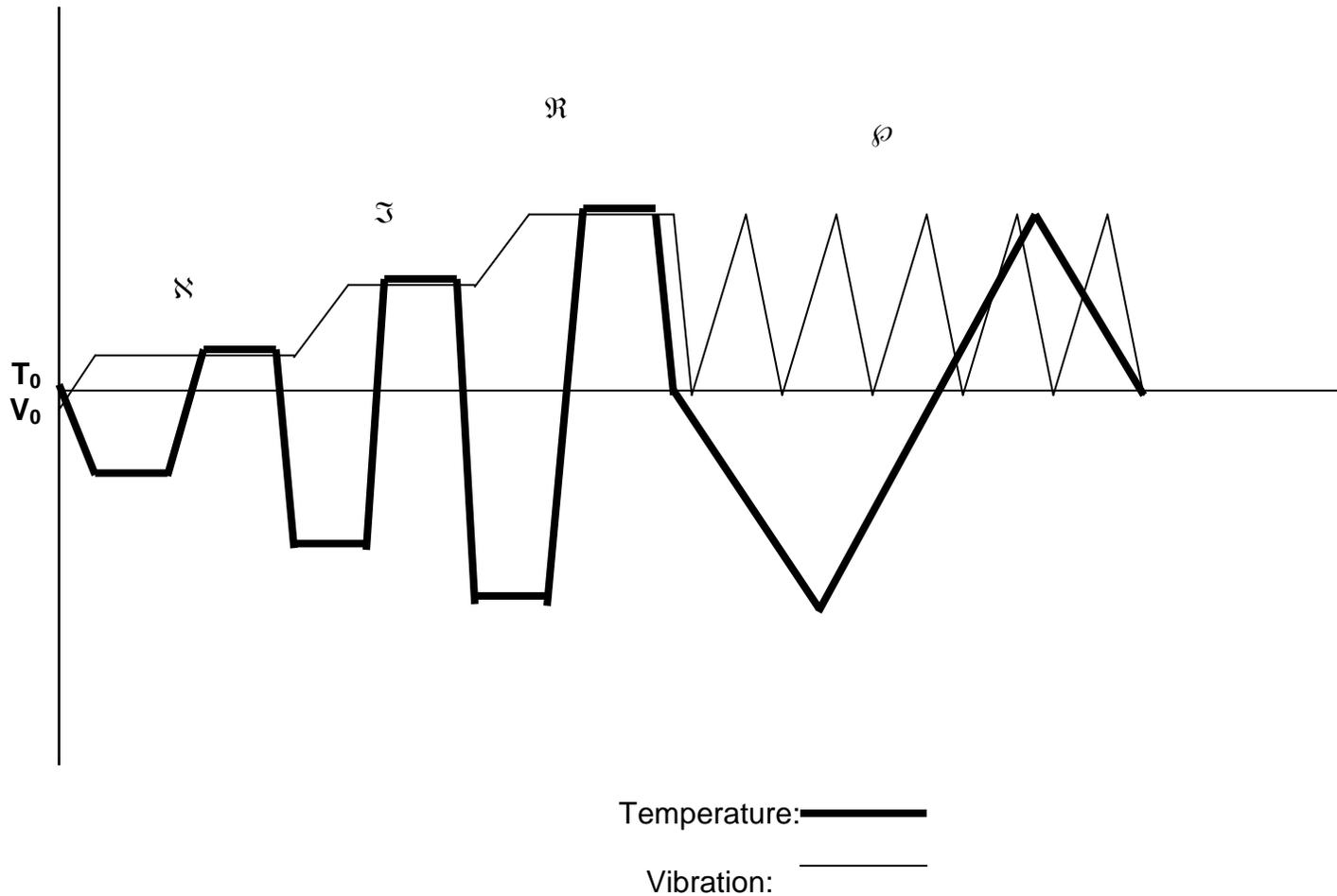
In addition, the “criticality” of the failure must be determined. A failure modes and effects analysis (FMEA) – Ref. [TBD] – can be used to do this.

<sup>4</sup> Precipitation is used for accelerating *latent* product failure mechanisms into *patent* defects.

<sup>5</sup> Detection is used to observe *patent* defects that were induced during precipitation.

<sup>6</sup> This database is an “informal” compilation of all sources of failure data within Carrier Electronics.

**Figure 4-3**  
**HALT Combined Profile**



Notes:

$T_0 = 25^{\circ}\text{C}$ ;  $V_0 = 5 \text{ g}_{\text{rms}}$

Cycle # 1 = Precipitation: Temperature & vibration at 50% of operating limits; “Fast” temperature ramps; Dwell = 5 minutes + time for functional tests

Cycle # 2 = Precipitation: Temperature & vibration at 75% of operating limits; “Fast” temperature ramps; Dwell = 5 minutes + time for functional tests

Cycle # 3 = Precipitation: Temperature & vibration at 100% of operating limits; “Fast” temperature ramps; Dwell = 5 minutes + time for functional tests

Cycle # 4 = Detection: Temperature cycled “slowly” (1 to 5  $^{\circ}\text{C}/\text{min}$ ) between operating limits; Vibration cycled between 5  $\text{g}_{\text{rms}}$  and operating limit at a rate of 10 to 20  $\text{g}_{\text{rms}} / ^{\circ}\text{C}$  (“modulated excitation”)

#### 4.4 Initial HALT report

Reliability Engineering will create the initial HALT report. It shall be discussed with the product team and incorporated into the reliability database. Use Ref. [TBD] as the format for test reports.

The initial report shall contain the following information:

#	Description
1	Record product performance during single environment and combined environment testing. The format for the temperature and vibration operating and destruction limits is depicted in Figure 4-4 <sup>7</sup> .
2	A list of relevant defects. Criticality of the relevant defects, if known.
3	Recommendations for corrective action solution if the root cause is understood.
4	S/N, P/N, revision dates, supplier of samples tested.
5	Location of “product” and other T/C’s. Location of “product” accelerometer(s).

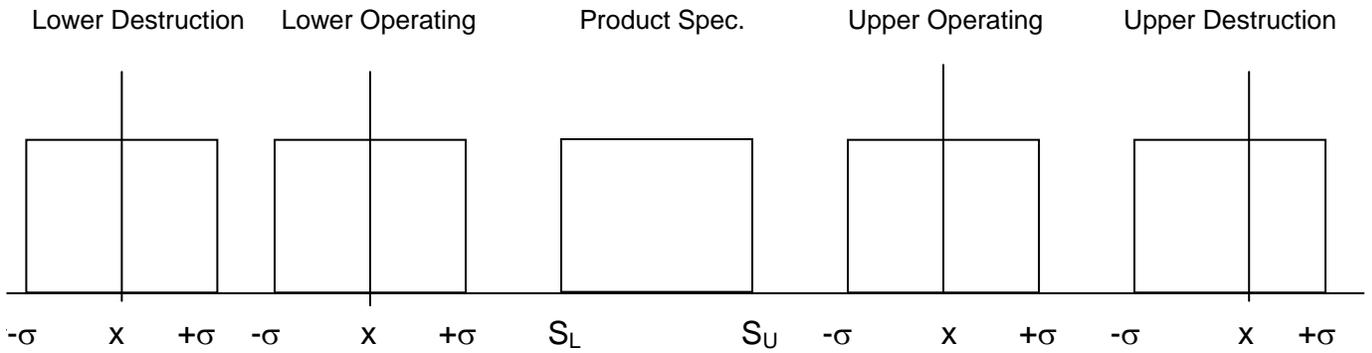
#### 4.5 Corrective action process

All relevant defects must have a root cause determined; and a solution identified, implemented, and verified by a re-test. Those defects having a “high” criticality should be corrected before those with a “lower” criticality.

The corrective action process is defined in Ref. [TBD] and the design issue tracking (DIT) method defined in Ref. [TBD] will track the progress. All relevant defects must achieve a status level of 5 before the product is ready for manufacturing and deployment.

<sup>7</sup> Required for HASS development.

**Figure 4-5**  
**HALT Results**  
**Distribution Format**



X = parameter average

$\pm\sigma$  = upper/lower limits as appropriate for strength distribution

$S_L$  = specification lower limit

$S_U$  = specification upper limit

#### 4.6 Final HALT report

Reliability Engineering will create the final HALT report. It shall be discussed with the product team and incorporated into the reliability database and reliability test report. Use Ref. [TBD] as the format for test reports.

The final report shall contain the following information:

#	Description
1	Reference to initial HALT report.
2	All test results, including updated operating and destruction limits.
3	S/N, P/N, revision date, supplier of samples.
4	Proof that the solution(s) for relevant defects from previous HALTs have eliminated the root cause and that no new relevant defects exist.

#### 4.7 Determine HASS applicability

The product team, in consultation with Reliability Engineering, shall make a determination of whether or not HASS is required.

The product reliability requirements and HALT results must be examined. If the requirements and test results necessitate the need for HASS, then an initial profile will be developed.

If HASS is not required, then the product will be manufactured and field reliability will be continuously reviewed and compared to the requirements according to Ref. [TBD].

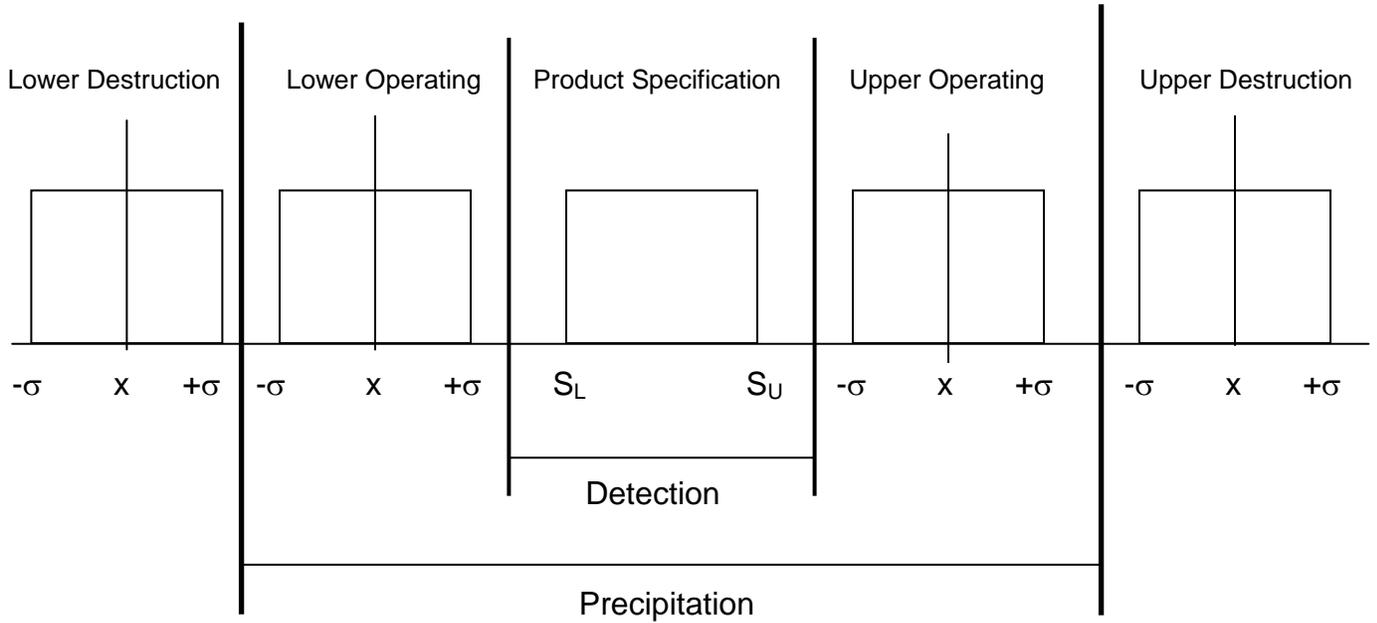
If the requirements are not achieved and HASS is determined to be the solution, HALT must be repeated on the current version of the product. This is necessary if a major design or process change has been made since the last HALT was performed.

#### 4.8 Develop initial HASS profile

If HASS is required, an profile will be developed by Reliability Engineering, the product team, and manufacturing. It will be based upon the final HALT results and reliability/physics-of-failure theory.

The initial profile format is depicted in Figure 4-5. The standard profile has separate precipitation and detection portions. Some profiles may have a combined precipitation/detection format.

**Figure 4-5**  
**Initial HASS**  
**Profile Format**

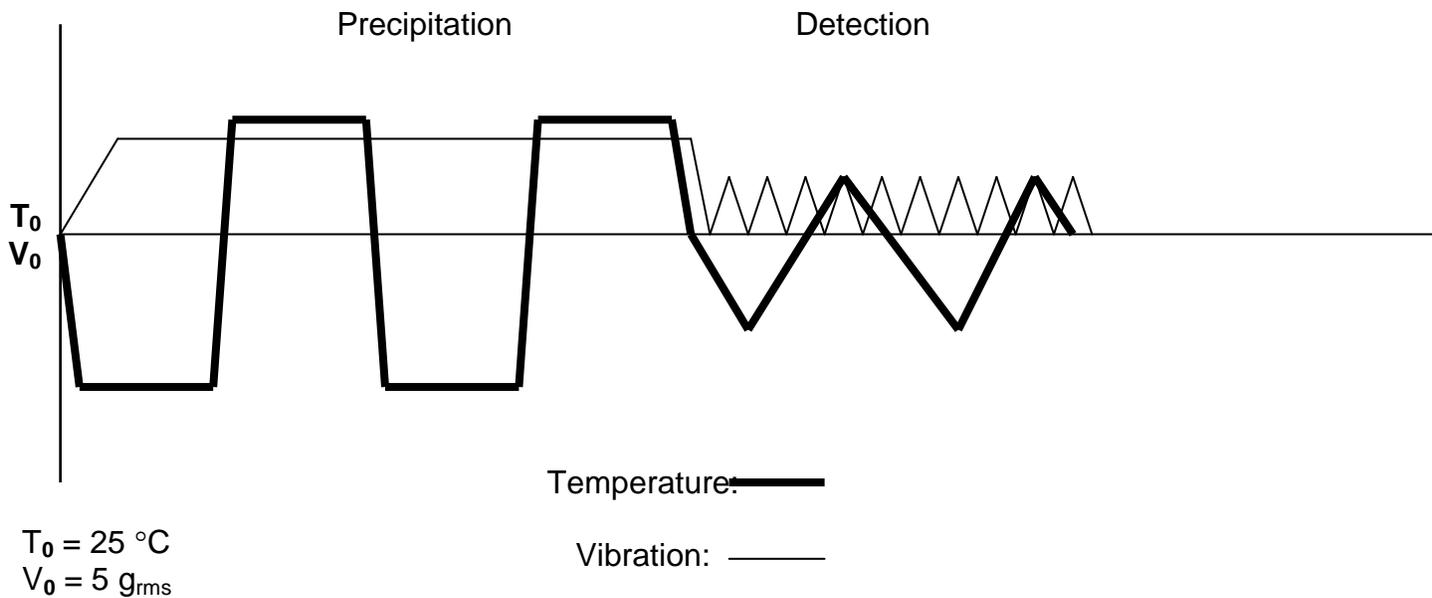


$X$  = parameter average

$\pm\sigma$  = upper/lower limits as appropriate for strength distribution

$S_L$  = specification lower limit

$S_U$  = specification upper limit



**4.8 (cont.)**

The characteristics of the initial HASS profile will be:

#	Description
1	For the precipitation portion, the temperature extremes (°C) and vibration ( $g_{RMS}$ ) levels will be between the product destruction and operating strength distributions determined during HALT. At least two temperature cycles shall be specified.
2	For the detection portion, the temperature extremes and vibration ( $g_{RMS}$ ) levels will be between the operating strength and specification distributions. The detection portion consists of “modulated excitation” vibration. In addition, low level (or “tickle”) vibration can be used. At least two temperature cycles shall be specified.
3	Vibration will be applied constantly during the precipitation portion unless the HALT results or physics-of-failure theory indicates a different profile is more appropriate.
4	Average rate of temperature change (°C/min.) measured on the product will be as fast as possible during the precipitation portion and slower” during the detection portion. Factors will include the chamber capabilities and the thermal impedance of the product samples.
5	Dwell at the temperature extremes during the precipitation will be determined from the HALT results (or physics-of-failure theory) but will be at least 5 minutes or sufficient time to perform functional test/diagnostics. Dwelling is not required during the detection portion unless HALT results and physics-of-failure theory indicate it is necessary.
6	Power on/off cycles and variation as appropriate for the type of product – obtain and review power quality reliability test results.

**4.9 Field data review**

After a product is released into the field (“deployed”), reliability data shall be collected and analyzed according to Ref. [TBD]. Reports shall be published at periodic intervals by manufacturing or Reliability Engineering.

**4.10 Review product reliability requirements**

The product reliability requirements shall be developed according to Ref. [TBD] by the product team and Reliability Engineering and compared to the field performance.

**4.11 Corrective action process**

Using Ref. [TBD], as the standard, all failures, which result in the inability to meet product reliability requirements, must have the primary root cause(s) identified. Solution(s) must be developed, implemented, and verified.

## 5.0 SCREEN VERIFICATION & PROOF-OF-SCREEN (POS)

The screen verification and proof-of-screen (POS) process is depicted in Figure 5-1. These activities shall be performed before product manufacturing and deployment but using deployment phase test set-ups, equipment, and AST chamber(s).

Reliability Engineering, shall perform screen verification and POS.

### 5.1 Preparation

#	Description
1	Obtaining 1-3 samples for screen verification and a sufficient number for POS <sup>8</sup> .
2	Obtaining product specifications, schematics, and drawings.
3	Adapting functional test/diagnostics that were used in HALT for the manufacturing environment.
4	Determining chamber profile required so that the sample temperatures are according to the initial/revised HASS profile. It will be a function of product power dissipation and thermal impedance, and chamber capabilities.

### 5.2 Screen verification (“seeding” of defects)

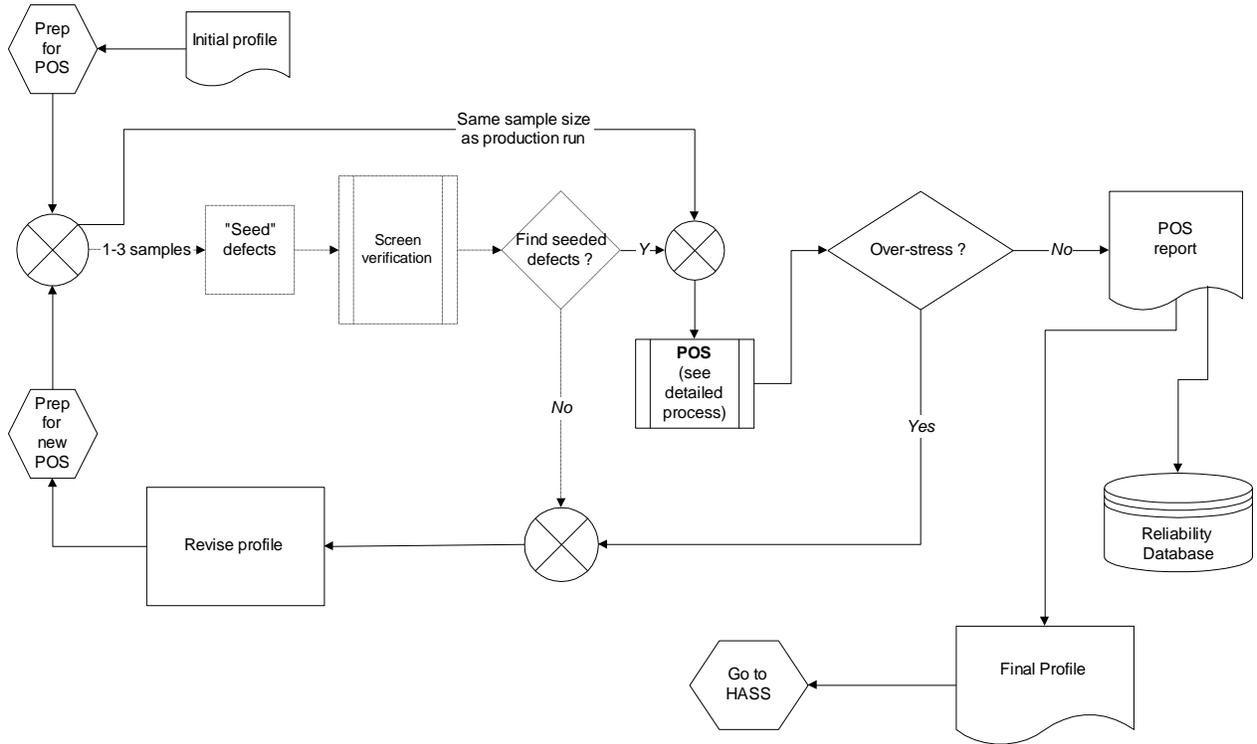
This is an optional step which will be performed on some products to verify that the screen is capable of detecting (observing) defects that have been noted on earlier versions or similar products.

The procedure is:

#	Description
1	“Seed” defects: create the same type of defects that have been observed during HALT, manufacturing, or deployment; or use reliability or physics-of-failure theory.
2	Perform the initial (or revised) HASS profile at least 5 times.
3	Verify that the “seeded” defects were detected during the first profile.
4	Revise profile if “seeded” defects were not observed.

<sup>8</sup> Each product mounting “position” inside AST chamber shall be populated during POS.

**Figure 5-1**  
**Screen verification & proof-of-screen process**



### 5.3 Proof-of-screen (POS)

The procedure is:

#	Description
1	On “non-seeded” samples, perform the initial (or revised) profile at least 25 times.
2	After removal from chamber, perform a subset of the standard reliability tests, Ref. [TBD], as appropriate for the product and previous test results. Reliability Engineering will determine which tests should be performed.

### 5.4 Revise HASS profile

The initial profile must be revised if the “seeded” defects were not detected or “over-stress” failures occurred:

#	Description
1	For the case of “seeded” defects not observed, increase the temperature and/or vibration range being careful not to intersect the upper or lower destruction distributions <sup>9</sup> . In addition, it may be necessary to increase the number of cycles, length of the screen, and/or temperature rate of change.
2	For the case of “over-stress” failures observed (or removal of “life” from product), decrease the range but do not intersect the product <i>specification</i> distribution <sup>10</sup> . In addition, it may be necessary to decrease the number of cycles, length of the screen, and/or temperature rate of change.
3	Repeat the procedures of sections 5.1 to 5.3.

<sup>9</sup> If not feasible to increase the limits then discontinue the HASS process until the product can be made more “robust” via corrective action – increase of product strength

<sup>10</sup> If the profile intersects with the product specification distribution, HASS may not be effective. The stress values will be too low to discover defects within a reasonable screening period. Therefore, it may be necessary to increase the product strength.

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**5.5 POS report**

A POS report must be created and discussed with the product team and manufacturing and then stored in the reliability database.

The report shall contain the following information:

#	Description
1	Corrective action recommendation, if necessary.
2	Initial and final HASS profiles.
3	P/N, S/N, revision date, supplier of samples tested.

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**6.0 HIGHLY ACCELERATED STRESS SCREENING (HASS)/ HIGHLY ACCELERATED STRESS AUDIT (HASA)**

The HASS/HASA process is depicted in Figure 6-1. Manufacturing shall implement the steps below.

**6.1 Preparation**

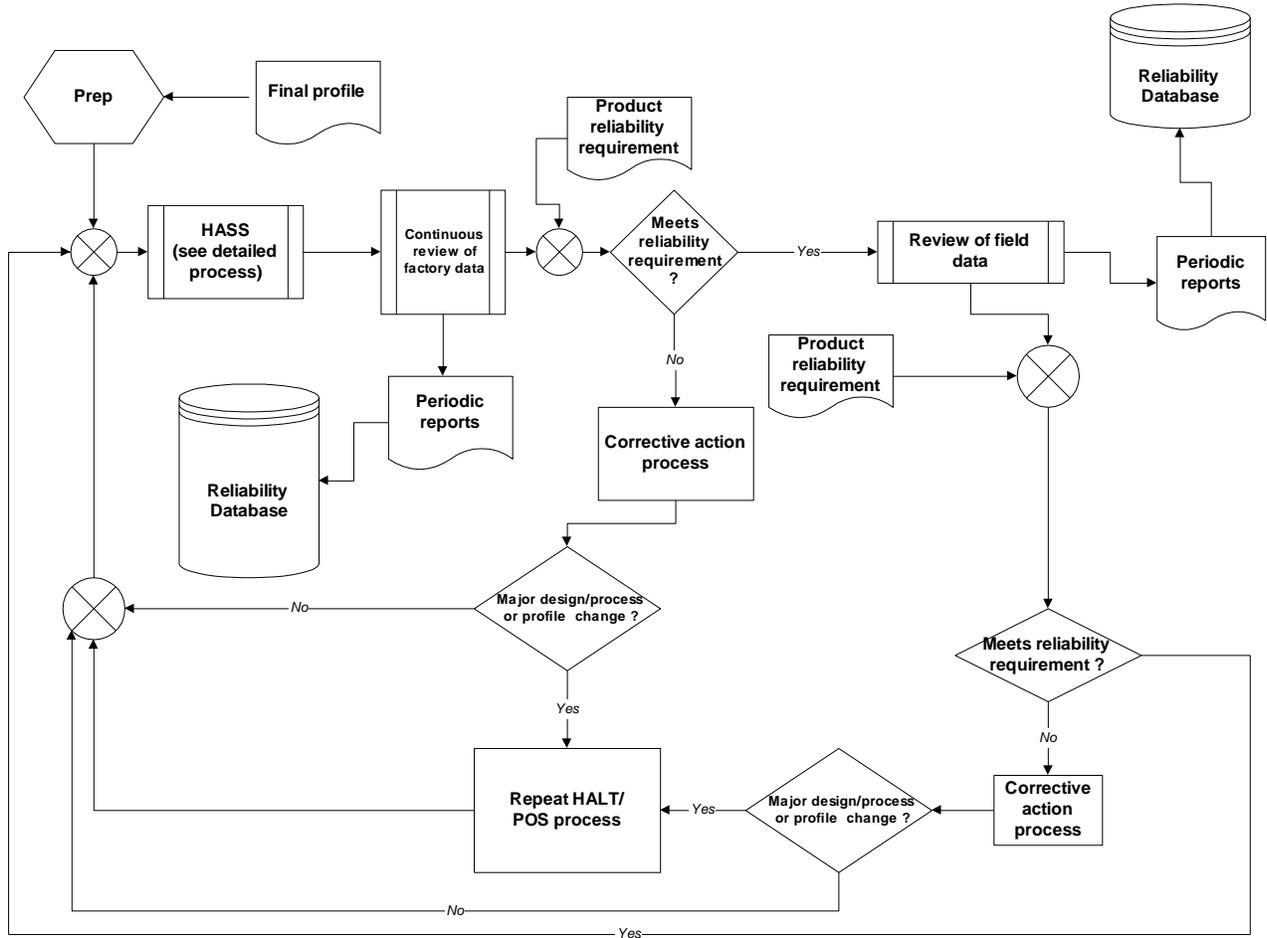
Preparation for HASS/HASA consists of the following steps:

#	Description
1	Obtaining product specifications, schematics, and drawings.
2	Obtaining all necessary set-ups for functional tests and diagnostics.
3	Scheduling HASS/HASA in conjunction with normal manufacturing, testing, and quality assurance tasks within the facility.
4	Ensuring that adequate supplies of LN <sub>2</sub> and compressed air are available.
5	Determining whether 100% screening or auditing on a sample basis will be performed. Factors in this decision could be the factory throughput requirements, reliability requirements, and previous reliability performance of the product.

**6.2 Perform HASS/HASA**

Perform the final HASS/HASA profile on production samples.

**Figure 6-1  
HASS/HASA process**



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### 6.3 Review factory data

Continuously review results and prepare periodic reports for each product screened. The data shall include:

#	Description
1	Number and S/Ns of units screened.
2	Number, % of total, S/Ns of failed units.
3	Time/Day when failed.
4	Root cause of all failures.

Incorporate the reports into the reliability database.

### 6.4 Compare results and reliability requirement

Continuously compare the results to the product reliability requirement.

If requirements are not achieved, initiate and track progress of corrective action.

### 6.5 Field data review

At periodic intervals, review product field performance and prepare reports according to Ref. [TBD]. Incorporate the reports into the reliability database.

### 6.6 Compare field data/reliability requirement

Compare the field data to the product reliability requirement.

If requirements are not achieved, initiate and track corrective action.

### 6.7 Corrective action process

Using Ref. [TBD], as the standard, all failures, which result in the inability to meet product reliability requirements, shall have the primary root cause identified. Solutions must be developed, implemented, and verified. Progress shall be tracked using Ref. [TBD].

If the corrective action requires a “major” redesign of the product or manufacturing process, or the HASS/HASA profile is revised significantly, then the HALT and/or screen verification/POS processes (sections 4 & 5) must be repeated.