

Institute of Environmental Sciences and Technology

IENT-RP-PR001.2

Product Reliability Division
Recommended Practice 001.2

Management and Technical Guidelines for the Environmental Stress Screening (ESS) Process



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Management and Technical Guidelines for the Environmental Stress Screening (ESS) Process

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Management and Technical Guidelines for the Environmental Stress Screening (ESS) Process

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1 SCOPE AND LIMITATIONS

1.1 Scope

This Recommended Practice (RP) supersedes IEST-RP-PR001.1, *Management and Technical Guidelines for the ESS Process* (1999). This RP provides an overview of the techniques and considerations needed to define a viable Environmental Stress Screening (ESS) program. This RP uses language that can be used by the military, government, and commercial communities.

This RP is intended to be an important tool that can be used by the electronics industry for conducting ESS. This document applies to a knowledgeable ESS practitioner as well as to those individuals who are new to ESS. Additionally, it provides the practitioner all of the tools required to successfully plan, develop, and implement a viable ESS program.

The process elements required to successfully implement ESS are discussed in this document, as well as those process steps necessary to keep the ESS process dynamic; i.e., successful planning, implementation of ESS, the collection of failure data, the analysis of failures, and implementation of corrective action.

It is not the intent of this document to describe engineering development or formal verification environmental tests. These subjects are valuable parts of the product development process, but because of their depth and complexity are beyond the scope of this document.

Rather, this document describes the application of thermal, vibration, and electrical performance as forcing functions during the ESS process because of their nearly universal utility. However, other types of forcing functions (such as pressure cycling) or performance evaluation (X-ray and infrared scanning, for example) may be appropriate in special circumstances for particular products. This document should not be construed as discouraging the application of other relevant forcing functions when appropriate.

This document stresses the need to expose product to forcing functions as early in the life of the product as possible. This will assist in producing the best product possible given requisite economic considerations.

It is recognized that a product will likely be composed of several different assemblies. As these assemblies are integrated and the product becomes more and more complex, the level of environmental loading that the lower level assemblies may experience can be greatly attenuated (i.e., thermal path restrictions and vibration dampening). With this in mind, and realizing that all assemblies are prone to process anomalies, this document emphasizes the need to perform ESS at the lowest practical assembly level.

This RP discusses the screening environments of temperature cycling, random vibration, and power cycling. For each of these environments, a discussion of the steps required to successfully incorporate them into the ESS program

is provided. This discussion includes facility requirements, establishing screening parameters based on product response to a forcing function, and how to keep the ESS process dynamic. Furthermore, every opportunity is given to tailor ESS parameters to account for both the inherent design capability and the customer working environment as it pertains to production of the product.

This document was prepared and updated by the IEST ESS Technical Committee Working Group to provide industry and government agencies with the latest thinking and experience to assist in the development and implementation of technically sound, cost-effective stress screening programs.

1.2 Limitations

This document is published by IEST to advance the state of technical and engineering sciences and is intended for guidance only. This RP does not recommend a specific screening implementation, screening environment, or screening parameter(s). Sound engineering judgment, as well as product and process knowledge, should be employed so that the specific application of these process steps considers the specific product characteristics, product phase, and the prevailing business strategy. The use of this document is entirely voluntary, and its application and suitability for any particular use is the sole responsibility of the user.

2 REFERENCES AND APPLICABLE DOCUMENTS

The editions of the following documents that are in effect on the date of invitation for bids or solicitation for offers are incorporated into this RP to the extent specified herein.

2.1 Institute of Environmental Sciences and Technology (IEST)

IEST-RD-DTE012.2: Handbook for Dynamic Data Acquisition and Analysis

IEST-RP-PR003: HALT and HASS

2.2 Other references

Harris, C. M. 2010. *Shock and Vibration Handbook*. 6th Edition. New York: McGraw Hill.

Steinberg, D. S. 2000. *Vibration Analysis for Electronic Equipment*. 3rd edition. Hoboken, NJ: John Wiley & Sons.

2.3 Sources

Referenced documents may be obtained from the following sources:

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3 TERMS AND DEFINITIONS

This RP features definitions that may differ in detail from similar definitions in other sources. These definitions are tailored to the context of this document and its particular applications.

accelerated test (see test, accelerated)

acceleration spectral density (ASD)

A measurement of the amplitude and frequency content of a given random vibration spectrum expressed in terms of acceleration per unit frequency (g^2/Hz) thus providing consistent results regardless of measurement bandwidth. Also referred to as power spectral density (PSD).

acceptance test (see test, acceptance)

ambient environment

Room conditions with no special environmental control imposed except for worker comfort.

assembly level

The product level of assembly at which a screen is applied, i.e., printed circuit board, module, unit, or system.

audit

A test which is applied to a meaningful portion of a production lot to determine the acceptability of the manufacturing process associated with that lot.

broad-band vibration (see vibration, broad-band)

burn-in

A form of product conditioning that subjects a product to a constant temperature or applied power, or both, for a specified period of time. The intent of burn-in is to stabilize the product characteristics and identify failures. In the context of this document, burn-in is not a form of ESS.

circuit card assembly (CCA)

An assembly containing individual components that are interconnected and mounted on a single (possibly multilayer) printed circuit board. Also referred to as printed circuit board assembly.

commercial product

A product from a manufacturer that is governed by the demands of the non-government market place.

component

A non-repairable throwaway item (i.e., integrated circuit, resistor, capacitor, diode, transistor, transformer, hybrid). Also referred to as a part or piece-part.

component defect (see defect, component)

corrective action

Step or steps taken to eliminate the root cause(s) of systematic defects in the overall product population. Corrective actions include changes in parts or materials sources, product design, or the production process.

cost effectiveness

The dollar difference between the cost of screening and the cost of benefits derived.

CTE

Coefficient of thermal expansion.

defect (latent defect)

A flaw in a product that would eventually prevent it from meeting its functional requirements when operating within its specified environment and within its expected lifetime.

component defect

A flaw that could result in the failure of a component to meet its design specification.

design defect

A defect caused by inadequate design of a product or the design of the processes used to manufacture the product.

manufacturing defect

A defect caused by manufacturing process errors or uncontrolled conditions during assembly, test, inspection, or handling of the product.

workmanship defect

A defect caused by human error during manufacturing, fabrication, or assembly.

design characterization

Application of forcing function(s) to a product for the primary purpose of defining the environmental operating limits of the product.

design defect (see defect, design)**design limit**

For any given forcing function, the actual capability of the product to withstand an applied forcing function without permanent damage or permanent out-of-specification performance. The design limit is typically in excess of the design requirement and operating limit.

design margin

A measure of the difference between an equipment design requirement and an intentionally added incremental capability above and beyond that requirement. In essence, design margin quantifies the capability for a given configuration beyond that for which the configuration was originally designed. Design requirements may include some margin above the worst-case operating condition.

design requirement

The environmental conditions for which the product is required (or specified) to operate in and deliver full performance and reliability. Also referred to as the specification limit.

electrodynamic (ED) vibration system

A vibration system that converts electrical current into a mechanical force. This system can control both the frequency content and amplitude of the input spectrum.

environmental stress screening (ESS)

A process for uncovering defects in a product. This process involves the application to a product of one or more specific types of forcing functions. The forcing function may be applied either in combination or in sequence on an accelerated basis but within product design limits. The product is stressed to precipitate to hard failure, latent or incipient defects or flaws which, if not corrected will cause premature product failure during customer usage.

environmental stress testing (EST)

Application of forcing function to a product for the purpose of characterizing the environmental performance of the product.

failure

The termination of the ability of an item to perform its required function.

hard failure

A failure that exists during any condition.

infant failure

A failure that occurs early in the operating life of a product.

soft failure

A failure that either does not occur or occurs intermittently during operations in an ambient environment but does occur either repeatedly or intermittently when subjected to one or more forcing function(s).

fixturing

Tooling designed to adapt the service mount of the test item to the mounting features of the vibration system or temperature chamber. **NOTE:** Vibration fixturing should be dynamically designed to account for responses due to vibration input. Thermal fixturing should take into account the thermo-dynamic effects on the attached product(s).

forcing function

An environmental load which, when imposed upon a product, causes stress concentrations that accelerate the precipitation of the latent defects of the product.

functional test (see test, functional)

g

The acceleration produced by the force of gravity, which varies with the latitude and elevation of the point of observation. The value of 980.665 cm/sec² (or 32.1739 ft/sec²) has been chosen as the standard acceleration due to gravity.

hard failure (see failure, hard)

infant failure (see failure, infant)

in-service environment

The conditions that exist as a function of where the product is used by the customer. In addition to operating environments, the transport, maintenance, and storage environments are also included.

life test (see test, life)

lot

A quantity of the same product manufactured or processed under substantially similar conditions. **NOTE:** That same quantity of products also is typically manufactured during a closely spaced period of time.

manufacturing defect (see defect, manufacturing)

module

An assembly of parts designed to function in conjunction with similar or different modules when assembled into a unit (e.g., CCA, power supply module, memory module).

narrow-band vibration (see vibration, narrow-band)

notching

The intentional removal of energy from a frequency band within a vibration spectrum.

OEM

Original equipment manufacturer.

on-off power cycling

Switching of product input power on and off at specified intervals.

operating limit

The maximum stress a product can experience before specification degradation occurs. **NOTE:** The operational limit can be viewed as the outer bound of the product performance capability, ideally well beyond the capability required during normal service life.

part

See component.

power spectral density (PSD)

A measurement of the amplitude and frequency content of a given random vibration spectrum expressed in terms of acceleration per unit frequency (g^2/Hz) thus providing consistent results regardless of measurement bandwidth. Also referred to as acceleration spectral density (ASD).

printed circuit board (PCB)

An insulating base material (e.g., epoxy glass or polyimide) with necessary dielectric, electric, and mechanical properties, which interconnects components when they are mounted to the circuit board.

product

An item that is fabricated by an individual or a company. A device that can be sold as a stand-alone item or needs to be integrated with other goods to form a finished good.

product ruggedization

The process of improving; the ability of a product to withstand environmental conditions based on results found during analysis, test, or both.

Q (sharpness of resonance)

A dimensionless value calculated by dividing the natural frequency by the bandwidth of the half power points associated with that natural frequency. The Q at any mode can be calculated for a PSD response value in g^2/Hz or a peak response value in g . For PSD data, the bandwidth is determined by measuring the frequency at each half power point (0.5 of the peak g^2/Hz value); for sine data, the bandwidth is determined by measuring the frequency at each

half power point (0.707 of the peak g value). Q can be calculated at any natural frequency, but is best calculated from transfer function data to avoid peaks that are misshapen due to abrupt changes in the input spectrum.

random vibration (see vibration, random)

repetitive shock (RS) system

A system in which the vibration table is excited with repeated shock pulses. This is typically accomplished with a number of pneumatic hammers attached to the vibration table.

resonance

A frequency at which a structure amplifies vibration input.

resonance search

Exposing a product to vibration over a range of frequencies while monitoring the product response with the purpose of identifying resonances.

resonant frequency

Frequency or narrow frequency band in a product that, when excited by vibration, can result in damage to good product, or consume a significant amount of useful life, or both.

sample test (see test, sample)

screen

The process of forcing defects to identifiable levels. A successful screen will uncover defects leading to actions that prevent marginal hardware from being delivered to the customer.

screen validation

A test performed to verify that a significant portion of the useful life of the product has not been consumed by the forcing function.

screening

A process or combination of processes applied to 100% of a lot or to an entire group of like products, this is an audit to identify and eliminate defects.

seeded sample

A test sample that is known to have a defect and is used to verify the effectiveness of a test. The sample may be a field return or a piece that is purposely weakened by the tester.

sinusoidal vibration (see vibration, sinusoidal)

soft failure (see failure, soft)

step stress testing

An experimental process of sequentially increasing forcing function levels, for periods of equal duration, incrementally so the effects of each forcing function level may be evaluated.

system

A group of units interconnected or assembled to perform some overall electronic function (e.g., computer workstation, electronic flight control system, communications system).

tailoring

The process of selecting an initial environmental stress screening program and then making subsequent changes to the methods and severity of the screen(s) to achieve maximum effectiveness.

temperature cycling

A screen that subjects a product to varying temperatures for specified periods of time. Also referred to as thermal cycling.

temperature shock

The effect of subjecting a product (component, PCB, module, unit, system) to high and low temperature limits, with the transition between temperature limits at a high rate of change (i.e., greater than or equal to 30 °C [54 °F]/min minimum). Also referred to as thermal shock. **NOTE:** Transition rates are customarily defined as the change rate of the media used to transfer heat to or from the product. May be performed in media other than air (such as air to liquid, liquid to liquid).

temperature stabilization period

The amount of time required to reach thermal equilibrium, within some nominal tolerance.

test

A process of subjecting a product to conditions designed to determine whether or not the product meets specified performance requirements.

accelerated test

The application of exaggerated (relative to typical service conditions) forcing functions or the increase in rate of occurrence of service loading events to accelerate the rate of flaw growth in a product or structure.

acceptance test

A test used to demonstrate compliance of a product to specified criteria as a condition of acceptability for “next” usage (e.g., next higher assembly, customer use).

functional test

A test that measures a specified number of critical parameters to verify the product is operating within its performance specification limits.

life test

A test performed on a product which is continued until a specified percentage of the product fails or until some other predetermined criteria for end of life has been satisfied.

sample test

A test performed on a limited number of product during the manufacturing process.

thermal survey

The measurement of the thermal response of various elements in the product to identify the slowest and fastest responding elements.

time-to-failure

Elapsed time to precipitate a product defect.

unit

A self-contained collection of components or assemblies, or both, within one chassis performing a specific function or group of functions, and removable as a single chassis from a system (e.g., automobile computer, VHF communications transmitter, disc drive).

vibration

An oscillation wherein the quantity is a parameter that defines the motion of a mechanical system.

broad-band vibration

Vibration containing significant levels (amplitudes) in a continuous spectrum over a broad frequency range.

narrow-band vibration

Vibration where the most significant energy is concentrated in a narrow band of frequency.

random vibration

Non-periodic vibration that possesses all frequencies within the defined band limits and has a continuously varying amplitude. The amplitude is specified as a probability that it will exceed a given value during a time interval. In other words, a probabilistic vibration where the instantaneous magnitude is characterized by a statistical probability distribution across a defined frequency band.

sinusoidal vibration

Vibration consisting of a single frequency component.

vibration survey

The measurement of the dynamic response(s) of the various elements in the product in order to identify product resonances.

workmanship defect (see defect, workmanship)

4 BACKGROUND AND PURPOSE

4.1 Background

Although the concept of Environmental Stress Screening (ESS) as it applies to avionics, electronics, and electromechanical systems and equipment is not new, acceptance and utilization of the discipline was slow until the late 1970s. This was primarily due to the lack of understanding and implementation of the closed-loop process, which in turn prevented realization of many cost benefits. Therefore, ESS was considered to be an added cost and that attitude still prevails to some degree today. However, much progress has been made in advancing ESS in industry and ESS is now routinely applied to a wide variety of products.

What brought ESS to the current level of recognition was the work of a triad (industry, the military community, and various technical societies) that acted to reduce confusion over terms and definitions and to evolve viable guidelines for the development and implementation of technical and cost-effective ESS programs. The ESS process became an integral part of the production process by providing valuable insight into production problems and part deficiencies. The value of applying the forcing function during product design and development also became clear.

In its infancy, ESS documents tended to establish screening baselines. This concept of baselines worked well for some products but for others was either damaging or ineffective. The state of the art has progressed to the point where the response of a product can be measured and used to determine the appropriate stress level(s) for an effective screen. In recognition of this trend, this document focuses on the technology of ESS and minimizes specific implementation discussions.

A clear understanding of ESS requires a good definition. The following definition addresses the key aspects of the screening process:

ESS is a process that involves the application to a product of one or more specific forcing functions with the intent to make latent defects detectable. Forcing functions may be applied either in combination or in sequence, on an accelerated basis but within product design limits. The product is stressed to precipitate to hard failure, latent or incipient defects or flaws which, if not corrected, will cause premature product failure during customer usage.

The key words or phrases in this definition are “process,” “accelerated (stress) basis,” and “design limits.” The phrase “design limits” and its meaning in the context of the screening definition should be emphasized because the context offers the means of allaying fear, which is one of the biggest hurdles to overcome when advocating the value of ESS. The imposition of an arbitrary forcing function in the form of screening requirements on a product can be disastrous. ESS should be developed based on knowledge of the environmental loading characteristics of a product as they relate to design limits. The goal of ESS is to precipitate to failure and to detect all product workmanship defects. ESS is not intended to be a design verification method.

4.2 Purpose

This document reflects the latest thinking and experience of the technical and management community from industry and government, and should provide a sound basis for the development and implementation of a dynamic, technically sound, cost beneficial ESS program(s). This document identifies the tradeoffs that should be considered when implementing an ESS program for a given product.

5 ESS FUNDAMENTALS

5.1 Concepts

ESS can serve a number of different and vital roles as a value-added process. One of the most important objectives of ESS is to improve the cost effectiveness of a product by discovering and correcting latent defects before the product is shipped to the customer. Another objective is to sustain and even improve a company’s reputation for delivering competitively priced products that are of high quality.

ESS achieves the objective of improving cost effectiveness in two ways:

- 1) ESS can lower per-unit costs.
- 2) ESS can reduce warranty and field service costs.

ESS relies on uncovering defects in a product. For a manufacturing process that is in control, these defects will be random in nature. For a manufacturing process that is not in control, definite failure trends will be established. These defects are accelerated to failure by subjecting the product to forcing function(s). For ESS to be effective, the process of uncovering latent defects should be accompanied by a rigorous failure analysis that determines why and how the problems were encountered so that, if warranted, the manufacturing processes can be corrected. The goal of this closed-loop process is to preclude a particular flaw from recurring.

During ESS, accelerated forcing functions are applied to the product at various levels of assembly. These elevated levels of stress are created to force hidden flaws to early hard failure. The important point is that the in-service environment of the product will also force these hidden flaws to hard failure, at some unpredictable time during the life of the product.

In addition to hard failures, intermittent and soft failures are also encountered during ESS. For example, the ability to detect temperature sensitive components, software deficiencies, and cold solder joints requires testing during the application of the forcing function. As with hard failures, some intermittent failures can also manifest themselves in the hands of the customer.

All forcing functions during ESS are applied within the operating limit of the product. When defining the operating limit, it is important to recognize that the product will not function properly at the forcing function extremes, but when returned to normal operating conditions the product will function properly.

Defining appropriate ESS parameters requires technical justification that balances the selection of a forcing function level within the operating limits against the risk of damaging otherwise good product. If wear-out failures occur during ESS, there is reason to suspect that the design limit has been exceeded and that the forcing function levels should be reduced, but not arbitrarily. If the operating limit for a particular product is unknown, the imposition of an arbitrary forcing function can be disastrous.

It is important to establish ESS levels based on product response data measured during an environmental survey to verify sufficient stimulus is being transmitted to potential defect sites without excessive attenuation or destructive amplification. Prior to implementation of ESS in the manufacturing process, validation of the stress screen(s) and associated facilities should be performed to verify the stress screen is not adversely affecting product performance or inducing damage to properly assembled product. Forcing function(s) should be developed based on knowledge of the product response levels as they relate to operating limits. Both the operating and design limits can be ascertained through the design characterization process.

Table 1 summarizes the characteristics of a well-designed stress screen. These characteristics are not achieved without a dedicated effort. The effort begins with consideration of the product to be screened at each level of assembly; characterization of the product involved; front-end design of each screen using valid techniques; conducting an assessment of the defect population, the reduction of which represents the objective of each discrete screen; and establishment of a well-conceived functional test program that compliments each screen.

Table 1. Characteristics of a well-designed screen.

Does	• Precipitate flaws rapidly • Precipitate adequate proportion of inherent flaws
Does not	• Cause inappropriate failures • Induce additional flaws • Consume a significant percentage of product life (minimize consumption of useful life)
Should not	• Be a governing design condition or constraint

The process of accelerating latent defects to failure, analyzing the failures to determine their root cause, and implementing the necessary corrective actions has several benefits:

- 1) The product outgoing quality can be improved by the identification and subsequent improvement of vendor-supplied components (vendor process changes can affect product performance while not affecting the product form or fit). This is particularly true if forcing function(s) are used during design and development to improve designed-in reliability.

- 2) Process control is improved. ESS can identify process steps that are introducing defects into the product, and these defects can be corrected.
- 3) Costs should be reduced because there will be fewer failures to rework or repair. Repetitive-type failures should be greatly reduced. This should minimize schedule delays and thus generate cost benefits.
- 4) As a result of ESS there will be fewer defects in the product, which increases the outgoing quality. This outcome alone should reduce both warranty and field service costs.

Key items to consider when evaluating the goals and objectives of ESS include:

- Reduced manufacturing rework/repair costs
- Reduced warranty and field support costs
- Increased customer satisfaction and goodwill

ESS benefits any party involved in the manufacturing or servicing of products. ESS is a variability reduction tool that reduces field failures by ensuring the control of internal production processes. This RP discusses the benefits of conducting ESS at levels of assembly commencing with the circuit card assembly (CCA).

5.2 Requirements for viable ESS programs

To be properly implemented, the ESS process should be properly managed. Above all, a viable ESS program requires a strong management commitment. In addition, management is responsible for providing the requisite support for ESS to be successfully implemented. Items to consider include:

- Adequately trained personnel to perform the various phases of ESS
- Facilities, equipment and associated space allocation required to perform ESS (e.g., instrumentation and data acquisition, temperature chambers, vibration systems, fixturing)
- Resources (product and personnel) to develop adequate initial screening profiles
- Funding and schedule to support environmental stress testing (EST) during product development and ESS during production; the value added by ESS versus the cost of conducting ESS should be considered
- Failure analysis that is capable of: (1) attributing any given failure to a specific root cause and (2) identifying the corrective action required to eliminate the recurrence of the failure
- Commitment to incorporate corrective actions
- Data system to track failures during manufacturing and from field returns to determine if any failure trends are evident that would necessitate revising the ESS process

5.3 ESS implementation considerations

5.3.1 Cross-functional disciplines needed during product development

EST during product development requires the cooperation of many disciplines within the facility. The design engineer(s) and the test engineer, who may be providing the facilities for forcing functions, are usually the primary people involved in the process during product development. When a failure occurs, they may need to draw on expertise available in the failure analysis lab. When failures are analyzed and root cause determinations are made, other disciplines will need to be accessed. To facilitate the failure analysis process, it is recommended that a cross-functional committee be established. This committee should meet at least monthly, and more frequently during design characterization. Items on the meeting agenda will change as product development progresses. Each discipline should take ownership of issues as they arise. For instance, after the product has been released to manufacturing and the number of solder defects being detected during the production screen is deemed excessive, manufacturing or process engineering could be expected to take ownership and correct the problem through a root cause corrective action process. Essential members of the cross-functional committee will continue to support failure analysis activities throughout production.

5.3.2 Disciplines involved in the ESS activity for production

The ESS program requires planning, implementation, and maintenance. Several separate but complementary disciplines are necessary to create and perpetuate a successful ESS program. These disciplines should form the core of an ESS steering committee that includes representatives from reliability engineering (usually serving as chair),

design engineering, environmental engineering, test engineering, quality engineering, manufacturing engineering, and procurement. This committee provides the infrastructure necessary to implement an effective ESS program.

Provisional roles and responsibilities for the group members may be as defined as follows. Note that the responsibilities as described may be divided differently according to the specific company organization:

- **Reliability engineering** provides the overall planning, coordination, and direction during the development, implementation, and tailoring of the ESS program. The reliability engineer is also involved in the integration of data and reporting of ESS results. Based on results, the reliability engineer may direct the investigation and resolution of significant failures resulting from the ESS program.
- **Design engineering** determines the design limits of the product, such as mechanical and thermal limitations. Design engineering also interfaces with test engineering to define performance characteristics useful during the performance of ESS and provides the technical leadership in solving design related quality and production defects. Design analysis verifies product dynamic and thermal responses as well as predicted fixture responses prior to fabrication.
- **Environmental engineering** determines the type(s) of forcing function to be applied, evaluates the effectiveness of the screen, contributes failure data, and identifies facility requirements. The environmental engineer also consults with test engineering regarding the accelerometer and thermocouple locations.
- **Test engineering** specifies and defines test tooling requirements, generates test procedure(s) and related software needed for performance measurement during ESS, and defines the locations of accelerometers and thermocouples for the product.
- **Quality engineering** provides throughput, defect, and yield summaries for the ESS program. The quality engineer interfaces with reliability engineering regarding workmanship and process related corrective action issues (manufacturing and customer defects), and prepares inspection procedures required to appraise the results of ESS.
- **Manufacturing engineering** develops and maintains ESS facilities, test fixturing, and data logging. Manufacturing engineering also operates facilities such as vibration, thermal cycling, and support test equipment.
- **Procurement** includes ESS requirements in purchase orders with subcontractors and suppliers, when necessary.
- **Process engineering** (production control) defines the process control plan and maintains program planning and scheduling.
- **Industrial engineering** minimizes waste to increase efficiency in the work stream and provides facility layout and planning support.

5.3.3 Defect detection capability

Defect detection capability involves the testing and monitoring capabilities at an ESS facility. Typical questions that should be considered are:

- Is power-on/monitoring of product performance feasible for a given stress screen? Technically, this is a highly desirable condition, but may not be economically feasible, particularly at the CCA level of assembly. Tradeoffs should be considered. However, if power is not applied to the product being screened it will be impossible to detect the presence of intermittent failures. As a result, these intermittent failures will be passed on to the next higher assembly.
- Is it economically and technically feasible to instrument the ESS facility for monitoring and functional test?
- Are pre-screen or post-screen, or both types of functional testing feasible and desirable?

The various product conditions under which a given stress screen is performed influences the level of cost and the effectiveness of the ESS process at uncovering defects. ESS is easiest to apply at the CCA level of assembly because appropriate stresses can be developed in the product to precipitate failures. Unfortunately, depending on volume, the nonrecurring cost to power and exercise CCAs may be prohibitive. Functional testing at the unit/box level may be more cost effective to perform because functional test setups developed for other parts of the program can be used. However, because this functional testing takes place at a higher level of assembly, it may be more difficult to develop appropriate stresses at the defect sites in subassemblies. Due to a combination of facility limitations, design-based vibration and thermal transmissibility, and functional performance monitoring issues, it may be more difficult to apply a forcing function at the system level. Consequently, ESS should be concentrated at lower levels of assemblies where rework/repair is much less costly.

5.3.4 Environmental considerations

Choosing the specific forcing function and level of stress to be utilized for ESS is extremely important if effective results are to be achieved. This is also the most misunderstood aspect of ESS due to the assumption that the in-service environment is the most effective screening environment.

The in-service environment will precipitate flaws to hard failure, but possibly only over an extended period of the life of the product. The ESS concept involves the application of an accelerated stress (i.e., greater in magnitude than the in-service environment), utilizing an environment tailored to precipitate discrete types of latent flaws in a shortened period of time. The important consideration when defining an accelerated forcing function is to verify that the failures uncovered are representative of failures expected in the field. For example, vibration can be applied in an accelerated manner and will induce failures. The resulting failures should be carefully analyzed to determine if they can be attributable to the presence of a defect. If no defect is present, then the applied forcing function may be inducing a failure that is not process related or that is exceeding the product design limit.

Experience has shown that rapid temperature cycling and random vibration are the most common and in general the most effective forcing functions that are used for assembly level ESS. The effectiveness of a given stress screen in precipitating flaws, without overstress, depends on the response of the product and its internal components to the accelerated forcing function.

a) Design requirements versus forcing function environment

Product design requirements may define the anticipated environment that the product is likely to experience during its life (both storage/transport and in-service application). Given sufficient time, this environment will turn latent defects into hard failures. **NOTE:** If the product design requirements are not known, at a minimum the product specifications should be known.

Exposing the product to a forcing function early in the design phase can highlight weak areas in the design that can be easily corrected. This product development testing helps ensure the design requirements are met. The product design should be robust enough to permit exposure to short duration, high-level stresses without damaging “defect-free” product. In addition, manufacturing process inadequacies can be detected by this early exposure to forcing functions. Finally, the early environmental stress testing data can be used to establish the initial ESS parameters for the production screen.

b) Product specific and generic forcing function

If every product were designed the same way, manufactured using identical processes, and comprised of the same parts, then the products would: (1) possess the same defect populations and (2) require exposure to the same screening environments to precipitate latent defects into hard failures. If all of these conditions existed, then generic forcing functions could be the only means used.

Unfortunately, these ideal conditions can never be realized. Differences in the physical design cause a varying transmissibility of the forcing function to components and different design-based sensitivity to parameter shift in components. It is generally not possible to use an identical generic forcing function with optimum efficiency. Defect populations will vary from product to product, as will the forcing function required to precipitate failures. As a result, the forcing function should be tailored to the product being screened in order to be effective, and at the same time preclude damage to good product.

Product specific forcing functions that should be considered for inclusion in the screening process, either alone or in combination, include:

- Thermal environment (dwell, change rate and range)
- Dynamic environment (shock and vibration)
- Cycling input power
- AC input voltage margining
- AC input frequency margining
- DC input voltage margining
- On-board oscillator margining
- Load regulation
- Any other forcing functions that are applicable

5.4 Product development and the forcing function

Although ESS is generally viewed as a manufacturing tool, there are distinct benefits of using forcing functions during evaluation of a product design prior to production.

Application of forcing functions early in product development is consistent with the goals of reducing time to market and product cost. Consistent with achieving these goals is the need to reduce test times with the use of effective stress levels to find defects. By properly applying the forcing function(s), design characterization (i.e., identifying product operating limits) will be highly effective during product development. Product costs can be minimized since the number of alternatives available to correct design flaws are dramatically reduced as the product approaches manufacturing, and design changes may be more expensive to implement than if corrected during product development.

If forcing functions are used early and throughout the design of the product to identify design flaws, the product design can then be changed to improve product robustness. Product design changes are the most cost effective at this time; therefore, it is important that they be identified and implemented before full-scale production starts.

The forcing function should be tailored to accelerate defects found during product design into hard failures. However, to maximize the effectiveness of the forcing function, the product design should be robust enough to permit exposure to short duration, high-level stresses without damaging defect-free product.

Evaluations are required early in the life of the product to assess design and performance. Based on the results of these preliminary evaluations, appropriate design changes can be implemented to improve the design and thus its performance. This will permit an efficient evaluation and concentration on design and performance issues.

Typically, screenable defects cause the majority of failures encountered during the product development program. A successful and efficient product design and development effort with some form of EST program is more likely to reduce or eliminate design and non-design problems.

a) Design evaluation

Exposing a product to forcing functions as early as possible in the design phase provides the user with many benefits. Some of these benefits include:

- 1) A mature product design for manufacturing: As a side benefit of detecting and correcting a marginal design, other design problems can be identified and corrected.
- 2) Less nonrecurring engineering effort: Manufacturing and process engineers can focus on improving processes and throughput rather than continually adjusting to design changes.
- 3) Lower overall product life-cycle costs: A more mature product at the start of manufacturing reduces costs associated with warranty and product support.
- 4) Customer goodwill (loyalty): Robust products can instill customer loyalty and increase market share.

One of the keys to implementing a successful production ESS program is establishing the initial ESS profile prior to production, preferably on product that closely approximates the production configuration. This concept allows the use of initial screens in production while the process of fine tuning each screen is pursued based on the results obtained from the production screens.

b) Sequence of forcing functions during product development

The sequence of forcing functions is not as important as is the need to uncover defects (failures). Combined forcing functions can be used effectively to accelerate the accomplishment of these objectives. It is not significant whether one forcing function or the other or the combination of forcing functions uncovered a defect; the process of causing defects to become patent (visible or detectable) is important. Almost always, the forcing function that precipitated a particular defect can be ascertained, if needed.

5.5 ESS during production

The manufacturing process is the focal point of ESS. It is here that stress screening is the most beneficial value-added process monitoring tool. The objective is the establishment and maintenance of process control, an indication

of controlled product quality, workmanship, and assembly operations throughout the manufacturing process. Benefits of using ESS during production include:

a) Reduction in rework/repair cost

The cost of rework and repair in manufacturing escalates by orders of magnitude as the assembly level proceeds from piece-part level to CCA/module, unit, system, and to the customer. Finding defects at the lowest possible level of assembly will minimize rework/repair cost. However, it should be kept in mind that some flaw types may manifest themselves only at the higher levels of assembly.

b) Effect on production schedule

A viable stress screening program, which includes effective corrective action at the source of the flaw, will preclude repetitive flaws. The objective is to remove the source of the flaw and smooth production flow.

c) Protection against worker turnover, inexperience, and process changes

ESS is often regarded primarily as a process for precipitating component infant mortality to hard failure. However, ESS can also identify the significant number of screenable defects caused by substandard workmanship. Turnover in the work force, worker inexperience, and process changes (e.g. manual vs. robotics fabrication or new build-to-print production line) can contribute to increases in workmanship defects. A well-designed screen helps pinpoint workstations where assembly defects are being generated, permitting analysis of the situation and subsequent corrective action.

d) Identification of vendors supplying defective subassemblies

This benefit occurs throughout the acquisition process, but it is most valuable during production when typically multiple vendors are supplying subassemblies. The ideal time to isolate subassembly problems is at receiving. Lot sampling techniques are typically applied to these subassemblies.

Depending on the adequacy of the sampling plan, CCA or module level screening can play a major role in identifying and solving critical subassembly problems. Effective ESS requires real-time process or component correction based on analysis of findings. Therefore, the vendor supplying subassemblies should perform screening rather than the customer (see Appendix E, Supplier ESS Process Requirements). Note that supplier ESS is a matter for negotiation.

e) Production hardware

The bottom line for the manufacturer is to make a profit for the operation. This is a basic prerequisite to remaining in business. From a producer's perspective some of the more important considerations are:

- ESS is a value-added process. When properly implemented, ESS can facilitate the manufacturing process by eliminating recurring failures and can provide feedback on specific assembly processes.
- ESS provides assessment of the quality of individual piece-parts and confirms that the parts meet the performance levels required by the product design.
- Through root cause failure analysis and corrective action, ESS can help eliminate specific, early-life failure mechanisms.
- ESS reduces the number of failures observed during the warranty period through root-cause failure analysis and corrective action.
- ESS preserves the product-inherent reliability that aids in maintaining customer satisfaction with the product.

However, the bottom line for consumers is that the product meets or exceeds their reliability/availability expectations. From a consumer's perspective, the following are important considerations:

- Products that have effective ESS included in their manufacturing process are likely to exhibit better performance and outgoing quality than those that do not receive ESS.
- The ESS process is indicative of a product (manufacturer) committed to quality and customer satisfaction.

Each perspective of ESS is unique. However, one common theme persists—a properly implemented ESS is a valuable process providing tangible benefits for both the producer and consumer of a particular product.

A viable production ESS program, therefore, will contribute to a manufacturer's capability to deliver high quality products in a timely fashion.

5.6 ESS at the part/component level

The value of ESS may begin with a viable piece-part stress screening effort by part vendors. If a part vendor does not have an effective process control or screening program, the original equipment manufacturer (OEM) should consider selective rescreening of incoming piece-part types.

Table 2 shows poor quality piece-parts can play havoc with CCA yield, with a resultant increase in assembly rework cost and scrap. Furthermore, as the piece-part count increases, the reliability decreases. Increasing the individual piece-part reliability may not achieve the goal of 100% good product. The most effective means of dealing with the piece-part quality issue is through management actions designed to facilitate communication between OEMs and vendors. Rescreening by OEMs is a costly and short-term solution, but may be necessary to preserve quality while long-term management solutions are formulated.

Table 2. Effect of defective piece parts on printed wiring assembly yield.

Good Part Probability		Number of Parts on CCA				
		50	100	200	300	400
0.97	CCA yield	21.8%	4.8%	0.226%	0.01%	0.005%
	Average number of defective parts on CCA	1.5	3.0	6.0	9.0	12.0
0.98	CCA yield	36.4%	13.3%	1.8%	0.23%	0.03%
	Average number of defective parts on CCA	1.0	2.0	4.0	6.0	8.0
0.99	CCA yield	60.5%	36.6%	13.4%	4.9%	1.8%
	Average number of defective parts on CCA	0.5	1.0	2.0	3.0	4.0
0.999	CCA yield	95.1%	90.5%	81.9%	74.1%	67.0%
	Average number of defective parts on CCA	0.05	0.1	0.2	0.3	0.4
0.9999	CCA yield	99.5%	99.0%	98.0%	97.0%	96.0%
	Average number of defective parts on CCA	0.005	0.01	0.02	0.03	0.04

NOTE: A defective part may contain more than a single flaw or flaw site, thus decreasing yields from those depicted.

5.7 ESS building blocks

The ESS process presented in this document can be viewed as a series of steps or building blocks arranged in the most efficient, cost-effective sequence for a particular product. These process steps are defined in this document and are applicable to all types of products. Specifically, these building blocks can be considered to be the following process steps:

- 1) Plan:
 - Which forcing functions will be used
 - How initial screening parameters will be defined
 - When ESS will be applied and to which assembly levels
 - How the process will be kept dynamic
 - What the cost objectives will be
- 2) Select forcing function(s) based on anticipated defect types and available facilities
- 3) Expose product to forcing function(s) during design and development to uncover design problems (design characterization)

- 4) Develop screens considering:
 - Facilities space available
 - Anticipated defect populations
 - Allowable cost for ESS
 - Product characteristics
- 5) Define initial screening parameters based on product survey results
- 6) Perform screen validation
- 7) Implement ESS
- 8) Confirm capability of data collection and failure analysis
- 9) Provide for a dynamic ESS process, i.e., adjustable to maintain maximum cost effectiveness

Maximum value from these process steps is achieved by implementing the ESS process early rather than later in the life of the product. Therefore, to capture the maximum benefits of the ESS process, the product being screened should be exposed to the screening environment as early as possible in its life cycle. Figure 1 illustrates the basic principles involved with the ESS process.

5.8 Considerations for dynamic ESS

The essence of a viable ESS program is the dynamic closed-loop process (Figure 1). An ESS program utilizes the types of forcing function most likely to precipitate known or anticipated manufacturing process defects. As a dynamic process, ESS can address issues resulting from supply chain differences, escapes, or even field trends.

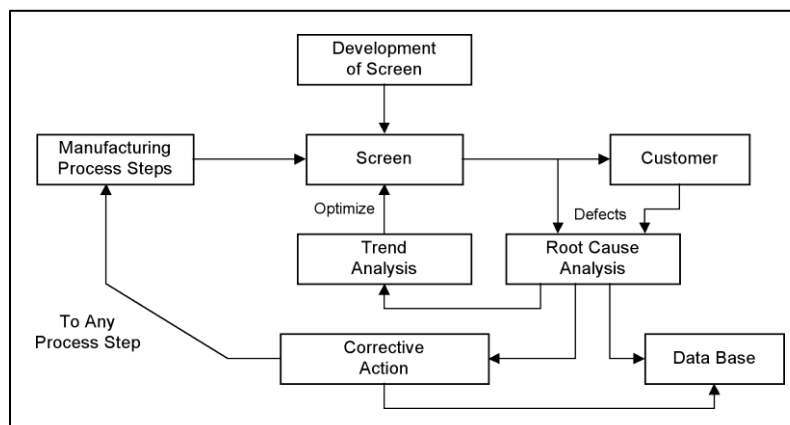


Figure 1—Dynamics of the screening process

If the manufacturing technology or methodology has not changed significantly, historical failure mechanisms will likely be repeated. Review of the existing stress screening results will provide a basis for determining which screens would be the more cost effective for the manufacturing process. When the manufacturing technology or methodology has changed, evaluation of the manufacturing process and physical aspects of the assembly of the product is necessary. Understanding the causes of previous failure modes provides a sound basis to develop technical questions about product performance and fabrication. It is advisable to solicit the concerns of the design and manufacturing engineer regarding fabrication of the product.

The ESS process should be managed and results continually monitored to optimize cost and technical effectiveness. Effective ESS program management may result in the elimination of certain screens at selected levels of assembly, the modification of ESS parameters as fallout or lack of fallout dictates, or the addition of certain screens based on the emergence of a new class of flaws. Since processes, assembly techniques, and manufacturing personnel are rarely error free, some form and degree of ESS should be an integral part of every production process. Market pressures and advancing technologies have significantly shortened product life cycles, thus a product may be obsolete by the time manufacturing has implemented ESS. This reinforces the need to begin EST in the early stages

of product development. It is essential that the product characterization testing begin during the development phases of the product.

A dynamic ESS process reacts to conditions. For example, ESS may be reduced when processes are under control; ESS may be increased or modified in response to shifts in the defect population. An important factor is the ability to perform root cause analyses of all failures, i.e., those that occurred in ESS, manufacturing, or in the field. Also, a database should be established and managed that permits tracking of failures and trend analyses. By focusing ESS on the failure modes/mechanisms of the product, the cost to perform ESS is continually minimized with no compromise in the integrity of the ESS process.

5.9 ESS plan

The ESS plan should be a living document that encompasses all aspects of the ESS process and is integrated into the overall manufacturing test plans. The plan should be a useful tool for identifying the resources required for conducting ESS and should include the necessary provisions for keeping ESS a dynamic process. Table 3 provides a checklist for the plan.

Table 3. ESS plan checklist.

Item	Yes	No	N/A
ESS has been properly planned and will be a dynamic process			
The facilities required to conduct ESS are available (or will be available in time to begin ESS)			
A root cause analysis capability is in place			
A database for tracking failure causes and trends exists and can be utilized			
Company management is committed to incorporating the necessary corrective actions to preclude the recurrence of defects/failures			
The screening environments selected will be effective based on prior experience, available facilities, and anticipated defect population			
Appropriate cost analyses have been completed to confirm ESS as planned will be cost effective			
An appropriate defect detection capability is in place and consistent with the goals and objectives of the planned ESS			

As a minimum, the ESS plan should contain the following items:

- The goals and objectives for the ESS process, including how to determine when the ESS process is meeting its objectives
- Overall ESS process flow chart
- A schedule identifying dates for the completion of ESS procedures and the beginning of ESS
- Which levels of assembly (including part number) will receive ESS
- Which forcing function(s) will be employed
- How the forcing functions will be applied to the product, i.e., ESS parameters, sequence of forcing functions, combined forcing functions
- Screening facilities used
- Methods for modifying the screening program based on product failures
- Decision-making ground rules applicable to failures
- Subcontractor/supplier ESS requirements
- ESS organization and management responsibilities
- ESS rework, repairs, modifications, spares, and field returns
- The data collection process
- Personnel and their responsibilities for the various functions within the ESS process, e.g., manufacturing engineering, quality engineering, test engineering, and reliability engineering

The process flow should be a closed-loop operation. The goal is to minimize manufacturing costs and increase productivity. These goals can be accomplished through corrective action feedback to the respective manufacturing process step. Performing root cause analysis of the failure and implementing corrective action is essential to the success of ESS. Derivatives of the ESS process are failure reports, throughput data, and ESS performance data. These derivatives are reviewed for trends and screening effectiveness. The database is essential for providing visibility into the ESS process.

Lastly, the customer should be considered as the next manufacturing operation as well as the user of the finished product.

5.9.1 Development of screen

Designing an effective screen is an empirical process; there is no such thing as a standard stress screen or a standard stress screening program. Certain screens may be reasonably effective for similar product configurations, especially at the CCA level. However, as a rule, an individual stress screen should be tailored to the product being screened, considering both the characteristics of the product and the anticipated defect types.

Different types of forcing functions have been used with varying degrees of success. This RP focuses on the most common types of screens used over the broad spectrum of known defect types. These common forcing functions are thermal cycling, broad-band random vibration, power cycling, and voltage variation.

Table 4 illustrates the types of defects that are precipitated to hard failure by temperature cycling and random vibration. Column 3, labeled “Combined Environment” lists the types of defects that may be precipitated by either forcing function. This effect occurs for two basic reasons: (1) certain defect types are susceptible to both temperature and vibration forcing functions; and (2) a synergistic effect exists between temperature cycling and random vibration. The synergistic effect may manifest itself when temperature cycling and random vibration forcing functions are applied either simultaneously (recommended), or in sequence. If applied in sequence, best results are most often achieved by the sequence of thermal cycling–vibration–thermal cycling, particularly at the unit/box level of assembly.

Table 4. Screening environments versus typical failure mechanisms.

Thermal cycling	Vibration	Combined Environment
• Component parameter drift • PCB open/short circuits • Component incorrectly installed • Wrong component • Hermetic seal failure • Chemical contamination • Poor CTE matches • Defective harness termination • Improper crimp • No solder	• Particle contamination • Chafed, pinched wires • Defective oscillator crystals • Mixer assembly • Adjacent CCAs rubbing • Two components shorting • Loose wires/hardware • Poorly bonded components • Poorly secured high-mass parts • Mechanical flaw • No solder	• Defective solder joints • Defective components • Broken components • PCB etch defective • All mechanisms under vibration and thermal cycling

The basic approach to be taken during screen development is to subject the product to the forcing function to ensure defects are being stimulated to failure. The type of defects to expect depends on how much is known about the product and the manufacturing processes. This knowledge can range from very detailed—i.e., specific defects to expect are known as is the product response required to precipitate the defect—to a lack of knowledge of either the anticipated defect population or the desired product response. The following examples illustrate the effect of this knowledge on the screen development process:

- Available data defined the type of defect to be targeted by ESS and the stresses to be developed in the defect site to precipitate a failure. This data is then correlated with a threshold response that the product must exhibit to precipitate the defects. Given this data is available, the screen validation process entails monitoring the response of the product and comparing these responses to the pre-defined thresholds.

- The response of the product is monitored and compared to product responses known to yield satisfactory ESS results. This historical data can be obtained from surveying existing products to determine their response to environmental stimuli known to yield satisfactory results. However, the success of this method depends on the product having the same defect population as the products that comprise the historical database.
- The anticipated defect population is known, but nothing is known about the response in the product required to precipitate failures. When implementing this method, seeded samples can be used effectively. These seeded samples are then subjected to the forcing function and the severity of the forcing function is adjusted (increased or decreased) to precipitate the defects in an appropriate amount of time.
- Neither the defect population nor the forcing functions required to precipitate latent defects into hard failures are known. In these situations, design characterization is the best approach to pursue. There will be variations in the product and process through time, which can affect the response of the product to the ESS environment. Therefore, a sufficient quantity of units should be subjected to the forcing function, preferably to failure, to take this into account. When this approach is implemented, the resulting screening environment should be applied to sufficient quantity of product to verify its viability.

5.9.2 Root cause analysis

An important part of the ESS process is to identify the cause of the failure and provide adequate attention in the ESS plan. Once identified, the root cause of the failure is analyzed with the intention to remove the cause of the failure. This identification will involve physics of failure (PoF) analyses for parts related issues and manufacturing engineering for process related issues.

5.9.3 Corrective action

After the root cause has been identified, corrected, and verified, the corrective action used should be implemented for all ensuing product. A verification of the corrective action should be done to verify that the action was correct and no new anomaly was introduced. It should be noted that the corrective action may already have been implemented by the time ESS catches a flaw. A process problem may be uncovered during the build cycle of a product and changes made prior to ESS but not before other products are processed through ESS. Corrective action assignments may be made that are not readily apparent to the personnel responsible for data collection since they may not have adequate visibility. Two methods of dealing with this problem are to (1) form a team that meets regularly to discuss build problems and their solutions, and (2) start data collection prior to ESS (see 5.3.2).

Corrective actions that preclude the recurrence of the failures result in a better product for the customer. Thus, precluding the recurrence of the failures reduces rework and repair costs, increases productivity, and improves product quality.

5.9.4 Metrics

Cost-benefit metrics should be developed and tracked prior to start of ESS and updated during the early phase of the program. Once the ESS program is underway, yield rates, types of failures, cycle or axis of failure, and data quality should be monitored and presented on a regular basis to the program management.

5.9.5 Database

A critical part of ESS is data collection. The database should be able to track and report failures that occur at all levels of assembly. The database should collect at least the following information:

- Assembly part number
- Serial number
- Date and time of anomaly
- Conditions noted at the time of the anomaly
- Steps taken to rectify the anomaly, including troubleshooting, fault isolation results of failure analysis, and identification of the root cause of the failure
- Determination of corrective action
- Part number of failed component

Other data fields that should be included in the database are:

- Axis of vibration in which the anomaly was noted (when applicable)
- Thermal cycle number and temperature when the anomaly was noted (when applicable)
- Time-to-failure information
- Repair times

Once sufficient data has been collected, the data will allow the manufacturer to modify ESS manufacturing and repair processes to a more cost-effective approach. As an example, should no failures be recorded after the sixth thermal cycle (this could be considered a very long screen), given a statistical basis, the number of thermal cycles should be reduced to six. As another example, if there is an inordinate amount of troubleshooting time being recorded, the built-in-test capability of the product or test set should be improved to reduce repair time.

Each data type that has been determined necessary to be tracked as a metric should receive its own field in the database structure for sorting purposes. The true power of the database is the capability to sort and display contained data. Personnel involved in the data collection process (i.e., repair technicians, test technicians, database personnel, quality assurance, and management) should receive the necessary training to make the database a tool to benefit the quality of the product.

Another point to consider is when to start collecting data. It may be determined that by starting data collection at ESS, much of the previous history (i.e., corrective action) has been masked, making the database management task harder and the quality of the data collected of less value.

5.9.6 Trends

Once the database has been structured properly, trend analysis can be automated using one of the numerous commercially available software tools. Given that the critical item is contained in its own field, a routine can be established to perform the desired trend analysis at the touch of a key. Reports can be designed and modified to aptly present the data as an informative tool, describing the product and the associated manufacturing processes.

5.9.7 Failure-free requirement

The concept of “failure-free” operation is very important. Equally important is that point in the continuum of ESS and test at which the failure-free requirement is imposed. This factor is central to achieving the objective of failure-free operation of the product for the customer. Figure 2 shows the failure-free periods during various phases of the product life cycle. ESS may have a desired failure-free period, e.g., a number of thermal cycles or a specific amount of vibration time during an acceptance test procedure (ATP), or, more importantly, during customer use. The ESS failure-free period typically occurs at the end of the screening.

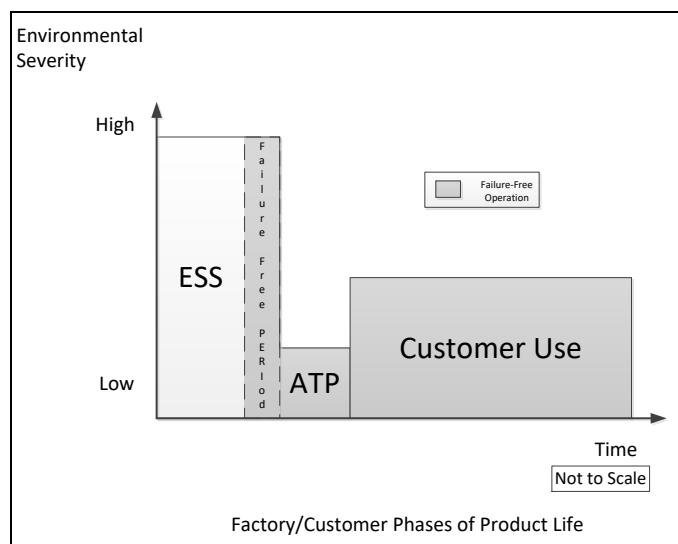


Figure 2—Deliverable product failure-free operation.

Since the objective of ESS is to reduce and, ideally, eliminate failures prior to customer use by forcing latent defects to detectable, hard failures through imposition of an accelerated forcing function, it is logical that failure-free operation is desirable during ESS. The imposition of failure-free requirements during ESS is consistent with the objectives of ESS but is difficult, time consuming, and costly to achieve for any reasonable length of time or number of cycles. All products will eventually fail; this is a function of the process controls and the statistical nature of the product material characteristics. Ideally, designed-in product reliability and process controls should drive product performance, under prescribed end use conditions, to exceed customer expectations. However, failure-free periods are appropriate after screenable defects have been detected and prior to shipment of the product to the customer. Consider failure-free operation at the end of the screen.

5.9.8 Limitations of ESS

In some situations the outcome of the ESS process may lead to less than optimum results. Several such situations are as follows:

a) Expected yield versus complexity of design

As the design complexity increases, the number of defects that can exist and be precipitated to hard failures via the ESS process may also increase. As a result, the ESS yield rate (percent passing the first time through the screen, i.e., first-pass yield, and not including re-screening of reworked or repaired product) may be correspondingly low. On the surface, low yield rates are indicative of processes that are not in control. However, for very complex designs, the processes may in fact be in control and the low yields can be attributed to the sheer number of potential defect sites. Therefore, for very complex designs for which ESS yield rates are unacceptable, the results of ESS should be carefully analyzed to determine whether or not correctable problems actually exist or if there are design related issues.

b) Modification of the ESS program

The ESS profile may be modified on an individual product basis. ESS modifications are based on either past product manufacturing, field performance, or both, or on potential risks identified during product development. If any forcing function is increased or added to the profile, a screen validation should be performed.

These modifications may either increase or decrease the requirements for ESS. Any modification implemented requires documented rationale and approval by program management.

Specific modification options are recommended as guidelines to minimize introduction of unacceptable risk. The allowable modifications are presented in three groups: ESS process modifications, thermal cycling modifications, and vibration modifications.

1) The following are examples of ESS process modifications:

- Add electrical performance monitoring to CCA vibration ESS
- Add CCA thermal test screen (powered and monitored)
- Add module vibration screen
- Add monitoring to module vibration screen
- Add performance test between thermal cycling and vibration ESS
- Eliminate performance test prior to CCA vibration screen
- Eliminate performance test following CCA thermal cycling
- Eliminate CCA thermal cycling
- Eliminate CCA vibration screen
- Eliminate unit thermal cycling
- Eliminate unit vibration screen
- Conduct ESS on a sampling basis (does not require a repeat of screen validation)
- Eliminate ESS (only when cost benefits are justifiable)

2) The following are examples of thermal cycling modifications:

- Reduce the number of thermal cycles
- Increase the number of thermal cycles
- Increase the average product temperature rate of change
- Change power cycling profile during thermal cycling