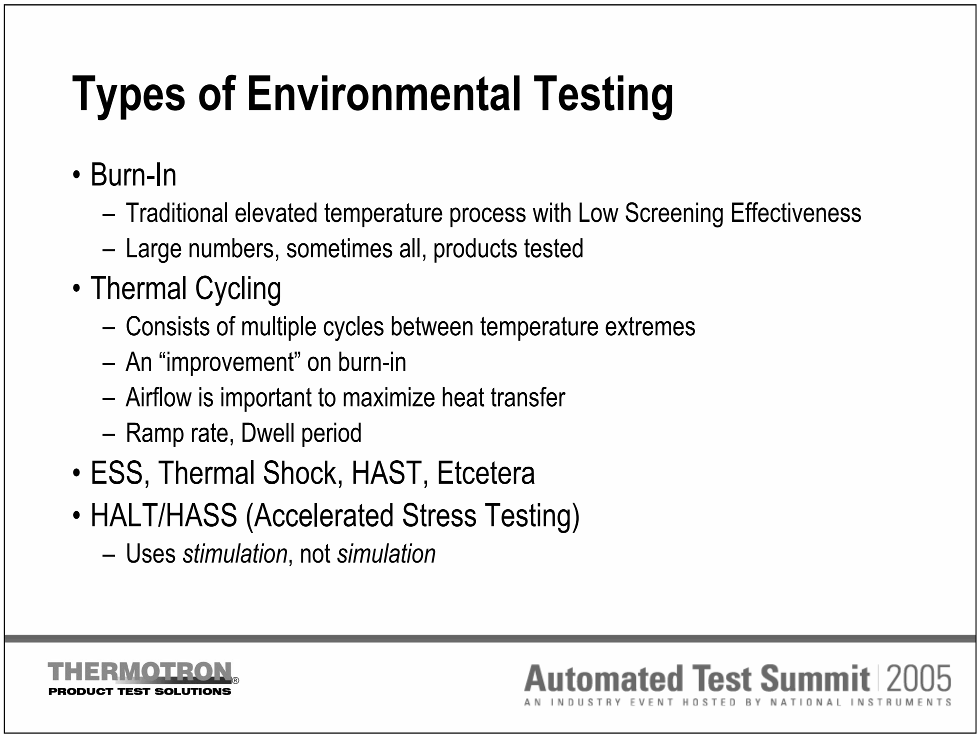
2.3 Implement Highly-Accelerated Stress Screening (HALT-HASS)

Incorporating Best Practices for Ensuring Product Quality



There are many types of environmental testing in use today. One of the oldest techniques in use is referred to as burn-in. Burn-in testing is performed by elevating the temperature of the items under test for a period of time. It is popular since the cost to implement it is consider low, and the equipment requirements are minimal. Burn-In is often used as a production process. It is considered one of the *least* effective methods of environmental testing and has a relatively low screening effectiveness.

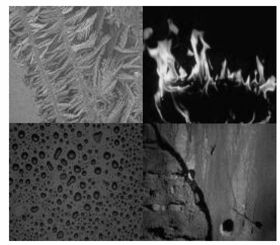
Thermal cycling is a more effective test process than burn-in. It uses multiple cycles of temperature transitioning between extremes. The rate that the temperature changes (ramp rate), the extremes to which it reaches, and the duration at the extreme (dwell) all define the effectiveness of he thermal cycling test.

There are other forms of environmental testing like ESS, Thermal Shock and HAST. Each of these techniques has an application in achieving certain test goals. For example, ESS uses thermal cycling as a screening process during production to identify weaknesses in the parts and processes that are used in creating a product. HAST, sometimes referred to as 85/85 uses high humidity, pressure and high temperatures. Keep in mind that the words used to describe the various environmental testing techniques are sometimes used loosely.

Alternate techniques of environmental testing have been created to satisfy the demands of today's shorter development times, faster product obsolescence and raised reliability expectations. The time required to perform environmental testing can be shortened by using more aggressive environmental stresses. This is referred to as Accelerated Stress Testing (AST). The most popular of these techniques are Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS). Note that Accelerated Stress testing uses *stimulation*, not *simulation*. *Simulation* duplicates real-word (natural) stresses whereas *stimulation* uses stresses beyond what the product would normally see.

Stresses Used in HALT and HASS

- Temperature
  - Electrical constants change
  - Often due to component variations
  - Expansion/Contraction
  - Coefficient of Thermal Expansion (CTE) mismatches
  - Interaction of dissimilar materials
    - Galvanic reaction
  - Changes in flexibility
  - Changes in viscosity
  - Delamination
- Vibration
  - Loss of mechanical strength due to fatigue
  - Cracking
  - Displacement
  - Mechanical functions impaired



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To help our understanding of environmental testing, and HALT and HASS in particular, we should turn our attention to some of the basics. The distinctive forms of stimulus used in environmental testing are referred to as “stresses”. The stresses can be divided into a variety of types. The two most common, and widely considered as the most effective, are temperature and vibration.

With changes in temperature, electrical constants can change, causing electronic circuits to vary their operation. An example of this is how some components change their resistance with a change of temperature.

Expansion and contraction caused by temperature changes can be a source of problems. These problems can be the source of weakened electrical connections, as seen in cases where the Coefficient of Thermal Expansion (CTE) is different for a IC package and the underlying printed circuit board.

Other stresses such as humidity, dust, and power cycling are also used. Generally, the overall effectiveness of these stresses are typically somewhat lower than temperature and vibration.

What is Highly Accelerated Life Testing (HALT)?

- General principle is to compress time of test
- Test to product failure (stimulus)
- Utilizes aggressive temperature changes and multi-axis vibration
- Learn product design weak points and improve reliability
- Low number of products tested

Thermotron AST-8

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HALT is a test technique that typically uses temperature and vibration step-stressing. HALT testing also implements repetitive multiple axis vibration, also known as quasi-random, omni-axial, or six-degree-of-freedom vibration.

Be aware that HALT/HASS can be a very “political/controversial” topic as everyone is “sold” on the effectiveness of these methods. Quite often, people are confused with the fact that HALT testing can use stress levels that go beyond the levels that a product would see in normal use. HALT can duplicate in a few hours what takes months or years to happen in the field environment.

The stresses are meant to precipitate problems in weak areas. For example, problems with a capacitor and it’s mounting method on a circuit board may be evaluated. The vibration stresses may help point out an inadequate mounting technique by breaking the capacitor mounting. A possible solution may consist of adding a small amount of silicone to more securely fasten the capacitor to the printed circuit board. Each failure and solution encountered needs to be examined to evaluate weather it is a valid failure, and if the solution is practical.

What is Highly Accelerated Stress Screening (HASS)?

- A type of accelerated stress testing used in production situations
- Uses “accelerated” stresses like HALT
  - Fast temperature change rates
  - Vibration
- Similar to Traditional ESS
- May use “limits” discovered in previous HALT testing

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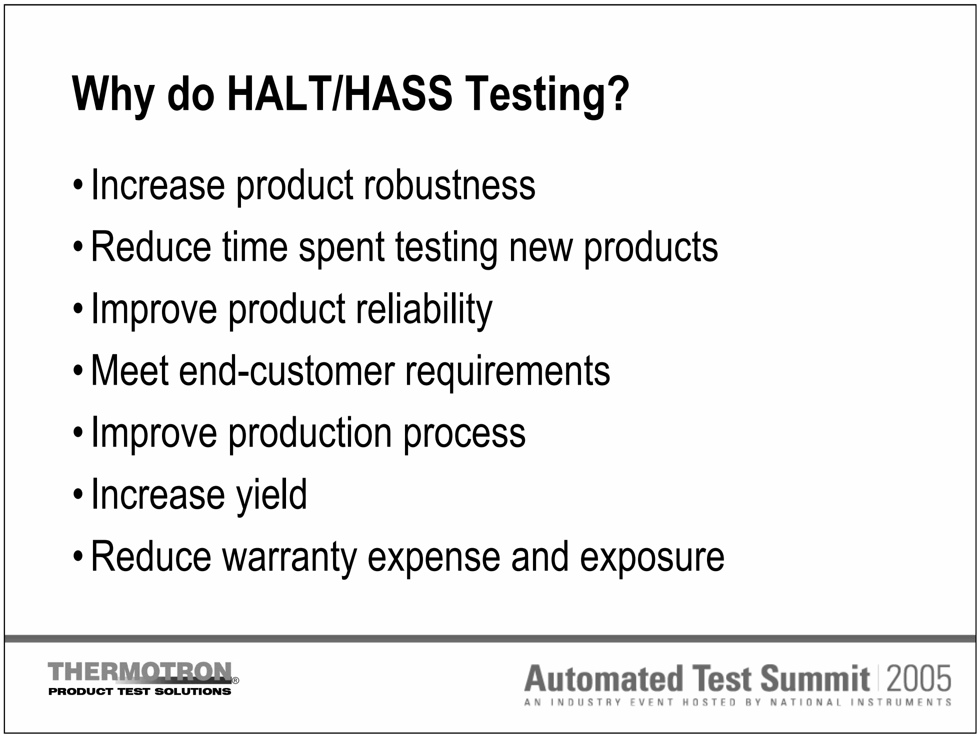
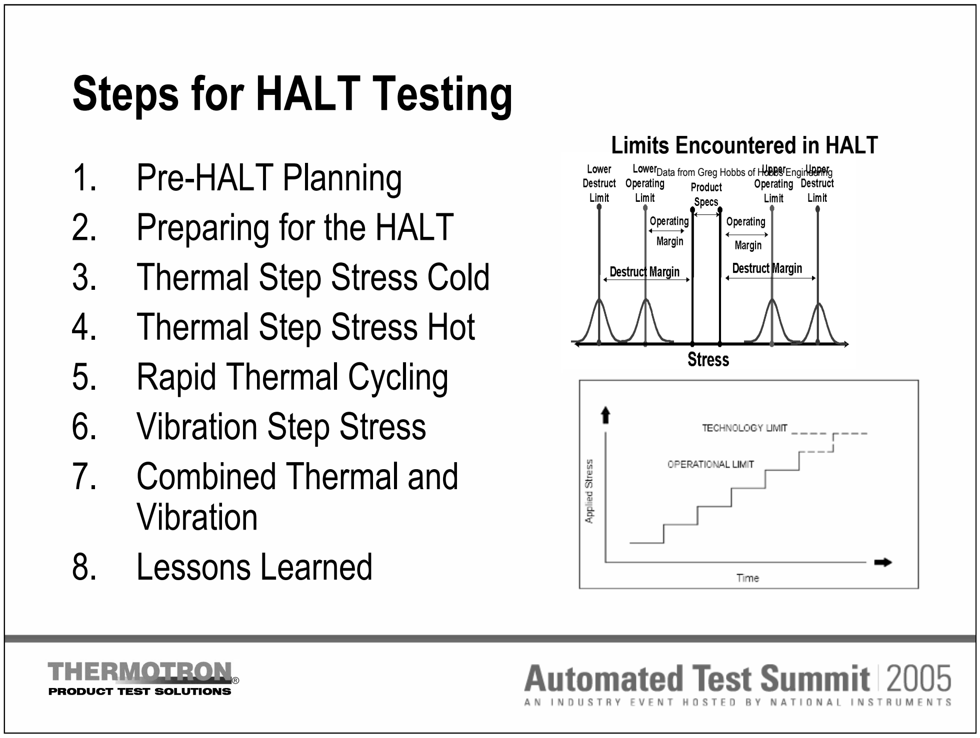
HASS is the production equivalent of HALT. You can think of HASS as an aggressive ESS. Thermal and vibration stresses, slightly less than those identified during HALT, are applied to screen products before they reach the customer. Typically the accelerated stress levels are near or beyond the operating limits, causing enough fatigue to precipitate failures due to process and assembly problems. The idea is to use enough stress to precipitate failures, but not enough to make a significant impact on the overall life of the product.



The intent of "product stimulation," including HALT, is to induce product fatigue by applying higher levels of stress than the product would experience in normal use. This type of testing is based on the concept that higher stresses applied to a product accelerate the rate at which relevant failures would become evident in the product's life. The key is that the failures caused during stimulation must be relevant to failures that the product would experience sometime during its expected life.

The reasons for stimulation testing are quite simple. First, it allows you to quickly gauge the overall ruggedness of a product early in the design phase by identifying operation failure limits. Next, it produces failures, which can be judged as relevant or irrelevant by the design team, and the corresponding corrective measures can be implemented quickly with minimal rework. Finally, it provides invaluable information regarding how the system reacts to various stress environments and operating conditions, and this information can help close the design feedback loop.



HALT testing offers a step-by-step process, which will by its very nature precipitate defects. It induces fatigue, which in turn causes failures that can be analyzed to determine the appropriate corrective action. These steps are:

1. Pre-HALT Planning
2. Preparing for the HALT
3. Thermal Step Stress Cold
4. Thermal Step Stress Hot
5. Rapid Thermal Cycling
6. Vibration Step Stress
7. Combined Thermal and Vibration Environments
8. Lessons Learned

A determination of the root cause of any failures found is made during testing (if possible). Repairs are performed “on-the-fly” and testing continues to wider operating margins until the fundamental limit of the product’s technology is reached.

HALT pushes a product to its true operating limit and beyond. Traditional test methods simulate field environments and test products within their specifications, which can be excessively time consuming. HALT stimulates products inside and outside of their specifications and significantly compresses the time needed for testing. Testing usually takes 3–5 days compared with weeks or months for traditional reliability assessments. HALT can be a very significant and cost-effective step in bringing high quality products to market in a very short period of time.

Accelerated Stress Test Chambers

- Typically liquid nitrogen cooled
- Fast product temperature change rates (>70 ºC/min)
- High velocity airflow
- Multi-axis repetitive shock
- Acceleration levels in excess of 50 g's

Thermotron AST-70

Thermotron AST-20R

Thermotron AST-70

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Now that we have a basic understanding of HALT and HASS, we want to look at some actual test chambers. The fast temperature change rates required for HALT testing are typically created through a combination of liquid nitrogen cooling and high velocity airflow. A controlled source of liquid nitrogen feeds into the workspace where high velocity airflow is directed at the units under test. Product change rates of greater than 70 ºC per minute can be achieved in this way.

For situations where the availability of nitrogen is not practical or economical, mechanical refrigeration methods are available. The unit shown in the center picture is an example of such a unit.

Pneumatic methods are typically used to create the multi-axis repetitive vibration. As you can see from the picture on the right, a table at the base of the workspace is connected to a series of pneumatic impactors. The unit under test is securely fastened to the top of the table, with the ducts directing the airflow toward it. The impactors cause the table to vibrate in a random manner and can reach up to 50g's in acceleration.

Integrating Functional Test with HALT and HASS

- HALT
  - Need to correlate detected failures to environmental conditions since conditions change quickly
  - Quick product changeover
- HASS
  - Multi-head (parallel) testing requirements
  - Fixturing requirements are extreme
- A few general rules
  - Do not test the tester
  - Do not put all of your eggs in one basket
  - Continuous monitoring is preferred

Thermotron Multi-Head
NI PXI Based Test System

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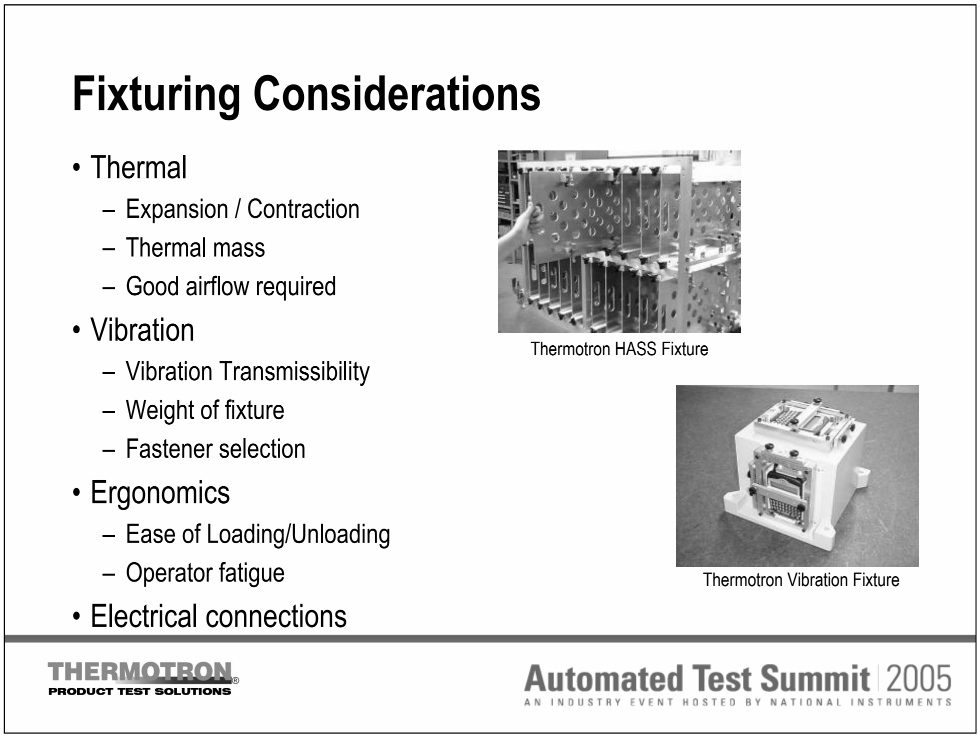
There are two distinct areas in AST that need to be understood: precipitating defects (which we have just discussed), and detecting failures. These topics are equally important. It is important to remember that if you precipitate failures without detecting them you have accomplished nothing.

When HALT testing is performed, usually a small number, possibly a single, unit is tested. Since HALT is performed as part of a design validation, only small numbers of products are typically available. Since the tests are relatively short in duration, and they will only be performed for a week or so, an “investment” in a permanent test system is somewhat reduced. More temporary solutions can be considered. However, when HASS is implemented for a production requirement, a overall testing solution with long term reliability, efficiency and resulting complexity is needed.

A few *general* rules in designing the test systems:

- **Do not test the tester**—Minimize the number of test system components exposed to the test environment. For example, don’t put other circuits in the chamber along with the units under test.
- **Do not put all of your eggs in one basket**—Multiple chambers can increase redundancy and allow for loading/unloading while testing is occurring. If one all encompassing system goes down, all testing stops.
- **Continuous monitoring is preferred**—Because intermittent failures can be very short duration, any multiplexing that is performed must not cause failures to be missed. Consider dedicating monitoring channels to provide more constant observation.



One of the first issues that needs to be addressed when implementing HALT or HASS testing is how to place the product in the environmental chamber. In HALT applications, since typically only a small number of products are being tested, very simple clamps and hold-downs can be used. In HASS applications, due to the fact that many production units will be run through the system, a more elaborate solution is required.

The thermal and vibration stresses used in the test make for a formidable design problem. The fixtures need to be light, yet strong. Vibration transmissibility needs to be considered. Good airflow is needed and thermal mass should be minimized. The fixtures need to be rugged, yet easy to load with products. Electrical connections and interconnect to the product under test needs to be specially designed for this application. Because of the difficulties in designing appropriate fixturing, it should be done early in the projects schedule.

Product Power and Stimulus Considerations

- Selecting bulk versus individual power supplies
- Power wiring
- Sense lines
- Power supply control
  - Remove power when failure detected?
- Interconnection of power with chamber
  - to prevent thermal run-away accidents
- Individual or parallel sourcing
- Detection of stimulus loading
- Product communication requirements

NI PXI Arbitrary Waveform Generator

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Assuming the products to be tested are electrical or electronic in nature, decisions need to be made for powering, stimulating, or communicating, to the products with other electrical signals.

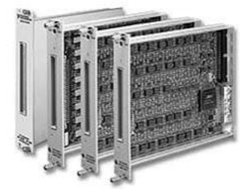
When testing multiple products, a decision needs to be made on weather bulk or individual power supplies will be used. Bulk power supplies can be more economical, but individual power supplies can provide the added advantage of individual voltage control, individual sense lines and individual current measurement. Also, individual supplies can provide the ability to unpower individual products when failures are detected, without adding complicating power switching devices.

In any case, it is important to interlock the operation of the power supplies to the operation of the environmental chamber, to prevent thermal run-away when heat producing products are operated in a inactive chamber.

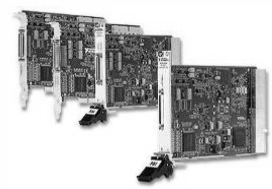
When other electrical stimulus is supplied to units under test, it is often helpful to use separate sources for each unit under test. Separate sources prevent problems when one unit under test affects the electrical stimulus, perhaps due to a failure.

Electrical Monitoring Considerations

- Continuous or multiplexed
- Signal conditioning
- Synchronization with other activities
- Accuracy, resolution and sampling rates
  - Lower accuracy may be acceptable during functional testing
- Failure recognition
  - Limits are easy to define
  - Requires removal of power?



NI SCXI Signal Conditioning



NI M Series DAQ

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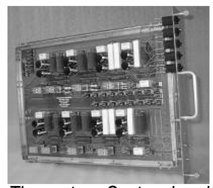
To gain any value out of the HALT or HASS test, it is absolutely necessary to know when the products fail, and what the environmental stresses are when the failure occurred.

As mentioned previously, we would prefer to perform a more continuous, non-multiplexed monitoring, to prevent missing any intermittent failure events. Similar to most test and measurement situations, some amount of signal conditioning may be required. There is typically a need to synchronize the monitoring with the changes in environmental conditions. Because functional (as opposed to parametric) testing is being performed during HALT and HASS, somewhat lower accuracies and resolutions may be allowed. When a test is being configured, it is convenient to specify limits that define what is considered a failure. For example, if a product output voltage is being monitored, being able to specify a high and low limit for the voltage will simplify the setup. And finally, when a failure is recognized, it may be necessary to remove power from the product to prevent damage or possibly self-destruction.

Product Loading and Interconnect Considerations

- Simulate actual use
- Removal of load heat
- Switching of load (values, short)
- Proximity of load to product
- Interconnect in the chamber
- Protection if interconnect
- Voltage drops
  - Wire and connectors
- Connectors
  - Specialized and possibly replaceable

Thermotron Programmable Load Module



Thermotron Custom Load Assembly

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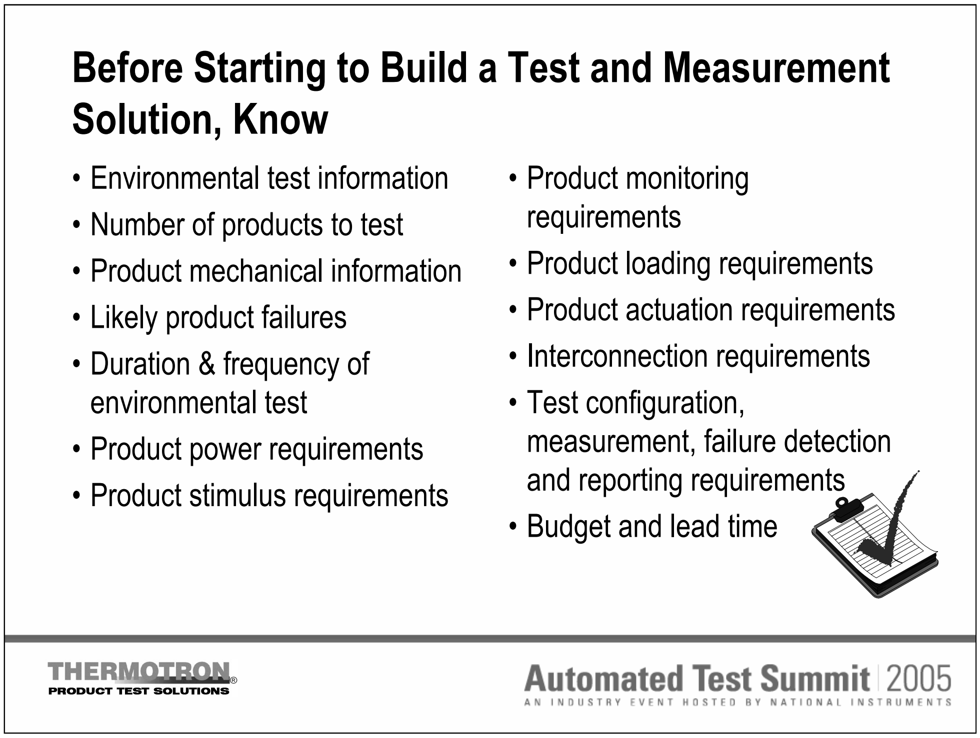
For products to operate during test, it is often necessary for electrical loads to connect to product outputs. The value of these loads may need to be changed during the test, and sometimes provide open or shorted conditions. In any case, it is often not possible to keep the loads near the products, due to the fact that they would be exposed to the test environment, or they would dissipate heat into the chamber that would adversely affect the test conditions.

For all of the power, stimulus, monitoring and loads connected to the product, interconnect (wiring) will be needed. Keep in mind that this interconnect will be exposed to the environmental test conditions. While a wire may be rated for a particular current rating, that rating may be based on room temperature conditions. Larger gauge, flexible conductors with suitable insulation is called for. Voltage drops due to the required conductor lengths should be considered.

A suitable scheme for connecting to the product will be needed. Either the connectors will need to be able to handle the environment, or the connectors will need to be replaced on a regular basis. Many conventional connectors are not rated for use in the environmental conditions, so specialized methods of electrical connection are often required.



When starting a large project, it is helpful to have a checklist of tasks that will need to be performed. Each situation will require more or less effort on each of these points. Having a planned solutions for everything will make the project go more smoothly, and will make the likelihood of success higher.

- Since HALT and HASS are relatively new approaches to environmental testing, there are few formal specifications to go by. However it will be necessary to know all of the environmental stresses that will be in use and to what levels they will be taken.
- The number of products, or the number of test heads, will affect the size and complexity of the tests system
- Product mechanical information will provide information that indicates the thermal mass and the fixturing requirements.
- Likely product failure mechanisms will provide an indication as to what needs to be monitored.
- The duration and frequency of the environmental test will provide insight into the amount of information to be recorded and the ergonomics and product loading issues of the fixturing.
- Knowing the product power requirements will not only help make intelligent power supply choices, but it will help to understand the amount of power to be dissipated in the chamber (which can affect the temperature changes rates).
- As discussed previously, the product stimulus, monitoring, loading, and interconnection requirements will determine the architecture and complexity of the test and measurement solution.
- Software which implements the test system configuration, measurement, failure detection and reporting requirements will be necessary, so make sure you allow enough time for it’s design, implementation and testing.
- Keep your budget and lead-time in mind. Planning for the testing phase of a products development and production is sometimes left as the final item considered. You will do yourself, and your company, a big favor by planning for and implementing the environmental test system as soon a is possible.

Conclusions

- Successfully integrating test and measurement with HALT and HASS will:
  - Increase product robustness
  - Improve product reliability
  - Improve the production process
  - Increase yields
  - Reduce warranty expense & exposure
- To achieve these benefits, the test equipment integrator must understand the issues outlined in this presentation

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As we have seen, there are many types of environmental testing that can be used. The different types of environmental testing use a variety of environmental stresses to achieve different goals. When the goal is to quickly understand where a particular design can be enhanced, HALT should be considered. When HALT has been performed, and a production screening process is needed, HASS should be considered.

To make effective use of HALT and HASS, special consideration needs to be made on how this type of testing affects test and measurement. This consideration should include a thorough understanding of the product and it's likely modes of failure. Knowledge of intermittent failures and environmental stresses will further enhance the likelihood that a successful HALT and HASS process can be performed. To achieve the desired results, the people who implement the test and measurement solutions for HALT, HASS should be knowledgeable, experienced and capable.

Thank you for your attention today. If you would like a copy of the Thermotron handbook concerning Accelerated Stress Testing, stop by our exhibit later today.