AD

6

AD-A206 350

# technical Report

United States Army
Belvoir Research, Development & Engineering Center
Fort Belvoir, Virginia 22060-5606

**Report 2477**

# Environmental Stress Screening (ESS) Guide

Authored By: **William H. Horner, Project Manager**

Report Date: **January 1989**





89 4 07 071

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

ADA206350

# REPORT DOCUMENTATION PAGE

*Form Approved OMB No. 0704-0188*

| | |
|---|---|
| 1a. REPORT SECURITY CLASSIFICATION<br>Unclassified | 1b. RESTRICTIVE MARKINGS<br>None |
| 2a. SECURITY CLASSIFICATION AUTHORITY | 3. DISTRIBUTION/AVAILABILITY OF REPORT<br>Distribution unlimited; approved for public release. |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE | |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S)<br>2477 | 5. MONITORING ORGANIZATION REPORT NUMBER(S) |
| 6a. NAME OF PERFORMING ORGANIZATION<br>Belvoir RD&E Center<br>Product Assurance Division<br>6b. OFFICE SYMBOL *(If applicable)*<br>STRBE-TQE | 7a. NAME OF MONITORING ORGANIZATION |
| 6c. ADDRESS *(City, State, and ZIP Code)*<br>Fort Belvoir, VA 22060-5606 | 7b. ADDRESS *(City, State, and ZIP Code)* |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION<br>8b. OFFICE SYMBOL *(If applicable)* | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER |
| 8c. ADDRESS *(City, State, and ZIP Code)* | 10. SOURCE OF FUNDING NUMBERS<br>PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. |

11. TITLE *(Include Security Classification)*
Environmental Stress Screening (ESS) Guide (U)

12. PERSONAL AUTHOR(S)
William H. Horner, Project Manager, and Evaluation Research Corporation, McLean, VA

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT *(Year, Month, Day)* | 15. PAGE COUNT |
|---|---|---|---|
| Final | FROM ______ TO ______ | January 1989 | 117 |

16. SUPPLEMENTARY NOTATION

| 17. COSATI CODES | | | 18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)* |
|---|---|---|---|
| FIELD | GROUP | SUB-GROUP | Thermal cycling; Random vibration. |

19. ABSTRCT *(Continue on reverse if necessary and identify by block number)*

This guide provides a step-by-step approach to the planning, implementing, and monitoring of an Environmental Stress Screening (ESS) Program for Army Materiel Command (AMC) Troop Support Command (TROSCOM) hardware contracts and repair activities. This guide does not replace logical thinking on the part of the user, but presents the various elements of an ESS Program and advise the user in their selection and use.

| | |
|---|---|
| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT<br>[x] UNCLASSIFIED/UNLIMITED [x] SAME AS REPORT [ ] DTIC USERS | 21. ABSTRACT SECURITY CLASSIFICATION<br>Unclassified |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL<br>William H. Horner | 22b. TELEPHONE *(Include Area Code)*<br>703-664-5771<br>22c. Office Symbol<br>STRBE-TQE |

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

# PREFACE

## PURPOSE

This guide provides a step-by-step approach to the planning, implementing, and monitoring of an Environmental Stress Screening (ESS) Program for Army Materiel Command (AMC) Troop Support Command (TROSCOM) hardware contracts and repair activities. This guide will not replace logical thinking on the part of the user, but will present the various elements of an ESS Program and advise the user in their selection and use.

## AUDIENCE

This guide is intended for use by product assurance engineers, project engineers, project managers, item managers, and administrative personnel who are responsible for planning, implementing, or monitoring an ESS Program.

## WHAT IS ESS?

In any manufacturing or assembly process involving people and machinery, a small percentage of defects usually occurs. There are many techniques used by industry to reduce the number of defects remaining in hardware when it leaves the factory. These techniques include process control, training, inspection, and testing. A number of these defects will escape detection in the factory in spite of these standard defect prevention techniques. These undetected defects will be manifest as early life failures during the hardware's field use. These early life, or infant, failures will reduce field reliability, even though the number of undetected defects is small. For this reason, it is important to detect and eliminate as many defects as possible before the hardware leaves the factory. The increasing complexity of mechanical equipment and miniaturization of electronic equipment has made traditional methods of defect detection less efficient. One of the most effective techniques used to identify and eliminate these defects is environmental stress screening (ESS). ESS is the process of applying environmental stresses, in conjunction with functional testing, in order to stimulate the failure mechanisms of defects to the point of detection. Most of these defects are caused by flawed parts and poor assembly workmanship. The stress levels of applied stimuli must be as harsh as possible to precipitate the defects without causing damage to or reducing the useful life of properly manufactured hardware. The application of environmental stresses will accelerate the latent (or undetected) defects to become patent (detected), with functional testing required to detect failures. Functional testing can be performed either during or after the application of stress. The advantage of functional testing during stress application is that it allows the detection of intermittent failures.

ESS had its beginning in the space programs of the 1960s,where high reliability requirements and the absence of supportability dictated that equipment be 100% defect-free. Since that time, ESS has gained increasing recognition throughout the defense industry as a cost effective quality control method. Today, each military department has made ESS an integral part of major systems acquisitions. The exceptional benefits derived from ESS applications will ensure its institutionalization in the defense system's acquisition process.

## ORGANIZATION

This guide is intended to be used by both experienced and inexperienced engineers to develop statements of work (SOWs) to implement ESS. Several sections describe ESS, when it should be applied, and how to develop stress intensity levels. These sections contain basic explanatory information and lay the foundation for decisions that must be made when specifying ESS. Users of this guide who have **not** been exposed to ESS should begin by reading the tutorial Sections I through IV, and becoming familiar with the definitions and acronyms on the following pages.

Section V contains a description of the different contract deliverables normally required in an ESS Program. Along with a discussion of the requirement , a sample SOW clause invoking it and a checklist for reviewing the deliverable are included.

Section IX contains the description of the ESS cost model. All screening decisions should be made with an eye to the cost-benefits. The cost model is used to estimate the cost of the screening program and the break-even point where the screening becomes cost-effective. All users of this guide should use the cost model to justify the cost of implementing a screening system.

## DEFINITIONS

| | |
|---|---|
| Assembly | A combination of parts joined together to perform a specific function and be capable of disassembly. |
| Design capability | The level of stress (*thermal* or *mechanical*) which an item is able to achieve or endure without damage or significant reduction of its overall usable life. |
| Failure mode | The fundamental physical or chemical process responsible for a failure; the causative agents of a failure, including circumstances during design, manufacture or use that may lead to a failure. |
| Hermeticity | The ability of a sealed item to remain impervious to outside contaminants. |

| | |
|---|---|
| Indenture level | Level of assembly; the highest indenture level is a *system*, the lowest is a *part*. |
| Infant mortality | Failures occurring on units in the field. |
| Isolation | The reduction in severity of response force or motion to input stimulus. |
| Latent defect | An inherent or induced weakness, not detectable by ordinary means, which will either be precipitated to early failure under ESS conditions or eventually fail in the intended-use environment. |
| Module | A self-contained collection of chassis-mounted components and/or printed wiring assemblies (PWAs) within one package which performs a specific function or group of functions, and which is removable as a single package from an operating system. |
| Part | Any identifiable item within the product which can be removed or repaired (e.g., discrete semiconductor, resistor, integrated circuit, solder joint, connector); used interchangeably with piece part, component part, and device. |
| Patent defect | An inherent or induced weakness which can be detected by *inspection*, functional test, or other defined means without the need for stress screens. |
| Precipitation (of defects) | The process of transforming a latent *(undetected)* defect into a patent *(detected)* defect through the application of stress screens. |
| Printed wiring assembly (PWA) | An assembly containing a group of interconnected components mounted on a single printed circuit board; equivalent terminology is *circuit card* assembly and *printed circuit* assembly. |
| Screening effectiveness | Generally, a measure of the capability of a screen to precipitate latent defects to failures; sometimes used specifically to mean screening strength. |
| Screening strength | The probability that a specific screen will precipitate a latent defect to failure, given that a latent defect susceptible to the screen is present. |
| Stress screening | The process of applying mechanical, electrical, and/or thermal stresses to an equipment item for the purpose of precipitating latent part and workmanship defects to early failure. |

| | |
|---|---|
| *System* | A group of units interconnected or assembled to perform an overall function. |
| Transmissibility | The ratio of output response to input motion. |
| Unit | A group of modules interconnected or assembled to perform a specific function with a system. |

**ACRONYMS**

| | |
|---|---|
| AMCCOM | US Army Armaments, Munitions, and Chemical Command |
| AMC-R | US Army Materiel Command Regulation |
| AQL | Acceptable Quality Level |
| ATP | Acceptance Test Procedure |
| CCA | Circuit Card Assembly |
| CDRL | Contract Data Requirements List |
| CDU | Control and Display Unit |
| cf | Cubic Foot |
| dB | Decibel |
| DID | Data Item Description |
| DOD | Department of Defense |
| DPA | Die Shear Physical Analysis |
| DT/OT | Development Test/Operational Test |
| EC | Equipment Cost |
| ECP | Engineering Change Proposal |
| ED | Equipment Design |
| EIR | Equipment Improvement Recommendation |
| EMW | Equipment Manufacturing Workmanship |
| ESS | Environmental Stress Screening |
| ETU | Engineering Test Unit |
| FCAC | Family of Compact Air Conditioners |
| FFT | Fast Fourier Transform |
| FRACA | Failure Reporting, Analysis, and Corrective Action |
| FSED | Full Scale Engineering Development |
| FTU | Field Test Unit |
| FY | Fiscal Year |

| | |
|---|---|
| HMMWV | High Mobility Multiwheeled Vehicle |
| | |
| IC | Integrated Circuit |
| IEEE | Institute of Electronic and Electrical Engineers |
| IES | Institute of Environmental Sciences |
| IMU | Inertial Measurement Unit |
| I/O | Input/Output |
| IPT | Initial Production Test |
| | |
| JSIIDS | Joint Service Interior Intrusion Detection System |
| | |
| LRU | Line Replaceable Unit |
| LSI | Large Scale Integration |
| | |
| MIL-STD | Military Standard |
| MRSA | USAMC Materiel Readiness Support Activity |
| MTBF | Mean Time Between Failure |
| MTBR | Mean Time Between Replacement |
| MTBUME | Mean Time Between Unscheduled Maintenance Events |
| | |
| NAVMAT | Naval Material Command |
| NDI | Nondevelopment Item |
| NPN | Negative-Positive-Negative |
| NSN | National Stock Number |
| | |
| OTS | Off the Shelf |
| | |
| PA | Percent Approximate |
| PADS | Position and Azimuth Determining System |
| PCB | Printed Circuit Board |
| PD | Part Design |
| PIND | Particle Impact Noise Detection |
| PMW | Part Manufacturing Workmanship |
| PNP | Positive-Negative-Positive |
| ppm | Parts Per Million |
| PS | Power Supply |
| PSD | Power Spectral Density |
| PWA | Printed Wiring Assembly |
| | |
| QC | Quality Control |
| QDR | Quality Deficiency Report |

| | |
|---|---|
| RADC | Rome Air Development Center |
| R&M | Reliability and Maintainability |
| RAM | Reliability, Availability, and Maintainability |
| RGA | Residual Gas Analysis |
| RFP | Request for Proposal |
| RMS | Root Mean Square |
| rpm | Revolutions Per Minute |
| | |
| SDC | Sample Data Collection |
| SE | Software Errors |
| SMM | Status Monitor Module |
| SOW | Statement of Work |
| SS | Screening Strength |
| | |
| TAMMS | The Army Maintenance Management System |
| TDP | Technical Data Package |
| TECOM | US Army Test and Evaluation Command |
| TROSCOM | US Army Troop Support Command |
| | |
| UME | Unscheduled Maintenance Event |
| | |
| VLSI | Very Large Scale Integration |

# TABLE OF CONTENTS

## FIGURES



## TABLES

# SECTION I. GENERAL LEVELS OF ASSEMBLY

Different stress types are associated with different levels of assembly. The same stress that produces good results during part level screening may not produce the same outcome at a higher level of assembly. For example, a high temperature bake is a good part level screen but is not an effective screen for a printed wiring assembly. This is because the defect types and the equipment response can be different at different levels of assembly. As the level of assembly increases, the equipment structural and thermal characteristics change. Equipment response is the mechanism that accelerates defects to failure. As equipment response changes, the screening efficiency changes. Stress types must be modified as the level of assembly changes.

The proper application of ESS largely depends on the degree to which it is understood. While the underlying mechanisms remain unchanged, the application of ESS to different levels of assembly requires different test equipment, stress levels, and cost considerations. This section identifies the factors involved in deciding to perform ESS at different levels of assembly.

Screening at the lowest level of assembly is the least costly option in terms of rework costs. The labor and material resources required to troubleshoot, repair, and retest a failed item increase by at least one order of magnitude at each higher level of assembly. Finding a defective component at the part level screen will prevent its introduction into a higher level assembly where the task of isolating the defect is more complex. Another factor, schedule slippage, increases as defects are discovered later in the manufacturing process. Early detection of defects minimizes rework time by virtue of less complex rework and retest procedures. It also permits earlier reprocurement of defective parts, in order to maintain original production schedules. Failures occurring at higher levels of assembly require more time to troubleshoot, rework, and retest, resulting in more immediate impact on the production schedule. Early detection of defects has less impact because it requires less time to repair defects and the repair time can be absorbed over a longer period remaining in the production schedule.

Figure 1 shows the increased costs of repair associated with higher levels of assembly. Repair or replacement cost at the part level range from $1 to $5. At the assembly level, repair costs typically range from $30 to $50, while in the field, total support costs of $5,000 to $15,000 per failure are typical.

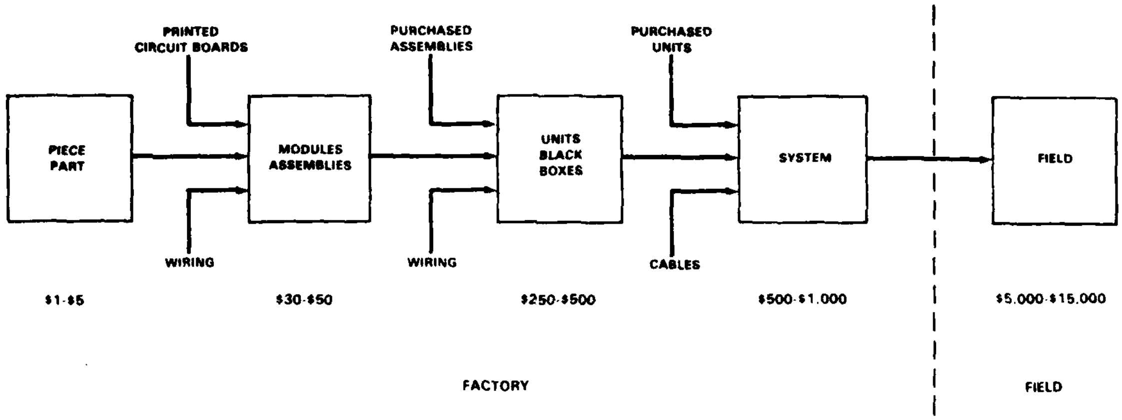


**Figure 1. Repair Cost Per Failure Location (Ref: RADC TR-82-87)**

Another important benefit of early defect detection is that more immediate feedback can be given to the activity responsible for the defect. Corrective action will be more effective if less time has expired between creation and detection of the defect. Circumstances surrounding the event can be more readily remembered or recreated. Operators' methods are still fresh in their minds. Evidence contributing to the investigation of the root cause of failure is more likely to be present if the defect is detected soon after is was caused. These facilitates analysis and implementation of corrective action to preclude recurrence of the problem. Screening at the lowest level of assembly creates additional effort in the early stages of development and production, but fosters cost savings and project success by reducing later failures.

This section provides a general discussion of three different levels of assembly for stress screening; *part* (or component), *assembly,* and *unit.* A more detailed discussion of the types of stress for each level of assembly can be found in Sections II through V.

## PART LEVEL SCREENING

At this level, screens are conducted on individual piece parts such as an integrated circuit (IC), resistor, diode, transistor, transformer or other nonrepairable electronic component. Part level screens are usually performed, as a minimum, by the part vendor or an outside screening facility. Reducing defects at the part level is the most cost-effective approach and is of such great importance that the US Air Force Reliability and Maintainability (R&M) 2000 ESS policy requires that the manufacturing process begin with piece parts having a remaining part fraction defective below 1,000 parts per million (ppm) by Fiscal Year (FY) 1987 and below 100 ppm by FY90. Data from one military hardware contractor indicated a defect rate of 6,000 ppm on incoming parts.[1] This presents a significant challenge to hardware contractors and component manufacturers if they are to meet the R&M 2000 goal and produce truly reliable hardware.

The defect rate of incoming parts has a significant impact on the assembly defect rate. As the number of parts in an assembly increases, the effect of the part defect rate is more pronounced. Figure 2 illustrates the effect that a higher proportion of part defectives has on the incidence of assembly defectives. For example, a 150-part assembly containing parts with a fraction defective of 0.1 has an assembly fraction defective of 0.8. In this case, first-time assembly test yield would be only 20%.

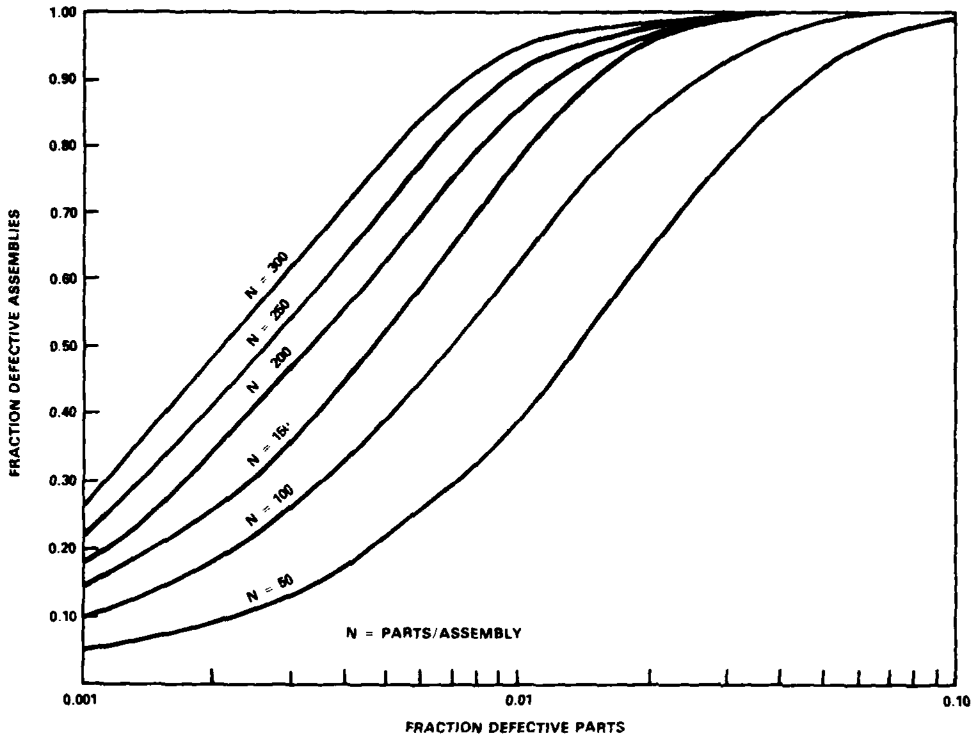


**Figure 2. Fraction Defective Parts vs. Fraction Defective Assemblies**

For an assembly containing 300 parts having a .001% defective, the fraction defective at the assembly level is 0.27, barring any further defects being introduced by the assembly process. Experience has shown, however, that many additional defects are caused during the manufacturing process.

## ASSEMBLY LEVEL SCREENING

Screening at the assembly level exposes interconnections, fasteners, and manufacturing processes performed by the assembly manufacturer to environmental stress. An assembly level screen provides the first stimulation of defects caused by the assembly manufacturer's own personnel, manufacturing methods, and production equipment. A study performed by the Institute of Environmental Sciences in 1984 revealed that failures discovered during unit level testing were reduced by 27 to 70% after the introduction of assembly level screening.[2] The following types of defects can be introduced into an assembly during the production process:

**Parts**

- Broken or damaged in handling
- Wrong one installed
- Correct one installed incorrectly
- Failure due to electrical overstress or electrostatic discharge
- Missing.

**Interconnections**

- Incorrect wire termination
- Open wire due to handling damage
- Wire short to ground due to misrouting or insulation damage
- Missing wire
- Open etch on printed wiring board
- Open plated—through hole
- Shorted etch
- Solder bridge
- Loose wire strand
- Ineffective potting
- Leaking seals.

ESS is applied to assemblies to precipitate these defects before further assembly into units or systems. ESS is not intended for detecting failures that can be detected by other quality control (QC) means (less expensive) such as visual inspection, x-ray, burn-in, etc.

Screening at the assembly level requires design and fabrication of specialized test equipment. The function of an assembly may be to process various electrical signals and generate a certain output. The equipment needed to power and monitor this assembly must be able to create similar input signals and record the required output. This simulates the functional test equipment needed for pre-ESS and post-ESS functional testing and is considered *specialized* test equipment. Such equipment may be required for use during the actual stress screen, if specifications require the assembly to be screened with power on and monitored. Such test fixturing will increase the costs associated with assembly level ESS. To avoid such costs yet still derive some benefit from thermal cycling and random vibration stress screens, AMC Regulation 702-25 recommends that baseline conditions for assembly level screens should have power off and no monitoring. This policy is intended to discourage elaborate test fixturing for assembly level screens, unless such screens are found to be necessary because of equipment criticality, equipment design, manufacturing methods or cost. An undesirable shortcoming of not powering and monitoring assemblies during screening is that intermittent shorts, opens or other problems occurring only under thermal or vibration stress may not be detected. If the occurrence of such defects is critical, the cost consideration may be outweighed, and the assembly may have to be powered and monitored during screening. If not powered and monitored, detecting these intermittent failures may be delayed until a higher level screen.

Mechanical or electromechanical equipment may contain defective sealed or pressurized assemblies that are subject to failure and should require ESS. Performing a vibration or thermal cycling may precipitate failures before further assembly. The degree to which the assembly is an integral part of a unit, and the ability to isolate inputs and outputs of the assembly will determine the cost of test fixtures needed to monitor, test or inspect the assembly after stress application. Where complicated interconnections are required for mechanical assembly level ESS, unit level testing may prove cost effective. However, postponing the stress screen of an assembly causes delayed identification of defects and may impact the delivery schedule. Field failures of the assembly are an indication of ineffective screening and may justify the cost of the test fixturing required for performing ESS at the assembly rather than unit or system level.

## UNIT (OR HIGHER) LEVEL SCREENING

Screening at this level is favored by many manufacturers because electrical and mechanical fixturing are relatively simple. Units are typically self-supporting structures with limited input cabling and few output channels to monitor. Interfaces are more standard at this level than at the lower assembly level, facilitating fixture design. Units can be mounted directly on shaker tables without requiring special fixtures. For units too large to be mounted on shaker tables, vibration transducers can be directly mounted on the unit to provide vibration stimulus.

Stresses applied during assembly and unit level screens should not be as severe as during part level screens. As the level of assembly increases, the equipment is more susceptible to damage (from vibration resonance or temperature limited components) and stress intensity must be reduced accordingly. Also, the assemblies and components in units or systems may have already been screened to eliminate defects arising from parts or lower level assembly operations. The purpose of unit or system level screening is to stimulate defects in fasteners and interconnections between PWAs, subassemblies, and assemblies. These interconnections may not have been screened previously and should be stressed before leaving the factory. Screening at this level is important, as it is the first opportunity to detect defects arising from final assembly operations that would otherwise result in field failures. Low frequency vibration screening should be applied at the unit level to precipitate those defects that could be stimulated by the transportation environment.

For mechanical or electromechanical equipment, a failure-free functional test may be the best screen available. Large systems with self-contained cooling features, generators, engines, pumps, and motors can be adequately screened by a functional test at or slightly over design rating. Operating a pump at 110% of design pressure will sufficiently stress marginal components or assemblies to failure. Running an internal combustion engine to 110% of design revolutions per minute (rpm) will disclose part and workmanship defects that may not have been detected at normal stress levels. Operating heaters and air conditioners at maximum and minimum temperature limits will allow detection of performance loss due to flow restriction, inadequate heat transfer, or other manufacturing-induced deficiencies. Ambient environmental operation or low speed operation of such mechanical assemblies will not disclose defects that are only detectable when the unit is subjected to stress.

## SUMMARY

In summary, screening at lower levels of assembly can reduce schedule impact as well as rework costs. Stress screening at the part level is generally the most cost effective. ESS at higher levels of assembly is necessary to assure the integrity of interconnections and fasteners introduced during later assembly stages, and to stimulate transportation-induced types of failures. For units that are not suited to conventional temperature and vibration ESS, full performance or slight overstress testing can serve as an effective screen for part and workmanship defects.

# SECTION II. PART LEVEL SCREENS

This section concerns screens used for piece parts only. Screens for assemblies, units, and higher levels of assembly are described in Section III.

Screening at the part level is generally the most cost-effective method for reducing the number of defective parts prior to assembly. The cost of finding defective parts at the PWA level is approximately 10 times greater than finding them at the part level. Based on the number of parts to be used, this can result in sizable cost savings.

## IC AND SEMICONDUCTOR DEFECT MODES

To develop an effective part level screening program, it is necessary to understand the defect modes for ICs and semiconductors. The failures can usually be attributed to one of two major causes: (1) chip or die-related failures resulting from the fabrication process, or (2) package-related defects caused by assembly errors. Examples of the failure causes are:

### Chip or Die-Related Failure Causes

- Oxide fault/pinholes/breakdown
- Oxide junction contaminants/leakage
- Diffusion defects (such as spikes)
- Passivation defects
- Mechanical defects in the chip (cracked dies, crystal imperfections, scratched dies)
- Design defects (mask faults)
- Foreign materials/particles
- Metallization defects (opens, shorts for both single and multilayer metal)
- Residual process chemical
- Human-derived chemical agents (spittle).

### Assembly or Package-Related Failure Causes

- Open/shorted wires
- Lifted/broken wire bonds
- Misplaced wire bonds
- Multiple wire bonds
- Lifted chips
- Improperly sealed packages
- Die attach defects
- Excessive seal material
- External lead defects
- Overbonding/underbonding

- Residual process chemicals
- Human-derived chemical agents (spittle)
- Moisture
- Outgassing polymers (poorly cured organic adhesives such as epoxy die attach)
- Broken wires
- Poor lead dress
- Corroded wires.

There are several other failure mechanisms in parts that can cause failure. The decomposition of sealants or adhesives can introduce materials that interact with IC materials to cause failure. The presence of water can cause internal shorts. Metal impurities in aluminum or gold bond wires could cause hardening or microcracks leading to failure.

## TEMPERATURE CYCLING (OR THERMAL SHOCK)

Temperature cycling and thermal shock impose mechanical stresses on parts through the expansion and contraction of materials. Microcracks, hard precipitates, and abnormally thin features become stress concentrators that will accelerate crack growth through cycling-induced fatigue. Good parts will experience some fatigue life loss. However, it should not be enough to cause degradation. Temperature cycling is generally composed of 10 cycles, between -65°C to +150°C, with a 5-minute maximum transfer time between temperature extremes. Temperature cycling uses an air-to-air medium, while thermal shock uses a liquid-to-liquid medium to increase the thermal rate of change. Thermal shock must be used carefully for screening as it is more likely than temperature cycling to damage good parts. Thermal shock can generate microcracks in insulators or dielectrics. These microcracks may then grown in size to the point where they cause failures during the storage or operating life of a device. Temperature cycling and thermal shock will precipitate the following types of defects:

- Bad bonds
- Thermal mismatch of materials, such as die-to-package interfaces
- Lid seal anomalies on hermetically sealed packages
- Inadequately or improperly cured plastic packages or material, such as epoxy die attach
- Cracked dies or substrate mounting.

## SUMMARY

Part screening tests are the most economical means of detecting parts defects. Screening at the part level is the least costly means of finding and eliminating part defects from hardware. In addition, it is not always possible to determine if a part defect found at the assembly level is an escape from a part level screen or if the defect was introduced during handling, test or assembly procedures. Therefore, part screening should be done for every program as it facilitates failure analysis at higher levels of assembly and reduces subsequent rework and schedule slippage.

# SECTION III. ASSEMBLY LEVEL SCREENS

When parts are combined into assemblies and units, defects will be introduced through workmanship errors, contamination, miscalibrated equipment, and the use of defective parts. If high reliability parts are utilized, the number of defective parts advancing to the assembly level should be minimal. Some defective parts will exist, however, and subsequent damage to good parts from handling, electrostatic discharge or overstressing during the assembly and testing processes results in some defects residing in higher level assemblies. For these reasons, it is necessary to subject assemblies and units to ESS to precipitate these defects.

There are many screens that can be used at the assembly level to precipitate and detect latent defects. These screens include:

- Thermal cycling
- Random vibration
- Immersion
- Overpressure, and
- Voltage variation.

Short descriptions of the most common screens are provided in the following paragraphs. Each of the screens primarily precipitates specific types of defects, although some may have overlapping capabilities. The choice of which screens to use depends on the equipment design and the types of defects expected to be found. Stress screening must be tailored to the specific equipment—it is not enough to simply impose thermal cycling and random vibration on all hardware. Form mechanical systems containing pressurized assemblies (fuel supply, pneumatics), these conventional stresses (thermal, vibration) may not precipitate as many defects as overpressure or pressure cycling.

For electronic systems, thermal cycling and random vibration have been found to be the most effective screens available, and are the most widely used. They are excellent for uncovering the microscopic defects that are present in electronic equipment. Table 1 shows the types of defects precipitated by thermal cycling and random vibration. As can be seen, there is a lot of overlap in the defect types precipitated by these two screens. The most effective ESS Program for electronic equipment would consist of both screens being used.

**Table 1. Assembly Level Defect Types Precipitated by Thermal and Vibration Screens**

| DEFECT TYPE DETECTED | THERMAL SCREEN | VIBRATION SCREEN |
|---|---|---|
| Defective part | X | X |
| Broken part | X | X |
| Improperly installed part | X | X |
| Solder connection | X | X |
| PCB etch, shorts, and opens | X | X |
| Loose contact | | X |
| Wire insulation | X | |
| Loose wire termination | X | X |
| Improper crimp or mating | X | |
| Contamination | X | |
| Debris | | X |
| Loose hardware | | X |
| Chafed, pinched wires | | X |
| Parameter drift | X | |
| Hermetic seal failure | X | |
| Adjacent boards/parts shorting | | X |

## THERMAL CYCLING

Thermal cycling is the least controversial and most widely used stress screen. It is an effective screen for precipitating defects at all levels of assembly, from PWAs to complete end items. Thermal cycling is a relatively inexpensive screen, especially when performed at the PWA level where many units can be screened simultaneously in one chamber.

Thermal cycling consists of changing the temperature of the equipment at a fairly high rate of change in order to induce stresses on the parts and connections. There are three main parameters that determine the strength of the screen: the temperature range, the thermal rate of change, and the number of cycles. The temperature range and rate of change must be specified as hardware temperature values, not as chamber air temperature values. The equipment being screened has a larger thermal mass than the chamber air, so equipment response will lag behind the input stress. Experimental surveys (see page 33) are necessary to ensure that the equipment response is stressful enough to precipitate defects while not damaging good units.

Thermal cycling causes stress in the test items through the expansion and contraction of materials due to temperature change. The repeated cycling will cause different materials to expand and contract at different rates, resulting in stress at mating points, such as solder joints and connections.

Stress concentrations caused by microcracks, voids or material impurities will cause failure from fatigue buildup, while good connections will have no stress concentrations. The high temperature will accelerate part failure mechanisms while the low temperature will precipitate electrical shorts due to condensation.

The equipment should be powered up and monitored when possible in order to detect intermittent faults. For example, a solder joint that has broken will contract at low temperature, creating an open circuit, but when the temperature returns to ambient, the joint will expand, establishing electrical continuity. If testing is only performed after screening is complete (at ambient temperature), the fault might not be found and could result in failure on a cold day in the field. Power-on monitoring is easier at the unit level than at the PWA level. If PWAs are not powered up and monitored at the PWA level, a power-on, monitored screen should be performed at a higher level to ensure all intermittent defects are discovered.

## RANDOM VIBRATION

Random vibration has been less widely accepted as an environmental screen than thermal cycling, but is equally effective. The major reason for the reluctance to use random vibration is that it is a relatively new stress type and the effect on the equipment is not always accurately predictable. Random vibration stress levels must be developed through experimentation with the equipment to be screened; so called "standard" stresses may cause damage through overstress. The standard stress levels must be used as baseline values only, with the contractor required to perform analysis to ensure that the equipment is not damaged during the application and that defects are screened out.

Random vibration has replaced sine and swept-sine vibration as a stress screen because it has been shown to be more effective in precipitating latent defects. *Sine* vibration applies energy at only one frequency and does not exercise all resonances of the equipment. In addition, the danger of fatigue failure is increased since all the energy goes into the one frequency. *Swept-sine* vibration applies energy at different frequencies sequentially. The dwell time at each frequency is not long enough to cause fatigue problems. Neither is the dwell time long enough to give the equipment enough time to fully respond to the input stimulus. Random vibration applies relatively constant energy in all frequencies. The energy applied at any one frequency is much smaller than that provided by sine vibration, so there is less danger of fatigue damage. Since the vibration occurs at all frequencies during the entire screen, the equipment also has time to reach a steady state response to the input. Random vibration is also the closest approximation ot the actual vibration seen by the equipment in the field. These factors all combine to make random vibration a more effective, less damaging screen when applied correctly. Experimental surveys (see page 33) are essential to ensure that the equipment is not damaged by the vibratory stress levels imposed for screening.

There are three parameters which determine the effectiveness of a random vibration screen: the response profile, the duration of the screen (in each axis), and the number of axis. The response profile is a measure of the total energy received by the equipment (as opposed to the input profile) and is determined by the excitation frequency range and the power spectral density (PSD), the energy input at each discrete frequency. The duration of screening in each axis should be 10 minutes. After 10 minutes, the fallout rate approaches zero and the screen effectiveness diminishes. The 10-minute random vibration should be performed on each of the three orthogonal axis. Excitation of multiple axis simultaneously gives a more realistic screen than discrete axis screening, and should be used when possible.

Random vibration stresses the equipment by imposing acceleration forces on solder joints and connectors. These forces cause stress concentrations around material impurities, voids, and microcracks. The repeated application of force will cause crack growth and failure due to fatigue. Good equipment will not be damaged by fatigue since the stress level is not great enough to cause failure except where stress concentrations are present. Random vibration is also effective in identifying conductive particles, debris, poor fasteners, and loose hardware.

# SECTION IV. DETERMINATION OF THERMAL CYCLING REQUIREMENTS

This section describes the methods for determining the stress intensity levels for thermal cycling.

## THERMAL CYCLING SCREEN

Thermal cycling should be performed on all items to detect part defects and workmanship errors. It should be used in conjunction with random vibration and is particularly applicable to electronic equipment. Thermal cycling, when using good parts and packaging techniques, is not degrading to the equipment, even after several hundred cycles. It is suggested that thermal cycling be done at least twice on each item, once at the PWA level and once at a higher indenture level. Power should be applied when possible and the hardware should be functionally tested during screening when economically feasible in order to identify defects that only become detectable under certain environmental conditions.

### Screen Strength

Thermal cycling is a much stronger screen than a high temperature burn-in or ambient burn-in. The screen strength is a measure of the effectiveness of the specific screen. The strength of the screen is defined as the probability that the screen will precipitate a given defect, providing the defect is present in the equipment, and is determined by the following equation:

$$SS_{TC} = 1 - \exp\left[-0.0017 \times (R+0.6)^{0.6} \times (\ln(e + dT))^{3} \times Ncy\right]$$

where

$SS_{TC}$ = Thermal Cycling Screening Strength
R = Temperature range, Tmax-Tmin (°C)
dT = Thermal rate of change (°C per minute)
Ncy = Number of cycles

The three parameters that determine the strength of the thermal cycling screen are the temperature range, the thermal rate of change, and the number of thermal cycles. Table 2 provides a tabulation of values of thermal cycling strength for different combinations of these parameters. The parametric values must be measured on the hardware, not the chamber air. The equation for screening strength is based on an analysis of actual results from many screening programs.

The thermal cycling requirements will be different for lower and higher levels of assemblies. Hardware characteristics such as thermal capacitance, materials, and part specifications will impact the values of the stress than can be applied during the screen. The development of stress values will be divided into PWAs and unit (or higher) level assemblies.

## Table 2. Screening Strength, Temperature Cycling Screens

| NUMBER OF CYCLES (Ncy) | dT | TEMPERATURE RANGE (R) (°C) 20 | 40 | 60 | 80 | 100 | 120 | 140 | 160 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 5. | .1633 | .2349 | .2886 | .3324 | .3697 | .4023 | .4312 | .4572 | .4809 |
| | 10. | .2907 | .4031 | .4812 | .5410 | .5891 | .6290 | .6629 | .6920 | .7173 |
| | 15. | .3911 | .5254 | .6124 | .6752 | .7232 | .7612 | .7920 | .8175 | .8388 |
| | 20. | .4707 | .6155 | .7034 | .7636 | .8075 | .8407 | .8665 | .8871 | .9037 |
| 4 | 5. | .2998 | .4147 | .4939 | .5543 | .6027 | .6427 | .6765 | .7054 | .7305 |
| | 10. | .4969 | .6437 | .7308 | .7893 | .8312 | .8624 | .8863 | .9051 | .9201 |
| | 15. | .6292 | .7748 | .8498 | .8945 | .9234 | .9430 | .9567 | .9667 | .9740 |
| | 20. | .7198 | .8522 | .9120 | .9441 | .9629 | .9746 | .9822 | .9873 | .9907 |
| 6 | 5. | .4141 | .5522 | .6400 | .7025 | .7496 | .7864 | .8160 | .8401 | .8601 |
| | 10. | .6431 | .7873 | .8603 | .9033 | .9306 | .9489 | .9617 | .9708 | .9774 |
| | 15. | .7742 | .8931 | .9418 | .9657 | .9788 | .9864 | .9910 | .9939 | .9958 |
| | 20. | .8517 | .9432 | .9739 | .9868 | .9929 | .9960 | .9976 | .9986 | .9991 |
| 8 | 5. | .5098 | .6574 | .7439 | .8014 | .8422 | .8723 | .8953 | .9132 | .9274 |
| | 10. | .7469 | .8731 | .9275 | .9556 | .9715 | .9811 | .9871 | .9910 | .9936 |
| | 15. | .8625 | .9493 | .9774 | .9889 | .9941 | .9967 | .9981 | .9989 | .9993 |
| | 20. | .9215 | .9781 | .9923 | .9969 | .9986 | .9994 | .9997 | .9998 | .9999 |
| 10 | 5. | .5898 | .7379 | .8178 | .8674 | .9005 | .9237 | .9405 | .9529 | .9623 |
| | 10. | .8204 | .9242 | .9624 | .9796 | .9883 | .9930 | .9956 | .9972 | .9982 |
| | 15. | .9163 | .9759 | .9913 | .9964 | .9984 | .9992 | .9996 | .9998 | .9999 |
| | 20. | .9585 | .9916 | .9977 | .9993 | .9997 | .9999 | .9999 | .9999 | .9999 |
| 12 | 5. | .6568 | .7994 | .8704 | .9115 | .9373 | .9544 | .9661 | .9744 | .9804 |
| | 10. | .8726 | .9548 | .9805 | .9906 | .9952 | .9974 | .9985 | .9991 | .9995 |
| | 15. | .9490 | .9886 | .9966 | .9988 | .9996 | .9998 | .9999 | .9999 | .9999 |
| | 20. | .9780 | .9968 | .9993 | .9998 | .9999 | .9999 | .9999 | .9999 | .9999 |

## Printed Wiring Assembly Requirements

### *Temperature Range*

For PWAs, the temperature range should be as large as component characteristics will permit. The nominal value for the PWA temperature range is -50°C to +75°C. One potential problem that must be considered when determining the temperature range is the thermal overstressing of component parts. If the PWA contains parts that are not rated to the nominal extremes cited above, the temperature range should be limited by the component part values. For best screening results, the range should be at least 110°C for PWAs. If component values reduce the range below 110°C, more cycles or a higher rate of change can be used to increase screening strength.

### *Rate of Change*

The thermal rate of change of the individual parts is the stress of interest, and is dependent on the chamber capacity and the size of the hardware. In general, the thermal rate of change should fall between 5°C/minute and 20°C/minute, with the higher rates providing a better screen. The thermal rate of change should be determined by a thermocouple mounted directly on the electronic component with the largest mass, not by the temperature of the input air. The PWA has a larger thermal capacitance than the chamber air, so the temperature of the PWA components will change more slowly. A thermal characteristic survey (see page 33) is required to determine the equipment response to the input air. The minimum rate of change for PWA screening shall be 5°C/minute.

### *Number of Cycles*

The number of thermal cycles required is more closely related to the temperature range and rate of change than to the equipment complexity or number of parts. For PWAs, there should be at least 20 cycles, with more required if the thermal rate of change is less than 15°C/minute or the range is less than 110°C. For every drop in rate of change of 5°C/minute, the number of cycles should be increased by 5; i.e., for a rate of change of 10°C/minute, there should be 25 cycles. For every 10°C drop in temperature range below 110°C, an additional 5 cycles should be required. These values are baseline values only, and the program should allow modification if effective screening can be achieved with different values.

### *Profile*

A profile of a typical thermal cycle for PWAs is presented in Figure 3 and shows both the chamber air temperature and the PWA thermocouple temperature. The dwell times at +70°C and -40°C should be only long enough to reach thermal stability. Thermal stability is achieved when the largest thermal mass within the PWA comes within 2°C of the temperature extreme or when the rate of change falls below 2°C/hour.

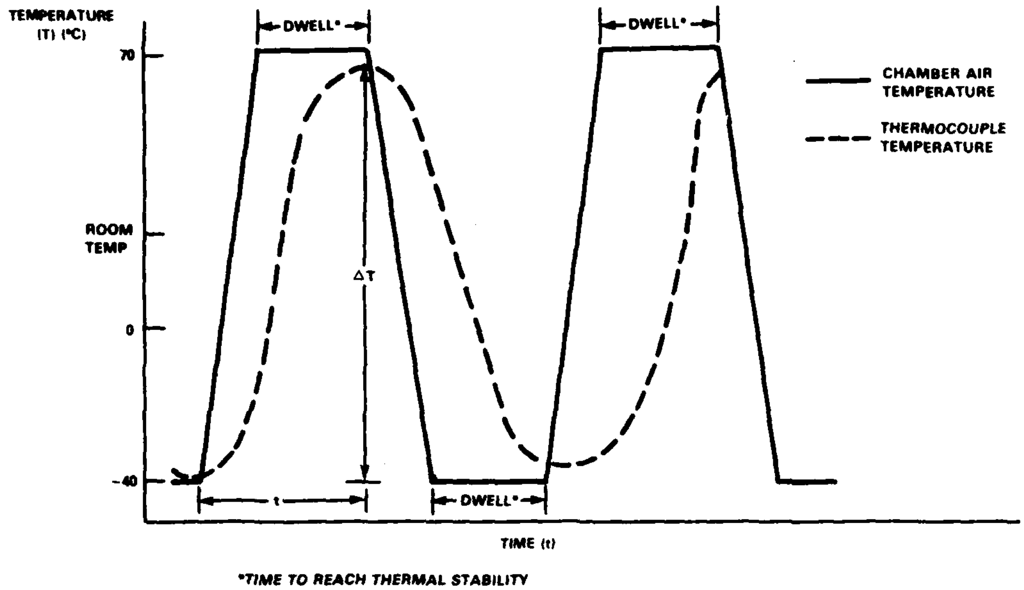


**Figure 3. Typical PWA Thermal Cycling Profile**

*Performance Monitoring*

Performance monitoring and power on-off cycling is usually not cost effective for PWAs. This is because it is difficult and expensive to develop the signal generating and output monitoring test equipment. It would be advantageous to monitor the PWAs in order to identify intermittent defects that only occur at temperature extremes. However, by requiring a power on, monitored thermal screen at a higher level of assembly, the majority of these defects can subsequently be identified and removed.

During screen development and initial implementation, the thermal cycling screen results should be monitored and analyzed to optimize the screen. It is suggested that a functional test be run after every 5 cycles to determine the fallout rate. The number of cycles can be modified if the majority of defects are consistently identified during the first part of the screen.

*Unit (or Higher) Assembly Level Requirements*

As the level of assembly increases, thermal cycling becomes more complex and harder to perform effectively. The thermal capacitance of the assembly increases due to more mass, and it becomes harder to stress parts internal to the assembly. Nevertheless, thermal cycling is an effective screen at the unit (and higher) levels of assembly.

*Temperature Range*

For unit level and higher, the equipment specifications for maximum and minimum storage and operating temperatures should be used to establish the baseline temperature range. Nominal values for the temperature range (storage) are -40°C to +70°C for units and -40°C to +60°C for complete systems. Care should be taken to ensure that the temperature range does not overstress any internal, temperature-dependent component parts. If the unit is powered up, the internal temperature will rise due to the parts' heat dissipation and could overshoot the input temperature extreme.

*Rate of Change*

The thermal rate of change for units is also dependent on the chamber capacity and the mass of the equipment. The rate of change should be between 5°C/minute and 10°C/minute, when measured by a thermocouple mounted on the largest PWA. The chamber air rate of change must be greater than this to overcome the unit's thermal capacitance. Typically, when chamber air is cycled at a rate of 5°C/minute, the actual equipment rate of change is 1°C/minute to 2°C/minute.

*Number of Cycles*

The number of cycles required for unit (or higher) level screening should be between 10 and 20. At the beginning of the screening program, the number of failures per cycle should be monitored and analyzed. If the data shows that a large majority of the defects can be screened out in fewer cycles, the number of cycles may be reduced in order to maximize the cost effectiveness. The nominal number of cycles for units or higher level assemblies is 12.

One failure-free cycle should be required during thermal cycling to ensure that all defects have been removed from the unit. A failure-free cycle is one complete cycle with no defects found during performance monitoring. In the event a defect is discovered, the unit should be repaired and required to pass another failure-free cycle.

*Profile*

A typical thermal cycle profile for a unit, showing both chamber air and PWA response temperatures, is presented in Figure 4. The dwell time at the maximum and minimum operating and storage temperatures should be only long enough to achieve thermal stability. When thermal stability is achieved at the upper and lower operating temperatures, a functional check should be performed to identify any temperature-induced defects.

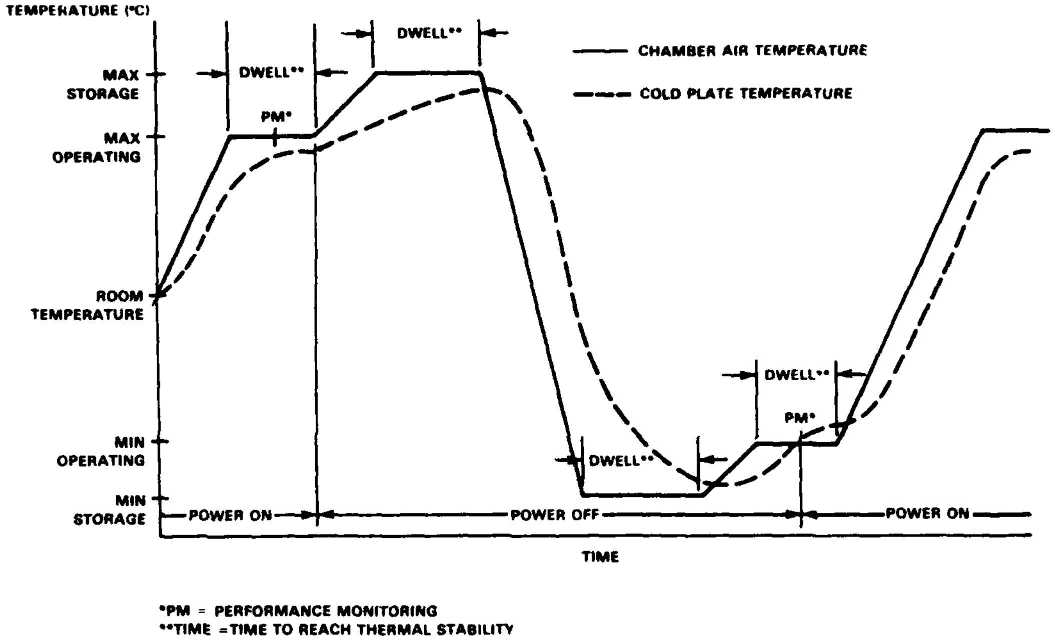


**Figure 4. Typical Unit (or Higher) Thermal Cycling Profile**

*Performance Monitoring*

Units (and higher assemblies) should have power-on cycling during the screen, as was shown in Figure 4. Power is applied at low operating temperature and the unit remains on during the increasing temperature ramp. Having the unit powered during the ramp increases the thermal rate of change due to the heat dissipation from the component parts. Once a functional check is performed at the high operating temperature, power should be cycled off to avoid thermally overstressing the unit during transition to the maximum storage temperature. It should remain off during the decreasing temperature ramp to aid in achieving a higher thermal rate of change. If power is on during the cold ramp, the chamber input air will have to overcome both the thermal capacitance of the equipment and the heat dissipated by the parts.

The unit (or higher assembly) should be monitored for functional integrity during the screen. This is especially important if PWA level screening is done without performance monitoring. A large percentage of ESS-detected defects are intermittents, occurring only under a specific set of environmental conditions. Monitoring performance will provide evidence of the intermittent defects, making their isolation and removal possible. Higher level test equipment is cheaper to develop than PWA equipment, since many of the input signals are internally generated.

## Special Considerations

### *Magnetic Devices*

Magnetic devices continue to be a problem area for thermal cycling. Poor quality magnetics can have a high fallout rate from thermal cycling. The problem is that magnetics are not effectively screened at the assembly level because their temperature rate of change lags behind the rate of change of the rest of the components by an excessive amount. A piece of equipment (excluding the magnetics) can reach thermal stability in 15 minutes, but it takes several hours for the magnetics to reach thermal stability. The dwell time at the temperature extremes is normally set for the smaller electronic components and not for the magnetics.

There is an alternative screen for magnetics. Magnetics should be built to MIL-T-27E and should be subjected to the optional MIL-STD-202F thermal shock screen on a 100% basis. While the data to support this is small, it appears that thermally shocked magnetics have little or no additional fallout with subsequent equipment thermal cycling. For some time, thermally shocking magnetics have been a requirement for power supply reliability.

### *Water-Cooled Power Supplies*

Power supply thermal cycling has presented some unique problems. There have been several cases of power supplies being subjected to thermal cycling while mounted on water-cooled cold plates. This means that the unit cannot be cycled to temperatures much below 0°C or the water in the cold plate will freeze. Worse, the water stabilizes the internal temperature of the unit which means the electronics are not actually experiencing the thermal cycling.

A better alternative is to perform most thermal cycling on power supplies without the water-cooled plates. In most cases, power can still be applied, but care must be taken not to cause degradation by thermally overstressing the components.

### *Potted Units*

There are many questions about the value of thermal cycling of potted power supplies and units. It might appear that this screen would have limited value for potted units. While there may be arguments that the screening effectiveness is less for potted units, there have been significant reliability improvements on a variety of power supplies from different vendors that have added thermal screening to existing designs. It can be stated that potted power supplies and units should have some thermal screening. In most cases, it is advisable to do the thermal cycling prior to potting.

## Summary

Thermal cycling is the most common stress screen used to precipitate latent defects at both the PWA and unit levels of assembly. The part or unit specifications should be used to determine the temperature range, and all parameters should be measured on the PWAs. While power-on cycling and functional monitoring are usually not cost effective at the PWA level, they should be performed at the unit (and higher) level of assembly to identify intermittent defects. Some components must have special consideration and may have to be removed from assemblies during screening. All baseline values are for guidance only; the final parameters should be based on equipment response and analysis of screening results. The nominal baseline stress levels to be used during development of thermal cycling are presented in Table 3.

**Table 3. Baseline Thermal Cycling Conditions**

| LEVEL | LOW TEMP | HIGH TEMP | RATE OF CHANGE | POWER ON | MONITOR | CYCLES | FAILURE FREE |
|---|---|---|---|---|---|---|---|
| Assembly | -50°C | +75°C | 15°C/minute | No | No | 20 | none |
| Unit | -40°C | +70°C | 10°C/minute | Yes | Yes | 12 | last 1 |
| System | -40°C | +60°C | 10°C/minute | Yes | Yes | 12 | last 1 |

## Sample Statement of Work (SOW) for Thermal Cycling

*Application: Production contract/Request for Proposal (RFP); Development contract/RFP PWAs, units, systems*

*Temperature cycling shall be conducted in accordance with the table below for each production unit, all printed circuit board assemblies, power supplies, and units including spares unless determined otherwise by the procuring activity.*

***Temperature Cycling Baseline Conditions***

| *LEVEL* | *LOW TEMP* | *HIGH TEMP* | *RATE OF CHANGE* | *POWER ON* | *MONITOR* | *CYCLES* | *FAILURE FREE* |
|---|---|---|---|---|---|---|---|
| *Assembly* | *-50°C* | *+75°C* | *15°C/minute* | *No* | *No* | *20* | *none* |
| *Unit* | *-40°C* | *+70°C* | *10°C/minute* | *Yes* | *Yes* | *12* | *last 1* |
| *System* | *-40°C* | *+60°C* | *10°C/minute* | *Yes* | *Yes* | *12* | *last 1* |

*Decreased stress levels are subject to Government approval, based on thermal survey results, component specifications, or other suitable technical justification submitted by the contractor in ESS procedures or other documents. Increased stress levels may be applied to improve screening effectiveness provided that the design capability is not exceeded.*

*Dwell time at the temperature extremes shall be sufficient to bring the point of maximum thermal inertia (see MIL-STD-781DE, Task 201) to within 2 °C of the specified limit, or to a thermal rate of change of 2 °C or less/hour. Functional testing shall be performed immediately prior to, and immediately following, thermal cycling. Failures occurring during thermal cycling shall be analyzed for root cause and entered into the contractor's failure reporting and corrective action system with verification that corrective action will preclude recurrence of the failure mode. If size, mass or cost preclude screening at the system or subsystem level, the contractor shall recommend thermal cycling at lower levels and/or full-scale performance testing of the entire system for a failure-free period, subject to approval by the procuring activity. Results of thermal cycling shall be included in Contract Data Requirements List (CDRL) number ______"ESS Performance Reports" and procedures used to conduct thermal cycling shall be included in CDRL number ______"ESS Procedures."*

## THERMAL CHARACTERIZATION SURVEY

After manufacture of an initial prototype in the development phase or a first article in the production phase, a unit shall be subjected to a thermal characterization survey. The purpose of the survey is to determine the thermal rate of change response and the time to reach thermal stabilization, and to identify any "hot spots" in the unit that could degrade equipment reliability. The thermal survey should be performed prior to implementing thermal screening.

MIL-STD-781D, Task 201, paragraph 201.2.1, is an appropriate task to be invoked in a contract SOW to perform a vibration survey. Data item description DI-RELI-80247 describes the data and report to be submitted by the contractor following the survey.

This survey should be conducted before other reliability testing because results may indicate the need for a design or processing change. Corrective action resulting from these discoveries can impact design and must be resolved prior to further testing to ensure valid results.

The outcome of the survey will also be used as input to ESS procedures, specifically to determine the temperature levels, time durations, and thermal rates of change needed to precipitate defects without damaging the article.

The temperature of each component identified as a high power-dissipating component shall be monitored during the survey to identify actual thermal stress and to compare actual operating temperatures to those arrived at analytically or through the manufacturer's specified limits. Cases of conflict or significant deviation from expected values shall require investigation, corrective action, and verification of problem resolution.

An output of the survey is a time/temperature plot showing actual temperatures of the high-power dissipating components, chamber air temperature, chamber controller temperature commands, and a time axis for the survey. This plot will yield a temperature rate of change that can be compared to the required values.

If the article has a self-contained cooling system, inlet and outlet temperatures and flow rates should be recorded. The report should also describe the test equipment, probe locations, and unit under test. A diagram of the test set-up should be included, as should a discussion of thermal measurements' accuracy.

A thermal survey should be conducted initially in the development phase to define ESS levels as early as possible. This also provides early feedback to the design process if any revisions are found necessary.

During the production phase, a first article should be subjected to the same thermal survey conducted during development to validate that the parts, processes, and personnel used in production have not caused a deviation from the performance of hardware produced during development. An approximate cost of a thermal survey is less than $1,000 for a printed circuit board (PCB) or small unit. If there is insufficient funding to perform a thermal survey during production, the validity of the development results will have to be assumed. This could lead to later identification of problems caused by parts or processing changes used in production. A thermal survey on production first articles ensures early identification of such problems, thereby maximizing the potential for project success.

### Sample Statement of Work (SOW) for Thermal Survey

*A thermal survey shall be performed in accordance with MIL-STD-781D, Task 201, paragraph .2.1, for each level of assembly to be screened. After performance of the surveys, a thermal survey report shall be prepared in accordance with data item description DI-RELI-80247 and delivered in accordance with the CDRL. The survey report shall contain the results of the surveys performed on each level of assembly subjected to screening. The thermal cycling baseline conditions shall be used as the thermal limits for the surveys.*

*Procedures used to conduct the thermal survey shall be included in CDRL number ______ "ESS Procedures," and shall be approved by the Government prior to use.*

### Review of Thermal Survey Report

The following is intended to assist the Government activity having responsibility for review and approval of the thermal survey report.

A thermal survey report provides the results of a survey performed by the contractor to determine the response of an article to thermal stress. The report should describe the techniques used to conduct the survey, the number and types of temperature probes used, locations of probes, temperature ranges applied, time durations, and identification of the article under test. These elements are derived from MIL-STD-781D, Task 201, paragraph 201.2.1, which is an appropriate task to be invoked in a contract SOW for performing a thermal survey. Additional details are defined by data item description DI-RELI-80247 which describes the data and report to be submitted by the contractor.

The thermal survey shall be used to determine hot spots on the article and the component of greatest thermal inertia, and to establish the time/temperature relationship between the equipment and the chamber air. The results shall be used to determine the thermal limits, the chamber air input requirements, and the screen time durations that will be incorporated into the ESS procedures.

The following checklist is to be used by the activity responsible for approval of the thermal survey report. The reviewer should note in the review any discrepancies or missing information. Essential deficiencies noted by the Government reviewer may constitute rejection of the report and require revision and resubmission by the contractor.

**Thermal Survey Report Checklist (Ref. MIL-STD-781D, Task 201, Paragraph 201.2.1, and DI-RELI-80247)**

- Temperature measurements are provided for those parts identified as high power-dissipating parts and those representative of part populations. These measurements are shown on a temperature versus time plot which also indicates the temperature being commanded by the chamber controller and the actual chamber temperature.
- Description of the item under test includes equipment serial number, date of test, and location of test facility.
- Identification of test equipment includes manufacturer, model numbers, accuracy, and a diagram showing test setup.
- Discussion of thermal measurement accuracy is provided.
- The flow rate of coolant used in the equipment (if applicable) and their inlet and outlet temperatures.
- Is power applied to the item during the survey?
- High and low temperature limits applied during the survey are given. If operating temperature limits are different from storage temperature limits, both are stated.
- Temperatures of the item and chamber air are recorded continuously and shown on a temperature versus time plot.
- Areas of heat concentration (hot spots) are identified and verified not to exceed item specifications at temperature extremes.

- Duty cycle and temperature durations are recorded.
- Temperature rate of change for heating and cooling cycle transitions is stated, based on recorded temperature/time data.
- The component of greatest thermal inertia is identified.
- The lower test temperature stabilization time is shown to be the point in time where the temperature of the component of maximum thermal inertia is within 2°C of the lower test temperature specified for thermal cycling, or the rate of change of this component is less than 2°C per hour. The upper test temperature stabilization time is determined likewise.
- All test failures, unexpected hot spots, or thermal excursions beyond specified limits have resulted in corrective action and been resolved.
- The number and types of probes and measuring devices are stated.
- The locations of probes and instrumentation used to measure temperatures of parts and ambient chamber air are stated.

# SECTION V. DETERMINATION OF RANDOM VIBRATION REQUIREMENTS

This section describes the method for determining stress intensity levels for random vibration.

## RANDOM VIBRATION SCREENING

Random vibration, while more controversial, is an effective stress screen and should be used in conjunction with thermal cycling to precipitate latent part and workmanship defects. The stress must be closely tailored to the equipment design capability to provide an effective screen without damaging good components. Specification of so called "standard" stress levels have resulted in screens which are either ineffective or cause hardware damage. Therefore, the stress levels specified in contracts should be baseline values only, and the contractor should be required to experiment with the equipment to determine either: (1) that the baseline values are not damaging and produce and effective screen or (2) that different stress levels are necessary.

Random vibration stress levels have been mistakenly specified as input stress values in many programs. The stress levels specified for random vibration must be the response levels measured on the equipment, not the input levels. The mechanism that accelerates the failure of marginal defects is the actual stress that is induced on the parts. In all assemblies, there are inherent structural characteristics which provide either amplification or attenuation of the input stress on its path to the component parts. For example, , if a PWA is vibrated at its natural frequency, the vibratory force seen by a component on the board can be many times larger than the driving force. Isolation of a board can result in much less stress being achieved at the part than intended. Structural characteristics of the test fixtures can also have an impact on the value of the stress applied at the part location. For these reasons, the random vibration stress levels must be specified as the levels achieved at the part, not as input values. A vibration survey (see page 33) must be performed on each assembly to be screened to determine the response of the equipment to the input forces and to develop the input stress levels necessary to achieve the required response.

### Screen Strength

There are two factors which determine the strength of a random vibration screen: the acceleration level and the duration of the applied stress. The strength of a screen is defined as the probability that the screen will precipitate a defect, given that the defect is present. Screen strength values have been determined experimentally by the Rome Air Development Center in several documents. The latest version of the screen strength equation for a random vibration screen is:

$$SS_{RV} = 1 - \exp\left[-0.0046\, Grms^{1.71}\, t\right]$$

where

$SS_{Rv}$ = Random vibration screen strength
Grms = The root mean square (rms) acceleration level
t = The duration of the screen (minutes)

Table 4 provides a tabulated summary of screen strength values determined by using this equation for various combinations of Grms level and time. The equation considers vibration in one axis at a time only. One note of caution: defects are not always equally screenable in each axis (i.e., a defect may be precipitated by z-axis vibration but not by x-axis or y-axis vibration), so the screen strength applies only to defects screenable in that axis.

**Table 4. Screening Strength for Random Vibration Screens**

| DURATION (minutes) | Grms LEVEL 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0.007 | 0.023 | 0.045 | 0.072 | 0.104 | 0.140 | 0.178 | 0.218 | 0.260 | 0.303 | 0.346 | 0.389 | 0.431 | 0.473 |
| 10 | 0.014 | 0.045 | 0.088 | 0.140 | 0.198 | 0.260 | 0.324 | 0.389 | 0.452 | 0.514 | 0.572 | 0.627 | 0.677 | 0.723 |
| 15 | 0.021 | 0.067 | 0.129 | 0.202 | 0.282 | 0.363 | 0.444 | 0.522 | 0.595 | 0.661 | 0.720 | 0.772 | 0.816 | 0.854 |
| 20 | 0.028 | 0.088 | 0.168 | 0.260 | 0.356 | 0.452 | 0.543 | 0.626 | 0.700 | 0.764 | 0.817 | 0.861 | 0.896 | 0.923 |
| 25 | 0.035 | 0.109 | 0.206 | 0.314 | 0.424 | 0.529 | 0.625 | 0.708 | 0.778 | 0.835 | 0.880 | 0.915 | 0.941 | 0.959 |
| 30 | 0.041 | 0.129 | 0.241 | 0.363 | 0.484 | 0.595 | 0.691 | 0.772 | 0.836 | 0.885 | 0.922 | 0.948 | 0.966 | 0.979 |
| 35 | 0.048 | 0.149 | 0.275 | 0.409 | 0.538 | 0.651 | 0.746 | 0.822 | 0.878 | 0.920 | 0.949 | 0.968 | 0.981 | 0.989 |
| 40 | 0.055 | 0.168 | 0.308 | 0.452 | 0.586 | 0.700 | 0.791 | 0.860 | 0.910 | 0.944 | 0.966 | 0.981 | 0.989 | 0.994 |
| 45 | 0.061 | 0.187 | 0.339 | 0.492 | 0.629 | 0.742 | 0.829 | 0.891 | 0.933 | 0.961 | 0.978 | 0.988 | 0.994 | 0.997 |
| 50 | 0.068 | 0.205 | 0.369 | 0.529 | 0.668 | 0.778 | 0.859 | 0.915 | 0.951 | 0.973 | 0.986 | 0.993 | 0.996 | 0.998 |
| 55 | 0.074 | 0.224 | 0.397 | 0.563 | 0.702 | 0.809 | 0.884 | 0.933 | 0.964 | 0.981 | 0.991 | 0.996 | 0.998 | 0.999 |
| 60 | 0.081 | 0.241 | 0.424 | 0.595 | 0.734 | 0.836 | 0.905 | 0.948 | 0.973 | 0.987 | 0.994 | 0.997 | 0.999 | 1.000 |

Since the random vibration stress levels must be so closely tailored to the design capabilities of each assembly to be screened, only general baseline values can be provided in specifications. The contractor must experiment with the equipment to find the optimal stress levels. The baseline values specified will not be different for different levels of assembly. The major differences between each assembly level will be whether or not power is applied and the system is monitored.

## Random Vibration Screening Parameters

There are five main parameters of random vibration screening which must be specified in the contract or SOW:,

1 Power spectral density (PDS)

2 Frequency range

3 Duration of screening

4 Number of axis, and

5 Performance monitoring.

The first two parameters, the PSD and the frequency range, are combined to give the overall Grms level and the vibration profile for the screen. Due to the varying parameters of electronic and electromechanical hardware and the complexity of optimizing the vibration levels, there is no one profile applicable for all equipment.

### *Vibration Profile*

The vibration profile specified by the Naval Material Command (NAVMAT) document P-9492,[3] implementing random vibration as a stress screen, is provided in Figure 5, Program F. Since NAVMAT P-9492 was published in 1979, this profile has been erroneously considered the "standard" random vibration profile and has been specified on numerous ESS programs. People have mistakenly assumed that since the profile was in the guidance document, it was applicable to all programs. In fact, this is the vibration profile as measured on the instrument panel in the cockpit of a military jet aircraft, and the profile was developed to screen a unit that would be used in that environment. Blanket imposition of this requirement, without consideration for the equipment design or the expected field environment, has resulted in screens that were ineffective or that caused damage to the hardware. A more efficient method of determining the required profile is to use the expected field environment as a baseline and experiment with the equipment to determine the PSD levels and profile necessary to screen out defects.

Random vibration profiles do not have to match the NAVMAT profile to be effective. Industrial studies have shown that effective screening can be accomplished with many different profiles. One study [4] of six different pieces of equipment shows good results with all six of the profiles shown in Figure 5. A profile giving white noise, such as in Program E, is probably the best one to start with in developing a screen. The Grms values of the six screens range from 2.67 through 6.3 Grms.

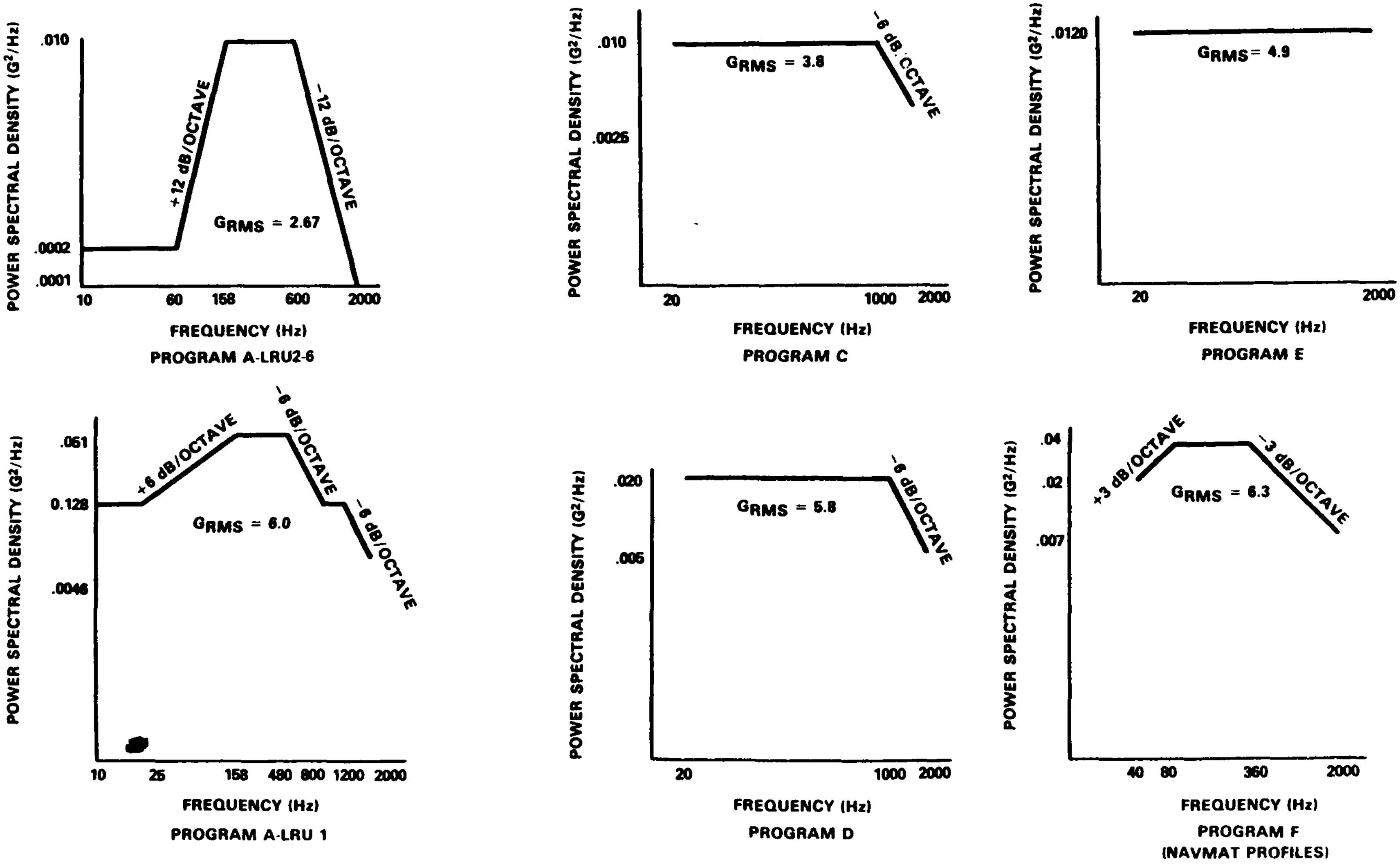


**Figure 5. Random Vibration Profiles**

*Root Mean Square Acceleration Force*

The Grms value is defined as the square root of the area under the vibration profile. In real terms, it is the time and frequency average of the vibratory energy produced by the profile. The energy introduced at any particular frequency is specified in terms of PSD. The dimensions of PSD are $g^2$ per hertz (Hz). Therefore, multiplying the PSD times the frequency bandwidth over which it is applied will give the energy in terms of $g^2$. The square root of this number will give the overall Grms level. The Institute of Environmental Sciences (IES) Guide to ESS for Assemblies[2] states that effective results have been achieved by random vibration screens with levels of 3 to 6 Grms. The NAVMAT profile produces a level of 6.04 Grms.

Figure 6 provides a random vibration envelope which may be used as a starting point for specific equipment random vibration screens. The parameters which determine the vibration profile are the PSD and the frequency. The PSD level should be between .02 and .07 $g^2$/Hz, with a nominal value of .04 $g^2$/Hz used as the baseline to begin tailoring the screen to the equipment. This level will be specified as the input level and the structural response of the equipment must be measured to ensure that the vibratory force is being transmitted to the component parts. The input level may be scaled up or down if the structural response of the equipment is not satisfactory.

*Frequency Range*

The frequency range is the other parameter in the development of the vibration profile. The input frequency range should be 5 to 2,000 Hz. The lower frequency stress will excite the same defects that will be exercised during transportation. The frequency range should excite a number of different modes of the equipment. The input bandwidth can be modified if experimental results show that the equipment response is still in the specified range.

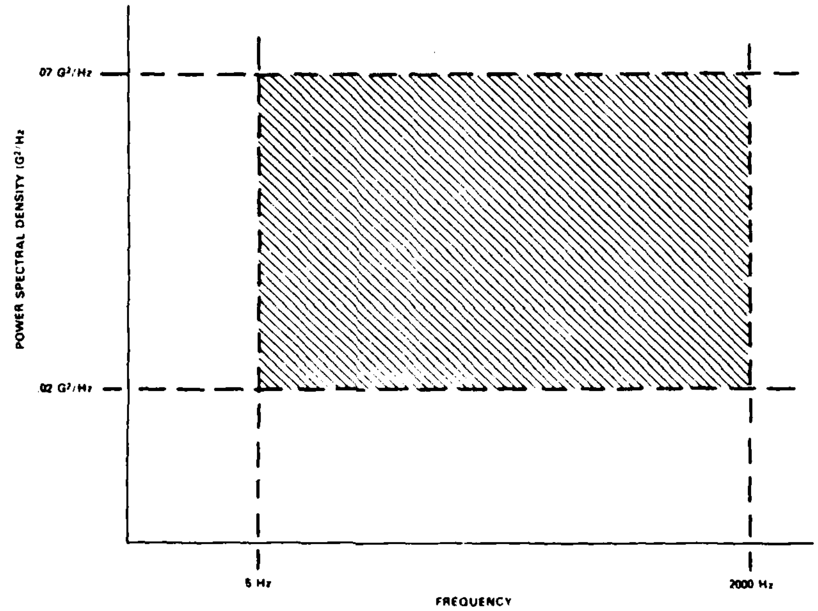


**Figure 6. Sample Envelope—Acceleration Spectra for Random Vibration**

If the equipment resonant frequencies fall within the input frequency range, excess energy could be seen by the equipment and damage could occur. During experimentation with the equipment, the resonant frequencies should be identified. When equipment resonant frequencies fall within the input bandwidth, there are two ways to prevent equipment damage. If the program is in the full-scale engineering development (FSED) stage, the equipment design can be modified to provide a more rugged unit and force the resonances to fall outside the frequency range. If this is not possible, or the equipment is in the production stage, intelligent notching of the input profile can be achieved.

Notching is the process of reducing the input PSD levels over a small frequency bandwidth so that equipment is not damaged due to overstress at the resonant frequencies. Notching the input profile must be closely tied to the equipment response. The notch should be only large enough so that the equipment response matches the specified profile. Overnotching, or reducing the input levels too much, will cause the equipment to see no stress at that frequency, so defects that would have been excited by that frequency go undetected. There is no notching in the field; those defects will show up as early life failures. Notching is a less desirable alternative than modifying the equipment; however, in some cases, design modifications are impractical.

Since the equipment response depends more on its structural characteristics than the input profile, tight control of the input profile is not necessary. It is recommended that tolerances of 20% be allowed for the overall Grms level, lower frequency limit, and upper frequency limit. Once the appropriate input PSD levels are determined, they should be controlled within ± 3 decibels (dB).

### *Screen Duration*

The other parameter in the screen strength equation for random vibration is the duration of the applied stress. The majority of the failures will be precipitated in the first portion of the screen, and continued screening will become less efficient. Figure 7 provides a graph showing the percent of defects that are precipitated in a 6 Grms screen over time. After 10 minutes, almost 70% of the screenable failures have been detected. Increasing the exposure time above 10 minutes may provide some additional fallout, but will also place extra stress on the good items. In addition, since the equipment should be exposed to vibration in each of the three orthogonal axis, screen duration should be kept as short as possible to reduce total screening time.

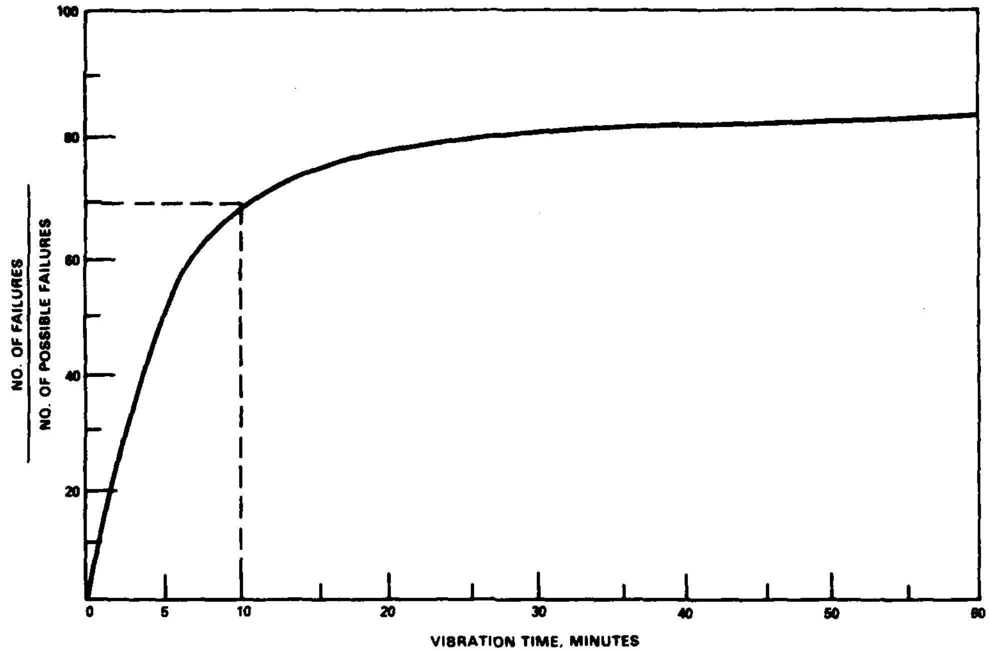


**Figure 7. Percent Fallout as Vibration Time Increases for Unit/System Level Screening (Using 6 Grms Random Vibration)**

*Number of Axis*

Defects are not always screenable in all three axis; some defect modes will only be precipitated by vibration in a specific axis. In order to screen as many defects as possible, random vibration should be applied in all three axis. This is especially true for units where parts can be mounted in many different orientations. For PWAs, screening may be reduced to one axis if the three-axis screening results indicate that a majority of the defects are precipitated in one axis. If single axis screening is used for PWAs, z-axis (perpendicular to the PWA plane) should be used. Simultaneous multi-axis excitation is also an acceptable method of performing a random vibration screen. If multi-axis screening is used, the duration of the screen should be at least 10 minutes.

*Performance Monitoring*

Powering up and functionally monitoring the equipment during vibration provides the most effective screen. However, for PWA screening, the cost and complexity of developing the monitoring equipment, signal generators, and associated cabling make most monitoring inefficient. Therefore, unless the PWA operation is simple enough for the monitoring system to be developed inexpensively, PWA screening should be done with power off and unmonitored. Unit (or higher) level random vibration screening should be done with power on and functional monitoring of the equipment. The intermittent failures that would be detected through monitoring will escape the PWA screen, but will be detected during the higher level screen.

## Summary

Random vibration is an effective screen for both PWAs and higher level assemblies. The vibration stress levels, however, must be tailored to the equipment design capabilities. The response of the equipment to the input stress is the factor of interest; the input does not have to be tightly controlled providing that the response is appropriate. The input stress may be either random or quasi-random. If equipment resonant frequencies are excited by the input stress, the equipment design should be modified to change the resonant frequency. If design modification is not possible, input stress notching may be applied, providing that the equipment response does not fall below the specified response levels. All specified values are baseline values to be used as take-off points for equipment experimentation to determine the actual stress levels. Equipment characterization surveys (see page 33) are necessary to determine the equipment response to the input stress. The baseline levels to be used in random vibration screening are presented in Table 5.

**Table 5. Baseline Vibration Conditions**

| LEVEL | INTENSITY (Grms: $g^2$/Hz) | AXIS | DURATION PER AXIS (minutes) | POWER ON | MONITOR | FREQUENCY RANGE (Hertz) |
|---|---|---|---|---|---|---|
| Assembly | 6: 0.04 | 3 | 10 | No | No | 5 - 2,000 |
| Unit | 6: 0.04 | 3 | 10 | Yes | Yes | 5 - 2,000 |
| System | 6: 0.04 | 3 | 10 | Yes | Yes | 5 - 2,000 |

## Sample Statement of Work (SOW) for Random Vibration

The following statement of work clause shall be utilized to specify the performance of random vibration screening on TROSCOM equipment:

*Random vibration shall be performed on all units, PWAs, and power supplies, including spares, produced under this contract. The baseline values provided in the following table shall be used as starting points for the development of the screen.*

| *LEVEL* | *INTENSITY (Grms: $g^2$/Hz)* | *AXIS* | *DURATION PER AXIS (minutes)* | *POWER ON* | *MONITOR* | *FREQUENCY RANGE (Hertz)* |
|---|---|---|---|---|---|---|
| *Assembly* | *6: 0.04* | *3* | *10* | *No* | *No* | *5 - 2,000* |
| *Unit* | *6: 0.04* | *3* | *10* | *Yes* | *Yes* | *5 - 2,000* |
| *System* | *6: 0.04* | *3* | *10* | *Yes* | *Yes* | *5 - 2,000* |

*The contractor shall conduct testing and analysis of initial units to determine the article response characteristics. The above baseline values may be modified, subject to Government approval, if the vibration levels cause damage to the test article, exceed design capability or fail to precipitate defects that surface at a later screen or in field use. The number of axis may be reduced, subject to Government approval, if evidence shows that vibration in fewer axes successfully screens out the same number of defects.*

*The specified intensity value shall be measured on the test article after mounting on the vibration fixture. Measured values at different points on the article shall be averaged to compare to the specified intensity. Functional testing shall be performed immediately prior to, and immediately following, the random vibration screen.*

*All the failures occurring during random vibration screening shall be analyzed for root cause, entered into the failure reporting and corrective action system, with verification that corrective action will preclude recurrence of the failure mode. If size, mass or cost preclude random vibration screening at the unit or system level, the contractor shall recommend vibration screening at lower levels and/or full scale performance testing of the entire system for a failure-free period, subject to approval by the procuring activity.*

*Results of vibration screening shall be included in CDRL number _____"ESS Performance Report" and procedures used to conduct vibration screening shall be included in CDRL number _____"ESS Procedures."*

## RANDOM VIBRATION CHARACTERIZATION SURVEY

After production of an initial prototype in the development phase or first article in the production phase, a unit shall be subjected to a vibration characterization survey. MIL-STD-781D, Task 201, paragraph 201.2.2, is an appropriate task to be invoked in a contract SOW to perform a vibration survey. Data item description DI-RELI-80248 provides a description of the data and structure of the report to be submitted by the contractor.

The purpose of the survey is to determine if any resonant conditions exist within the test article or test fixture. In addition, the survey will disclose design weaknesses that become apparent from exposure to vibration. Early discovery and correction of these weaknesses is essential to project success and incurs far less cost than later discovery. For this reason, the vibration survey should be conducted before other reliability testing is initiated.

The vibration characterization survey may be performed in parallel with, prior to, or after, the thermal survey. Corrective action resulting from discoveries made during these surveys can impact design and must be resolved prior to further testing to ensure valid results.

The results of the vibration survey will be used to validate the proposed baseline vibration levels or to establish alternate levels. The approved vibration intensity, frequency range, duration, and axis of acceleration will then be incorporated into the ESS procedure for performing vibration screening. Optimum levels of these parameters will be adequate to precipitate defects, but not cause damage to the article. The screen parameters should exceed the vibration environment expected during the article's life.

Vibration levels expected over an item's life cycle include those anticipated during use, storage, and transport. Transportation often involves trucks in Army environments, and it has been shown that truck transport induces vibration peaks at frequencies as low as 2 Hz. It is therefore important to include this low frequency vibration component for articles intended for truck transport.

An output of the survey is a plot showing vibration input levels compared to article response levels over the tested frequency range. This is important because the specified vibration levels are to be measured on the article rather than the fixture or control commands. The measured response of the article can vary from the input energy.

If the article has self-contained vibration dampers or isolators, these devices should be removed to ensure that vibration energy reaches internal components that may have workmanship flaws. A diagram of the survey setup should be included, as well as a discussion of measurement accuracy.

A vibration survey should be conducted initially in the development phase to define vibration ESS levels as early as possible. During the production phase, a first article from production should be subjected to the same vibration survey conducted during development to validate that the parts, processes, and personnel used in production have not caused a deviation from the performance of hardware produced during development.

Approximate cost for a vibration survey of a PC board or small unit is less than $1,000. If there is insufficient funding to perform a vibration survey during production, the validity of the development results will have to be assumed. This could lead to later identification of problems caused by parts or processing changes used in production. A vibration survey provides the earliest opportunity to disclose such problems, thereby maximizing the potential for project success.

**Sample Statement of Work (SOW) for Vibration Survey**

*A vibration characterization survey shall be performed in accordance with MIL-STD-781D, Task 201, paragraph 201.2.2, for each level of assembly to be screened. After performance of the survey, a vibration survey report shall be prepared in accordance with data item description DI-RELI-80248 and delivered in accordance with the CDRL. The report shall contain the results for each level of assembly subjected to screening. In addition to the requirements of DI-RELI-80248, a plot shall be included in the report showing vibration input, command levels, and test article response levels versus frequency.*

*Vibration levels for the article tested during the survey shall be the baseline levels specified for screening.*

*Procedures used to conduct the vibration survey shall be included in CDRL number _____ "ESS Procedures," and shall be approved by the Government prior to use.*

**Review of Vibration Survey Report**

This section assists the Government activity having responsibility for review and approval of the vibration survey report.

A vibration survey report provides the results of vibration tests conducted by the contractor to determine if any resonant conditions exist within the equipment. Accelerometers are placed at various locations on the article being vibrated to measure the acceleration forces at specific points. Measurement data can then be analyzed to assess possible overstress of structures or components. These elements are derived from MIL-STD-781D, Task 201, paragraph 201.2.2, which is appropriate task to invoke in a contract SOW for performing a vibration survey. Additional details are provided by data item description DI-RELI-80248 which describes the data and report to be submitted by the contractor.

The report should state the initial vibration intensity and frequency range, and any increased levels that my be applied. Any test article failures occurring during the vibration survey shall be reported, investigated, and analyzed for cause. Necessary corrective action shall be implemented and verified before further testing commences.

Equipment shall be mounted in a manner simulating actual use. Vibration in more than one axis may be required and should be accurately reported.

The following checklist is to be used by the activity responsible for approval of the vibration survey report. The reviewer should note in the review any discrepancies, missing information, or other shortcomings of the contractor's report. Essential comments (not suggestions) by the government reviewer will constitute rejection of the report and will require revision and resubmission by the contractor.

**Vibration Survey Report Checklist (Ref. MIL-STD-781D, Task 201, Paragraph 201.2.2, and Data Item Description DI-RELI-80248)**

- Vibration frequency spectra are stated. Revised frequency range is stated if applicable.
- Specified vibration intensity levels are stated. Revised levels are also stated in cases where intensity levels are modified during the survey.
- Location of accelerometers is stated.
- Axis of vibration are stated and are as required by the baseline values. Changes to the baseline values shall have technical justification described.
- Techniques used to perform the survey and record accelerometer output are described in sufficient detail.
- Fixture resonance was measured over the vibration test frequency range. Final test fixture configuration has no resonance within the screening frequency range.
- Duration of random vibration is stated.
- Rationale is provided for selection of items monitored by sensors and for accelerometer placement.
- Measured vibration values of the structural package and of parts and subassemblies mounted therein are reported.
- A comparison has been made of actual vibration data within calculated or specified levels.
- Identification of the article under test, date of test, and location of test facility are provided.
- Test methods are described including a description of instrumentation used, manufacturer, model number, and accuracy.
- A discussion of measurement accuracy is provided.
- Any resonant conditions exhibited in the article during vibration are identified.
- Analysis has been performed to assure that acceleration forces resulting from the identified resonance do not overstress any component or assembly.
- Description of failures occurring during the survey and corrective action taken to preclude recurrence.
- Failures are analyzed to determine whether cause of failure was due to defect or damage from screening.
- A plot is provided showing vibration input levels versus article response levels over the tested frequency range.

# SECTION VI. OTHER CONSIDERATIONS

This section discusses other factors to be considered when specifying ESS in production or development contracts.

## POWER ON vs. POWER OFF

The question arises during ESS planning, "Should the article under test be powered and monitored during screening?" The answer depends on the amount of effort required to fabricate operational interfaces with the article.

### Power On vs. Power Off—Part Level

At the part level, the fixture required to mount and test a part is relatively simple. Many companies produce component testing systems that will simultaneously test dozens or hundreds of a given component. The mounting interfaces can be adapted to many physical configurations, and the electrical input power and signals can be selected for a given type of component. Testing in large quantities and employing commercially available test equipment reduce the cost per part for functional testing.

Using such test equipment, parts can be subjected to environmental stresses while being powered and monitored to disclose intermittent failures that only occur under stress. Examples of such defects include poor internal solder joints or other intermittently open connections, or a contaminant that intermittently causes a short. Functional testing at room temperature will not expose such intermittent defects that only occur during temperature extremes or vibration.

Compared to the cost of detecting failures at higher levels of assembly, powered and monitored stress screening of parts is cost effective and prevents schedule slippage. For these reasons, it is recommended that part screening include powered and monitored stress screens.

### Power On vs. Power Off—Assembly Level

At the assembly level, functional test equipment usually has to be specially designed and built for the specific assembly to be tested. Generic test equipment for assemblies is not widely available commercially because assemblies perform specific processes, have specific input power and signal requirements, and produce specific outputs that are not common to other assemblies. Test equipment must be able to generate these input power voltages and signal types, and be able to record assembly output and response to signal variations and environmental stresses. The complexity of the test equipment increases rapidly and becomes a major cost consideration. In-house test engineering departments are often called upon to design and fabricate one or two test sets for a certain assembly. The cost per article tested is, therefore, quite high due to the specialized, one-of-a kind design and fabrication effort involved in producing the test set.

The objective of powered and monitored assembly screening is to detect intermittent defects that only occur under certain environmental stresses. Because of the cost consideration, powered and monitored stress screening may be postponed to the unit, or system level unless failure of the assembly is critical. ESS should still be performed on assemblies; it is simply done without powering up or monitoring the assembly.

Screening assemblies without being powered or monitored will precipitate the same number of defects as screening with power and monitoring. Some of the defects (50%) will be caught by the post-ESS functional test, but the rest will remain in the hardware until unit-level ESS is performed with power on and functional monitoring, or until the failure occurs in the field. Thermal cycling temperature limits are wider for assemblies than for units, allowing intermittent defects that occur only near the assembly-level temperature extremes to remain undetected. Postponing powered and monitored ESS from the assembly level to the unit level simply postpones the detection of defects precipitated by the unpowered, unmonitored stress screen applied at the assembly. One disadvantage of this practice is that failures detected at a higher level of assembly require more time and expense to diagnose and repair.

**Power On vs. Power Off—Unit (or Higher) Level Screening**

It is essential that articles undergoing unit (or higher) level ESS be powered up and monitored during the stress screen. These articles are at the last stage of production before being placed in field use. Undetected defects remaining after this screen will cause field failures that cost 10 to 15 times more to repair than in-house failures. Customer (user) satisfaction will wane and apparent reliability will decrease as a result of field failures.

Fabrication of interface devices is less complicated at the unit level, as internal processing need not be simulated for powering and monitoring. The performance of the unit as a whole can be monitored with fewer discrete output and input connections than for lower-level assemblies.

Although the temperature extremes for unit-level thermal cycling are less than those for assemblies, the stress is adequate to precipitate and detect most intermittent failures remaining in assemblies that were not powered and monitored during the previous screens. Production processes, piece parts, electrical connections, and fasteners that are added to a unit at final assembly require unit-level ESS to stimulate part or workmanship defects introduced by these final assembly operations. Powered and monitored stress screens at this stage are necessary to detect failures that only appear during temperature transition, temperature extremes, and vibration. Screening at lower levels of assembly will help reduce defects reaching this stage, but powered and monitored unit-level ESS is essential for detecting defects resulting from previous unmonitored screens and from final assembly operations.

## PRE- AND POSTSCREEN FUNCTIONAL TESTING

Pre- and postscreen functional tests are essential to a properly conducted ESS program. Screen effectiveness can only be determined through an evaluation of the failures precipitated by the screen. If there are defects present at the start of the screen, the apparent number of failures will be higher than the number of defects actually precipitated by the application of environmental stress. This could cause a screen to be evaluated as effective when, in actuality, the defects were present and detectable prior to screening. Postscreen testing is also essential to detect the defects that were precipitated during the screen. This is especially important if the item was not powered up and monitored during the screen.

Functional tests should be performed immediately prior to the screen and immediately after its completion. This will serve to eliminate concern about whether the defect was precipitated during the screen, or if it was introduced during cleaning or handling the item between the functional test and the application of stress. For best results, the pre- and postscreen tests should be performed when the item is in the test chamber and ready for screening. In addition, both functional test procedures must be identical to assure that the defects were precipitated by the screen, rather than being present, but undetected, prior to the screen.

Functional testing should be performed after the application of each stress, not just prior to and after the entire screening process. This will allow an analysis of the effectiveness of each stress and may be used for modifying the screening program. When possible and cost effective, functional testing should also be performed during the application of stresses. This will ensure that stress-dependent faults such as intermittents and temperature- or timing-sensitive defects will be detected and can be removed.

## SCREENING SEQUENCE

There is some debate over the sequence in which environmental stresses should be applied to hardware. The debate, however, is not over whether screening will be effective, but which sequence will optimize screening effectiveness. Screen effectiveness will be achieved regardless of the screening sequence used.

Most authorities agree that thermal cycling should be performed first at the PWA (or smallest assembly level) and followed by random vibration. This screen should then be followed by thermal cycling at the next highest level of assembly. Vibration and thermal cycling both work in conjunction with each other; one stress precipitates some defects close to the point of failure and the other stress then accelerates the failure to the point of detection.

There are no standard screening sequence requirements that should be used for all screening programs. The best way to determine the optimum sequence is through experimentation with different sequences, when time and money are available. If it is not possible to do this, thermal cycling should be performed first, followed by random vibration.

When other stresses are used for screening (i.e., overpressure, immersion, etc.), they should be performed after thermal cycling and random vibration (if they are applied). Thermal cycling and random vibration will serve to initially stress the connections and interfaces that will then be screened through applications of other stresses.

# SECTION VII. ESS PROGRAM ELEMENTS

This section describes the essential elements of an ESS Program, and provides sample SOWs which can be involved in whole or in part in contracts. Data items to be delivered in conjunction with the sample SOWs are also described and checklists are provided for reviewing data deliverables.

An ESS Program is recognized by military and commercial equipment manufacturers as an effective tool for reducing early life failures and improving field reliability. ESS results in fewer field failures by detecting defects in parts and workmanship before the equipment leaves the factory.

The essential elements in an effective ESS Program include the following:

- Equipment and Process Characterization
- ESS Plan
- ESS Procedures
- ESS Performance Reports

## EQUIPMENT AND PROCESS CHARACTERIZATION

The contractor must analyze the article being produced to identify its response to input stimuli. Different masses require different thermal cycling profiles to induce the same response in the article. This response is determined by a thermal characterization survey which will provide the contractor with the knowledge required to prevent damage to the article, while maintaining an effective screen. (For discussion of the thermal survey, and the associated report, refer to page 21).

The vibration characterization survey yields knowledge about the response of an article to input vibration stimulus. Resonances can be identified and article response can be measured to ensure adequate stimulation of hardware and avoidance of damage due to overstress. (For discussion of the vibration survey and its associated report, refer to page 33)

Production processes require analysis to determine possible failure modes that could result from workmanship errors, defective parts or materials, and flaws that are difficult to detect. Small electronic parts such as microcircuits and semiconductors can contain flaws that are impossible to detect visually, or only fail under specific stresses. Poor solder joints have typical failure modes that can be precipitated by certain types of stress. Sealed assemblies can be defective due to contamination or improperly applied sealant. Knowledge of the possible flaws in manufacturing methods and processes should be included in the determination of stress types within the ESS Program.

The design and intended use of the article being procured should be thoroughly analyzed by the ESS staff. Knowledge of hardware configuration is of primary importance in building an effective ESS

Program. Screens are not to be applied universally, without consideration of the types of parts and assemblies contained in the article. Defects in printed wiring assemblies are best detected with certain types and magnitudes of stress. Defects in electronic units are best detected by different profiles of applied stresses. Defects in mechanical assemblies can be precipitated by a variety of stress types that must be specific to the type of device and its method of manufacture.

The intended operational environment is another factor affecting the activities of the ESS Program. Transportation profiles provide input to the necessary vibration spectra. Storage and operational temperatures affect thermal screening profiles. An article should not be exposed to its maximum stress for the first time when it is in the user's hands in the field. Much military hardware is critical; i.e., failure could result in personnel injury or loss of mission. For this reason, it is imperative that military hardware be as defect-free as possible. Analysis of the article's environment throughout its life cycle can identify stress screens to precipitate failures that would otherwise occur in the field.

## ESS PLAN

An ESS Plan is the first deliverable document required by the contract, and is the Government's earliest opportunity to assess a manufacturer's ability to implement an ESS Program. The ESS Plan provides the manufacturer's general outlines for the design and implementation of ESS. In general, the ESS Plan should show that the manufacturer has a basic knowledge of ESS, including the types of stresses used, how to determine stress levels, and how to verify the effectiveness of the screens.

The areas covered by the ESS Plan will differ, depending on whether the contract is for development or production. The *development phase* ESS Plan should concentrate on the identification of stresses and assembly levels to be screened, experimentation to determine the most effective stress levels that will stimulate defects while not damaging good equipment, and gathering data to be used for effectiveness evaluation and future screening requirements.

The *production phase* ESS Plan should contain more well-defined ESS parameters, since the experimental work should have been done in the development phase. The production phase should include the identification of the items to be screened, the stress levels to be applied to each item, and the exposure time or number of thermal cycles used as a baseline. The ESS Plan in the production phase should also stress the importance of modifying the ESS Program based on screening results. Significant numbers of field failures attributable to workmanship could indicate an inadequate screen intensity. Damage to equipment during screening could indicate excessive screen intensity. The rationale and methods for adjusting screen intensity should be provided by the Plan.

### Sample Statement of Work (SOW) for ESS Plan

The following clause shall be inserted into the SOW for environmental stress screening:

*The contractor shall prepare and submit an ESS Plan, in accordance with CDRL number _____ describing the approach to the implementation of an ESS Program. The plan shall address, as a minimum, the following items:*

- *Identification of the levels of assembly to be screened*
- *How initial stress levels will be determined*
- *How screen effectiveness and nondegradation of equipment will be verified*
- *How failed equipment will be handled*
- *Description of the data collection and analysis system to be used*
- *Location of ESS efforts (whether in-house or contracted out)*
- *Description of the type and amount of equipment to be used*
- *A time and milestone schedule for getting the screening program on line.*

**ESS Plan Review**

When the ESS Plan is submitted, it will be reviewed by the responsible Government activity for completeness and soundness of the technical approach. If there are questions or uncertainties about the manufacturer's plan, the most appropriate time to resolve them is while the program is in the planning phase.

Since the Plan is delivered while the details are being worked out by the manufacturer, it will only contain a description of the screening approach. The Plan should address all the items called out in the SOW. A checklist to be used in reviewing the ESS Plan follows.

**ESS Plan Checklist (Ref. MIL-STD-781D, Task 401 and DI-R-8XXX85)**

- How assembly levels to be screened will be chosen
- Which types of stresses will be applied
- How applied stress levels will be determined
- How screens will be shown to be effective and nondamaging to good equipment
- Will the items have power applied and be monitored for intermittent defects during the screen
- When, why, and how screening will be modified
- How failed items will be rescreened
- What type of data collection and analysis system will be used

- What type and amount of equipment to be used

- Time and milestone schedule for implementing the screening program (delivery and installation of equipment, surveys, and effectiveness testing, training, etc.)

- How failure analysis will be conducted and the method for feedback of corrective action

- Where ESS will be performed (in-house or contracted out).

## ESS PROCEDURES

The ESS Procedures are the detailed steps taken during the implementation of the ESS Program. The Procedures should contain the specific method of accomplishing each task and should include all information necessary to perform ESS. The Procedures should cover the detailed steps of applying the environmental stresses, including the stress levels, applied stress profiles, and means of mounting the item to the test equipment. The Procedures should also define data collection and analysis, use of functional tests, and handling of defective units. Another important requirement is that ESS Procedures address the steps to be taken to modify the screening program when appropriate. The Procedures should also identify the analysis and results that would necessitate changes, as well as all authorizations (including Government authorization) that must be obtained prior to implementing the change.

The Procedures should follow the approach provided by the manufacturer in the ESS Plan. While baseline stress levels are given in the Plan and the SOW, the ESS Procedures must have provisions for modifying those levels based on analysis or experimental results.

Procedures for performing thermal cycling, random vibration, or any other prescribed stress screen shall be written in sufficient detail for an operator to understand and perform without seeking other guidance. In addition to procedures for performing production-type stress screens, preproduction surveys shall be governed by appropriate ESS Procedures.

If a thermal or vibration survey is required by the contract, the steps to be used during the surveys should be provided as ESS Procedures. Following the performance of the surveys, a revision of the ESS Procedures may be required in order to use the survey results to modify the applied stress levels.

ESS Procedures can also be used for inspecting and auditing a contractor's ESS Program. These give details on who, how, when, and why each step will be accomplished and are subject to verification by outside sources at any time during contract performance.

**Sample of Statement of Work (SOW) for ESS Procedures**

The following clause shall be used in the SOW to require delivery of ESS Procedures.

*The contractor shall prepare detailed ESS Procedures with associated stress levels for each item, at each applicable assembly level, as required in the Government-approved Plan. The individual ESS Procedures and stress levels shall be submitted as required by CDRL number _____. The approved approach as outlined in the ESS Plan shall be applied to develop each screen. The Procedures shall include, as a minimum, the following items:*

- *Identification of each assembly to be screened.*
- *Detailed description of the stress types, stress levels and profiles, and amounts of exposure time for each assembly to be screened. The description shall include the number of thermal cycles or axis of vibration, the thermal rate of change, number of failure-free cycles, and sequence of screening.*
- *Determination of whether power will be applied during screening and, if so, identification of the specific parameters to be monitored.*
- *Use of functional tests prior to screening to verify quality of equipment and after screening to ensure all defects are eliminated.*
- *Definition of what will be counted as a failure during screening.*
- *Identification of screening location.*
- *Description of procedure for modifying ESS Program, including justification for modification and obtaining in-house and Government approval.*
- *Procedure to be followed for feeding back screening results into screen specifications.*
- *Procedure for conducting thermal survey, if applicable.*
- *Procedure for conducting vibration survey, if applicable.*
- *Procedure for performing thermal stress screening, if applicable.*
- *Procedure for performing vibration screening, if applicable.*

## Review of Contractor ESS Procedures

The Government must review the contractor's ESS Procedures to ensure compliance with the contract and the adequacy of the technical program. The Procedures contain the detailed steps to be taken in the performance, monitoring, and modification of the ESS Program. Particular attention should be given to the feedback of thermal and vibration surveys to the applied stress levels, and to the necessity of iteration and modification of the Program based on screening and field performance results.

The following checklist may be used when reviewing the contractor's ESS Procedures. If any areas are not addressed, the contractor should be required to revise the Procedures prior to approval.

### ESS Procedures Checklist

- Are the stress types to be applied to each assembly identified?
- Are all assemblies to be screened identified?
- Are the stress levels, profiles, number of cycles/axis, thermal rate of change, stress exposure duration, failure-free intervals, and test fixture mounting identified?
- Do the procedures indicate, at each assembly level, whether power will be applied?
- Are the specific functional parameters to be monitored identified?
- Is the sequence of the screening tasks identified (pre- and postscreen functional tests, environmental screens)?
- Will the screening be done in-house or at a subcontractor?
- Is a failure defined?
- Is a data collection system described?
- Is rescreening of reworked items required?
- Do procedures identify all personnel who must sign approval and authorization for screen modification?

## PERIODIC ESS PERFORMANCE REPORTS

At the interval prescribed in the CDRL (usually every 30 days), the contractor should report the results of screening activities. The ESS Performance Report is a formal record of these results. DI-RELI-80249 provides a detailed description of the necessary contents of the report. when a contract requires only one type of stress application, the Data Item Description (DID) may require tailoring to delete the inapplicable sections.

All ESS activities should be reported, including the number and types of units tested, subassemblies tested or parts tested, and all failures occurring during these tests and during the functional tests immediately preceding and immediately following the stress screen.

Another important feature of this report is the analysis of screening results to determine screen effectiveness. Failures occurring at assembly or unit-level screens may indicate an ineffective screen at the subassembly or part level. This information should lead the contractor to increase the intensity of the lower level screen to precipitate more latent defects at the lower assembly level. An analysis of screening effectiveness is an essential tool for maintaining control of the ESS Program, and should be reported periodically by the contractor.

Approval of each monthly submittal would be a burden to the Government approval activity, so only the first submittal requires approval. The criteria for approval includes proper organization of the report, and verification that the elements contained in the attached checklist are addressed (when applicable).

### Sample Statement of Work (SOW) to Prepare ESS Performance Reports

*Application: Development/Production; Contract/RFP*

*The contractor shall prepare periodic environmental stress screening (ESS) reports in accordance with CDRL number _____ and DI-RELI-80249. The reports are the formal record of the contractor's ESS results, including results of the functional tests performed prior to and after each screen, and shall provide feedback to adjust the stress levels such that the screen is effective in precipitating most of the defects, but does not cause damage to the article.*

### Checklist for ESS Performance Report

*Random Vibration*

- Report period (dates of the time period covered by ESS report)
- Equipment nomenclature

- Equipment part number
- Subassembly part number (if ESS is performed at the subassembly level)
- Date of the vibration screen
- Serial number of the unit(s) subjected to vibration screen
- Axis of vibration
- Time at the start of vibration
- Time when vibration stopped
- Duration of the vibration screen
- Elapsed time from the start of the vibration screen to each failure (if any)
- Failed component (PWA, unit, or assembly)
- Part number or name of failed part
- Reference designation of failed part
- Description of part failure
- Cause of failure of part
- Corrective action required, taken or planned
- Analysis of results to determine screening effectiveness
- Any recommended changes to the ESS Procedures or Program
- Categorization of failure (design, parts, workmanship, etc.)

***Temperature Cycling***

- Report period (date(s) of the time period covered by ESS report)
- Equipment nomenclature

- Equipment part number
- Subassembly part number (if ESS is performed at the subassembly level)
- Date and time of temperature cycling (at the start of each cycle)
- Serial number of the unit(s) subjected to temperature cycling
- Elapsed time from start of temperature cycling to each failure (if any)
- Number of the cycle during which each failure occurred
- Indication of point in cycle when failure occurred (hot or cold)
- Failed component (PWA, unit, or subassembly)
- Part number and name of failed part
- Reference designation of failed part
- Failure mode of failed part
- Cause of failure of part
- Corrective action required, taken or planned
- Analysis of results to determine screening effectiveness
- Any recommended changes to the ESS Procedures or Program
- Categorization of failure (design, parts, workmanship, etc.)

***Laboratory Equipment Data***

The following data regarding laboratory equipment used to perform the environmental stress screen shall be included in the initial ESS report submittal. This data shall be included in a subsequent submittal only if any laboratory equipment is replaced prior to completion of the screening phase.

*Random Vibration Equipment*

- Identification by model number and manufacturer of equipment in the vibration system
- Description of mounting arrangement and accelerometer locations, if applicable
- A plot of the actual random vibration spectrum recorded during vibration and that which is used for control purposes, identifying frequencies, power spectral density, and degrees of freedom (or actual filter bandwidths used in the analyses of the spectrum)
- Description of procedure used to perform the vibration.

*Temperature Cycling Equipment*

- Identification by model number and manufacturer of the temperature chamber
- Maximum and minimum temperatures
- Maximum and minimum rate of change of temperature
- Description of procedure used to perform the temperature cycling.

***Functional Test Results***

The report includes results from functional tests performed immediately prior to and after subjecting a unit the the stress screen.

# SECTION VIII. ENVIRONMENTAL TESTING LABS

Using environmental testing labs (also referred to as screening houses) can be an alternative to performing in-house screening. The testing labs will perform all of the requirements for surveys and screening projects. Different labs offer different sizes of screening equipment to fit different needs. Some labs screen only microelectronics, while others will screen any variety of assemblies, units, or systems. Most, however, only perform thermal cycling and/or vibration screening. Since these two forms of screening are usually the most beneficial and widely used, most ESS Program needs can be satisfied through the use of screening houses.

The testing labs vary in price according to the screening required. For example, power-on screening is more expensive than power-off screening. Many labs require manuf .cturers to supply their own signal generators and monitoring equipment if power-on modes are desired. Others, however, have their own equipment for power-on screening and have technicians who will do the monitoring. Some labs do both thermal cycling and random vibration screening while others specialize in one area.

Screening houses can be very beneficial for the contractor who does not have the revenue to acquire all of the screening equipment he needs. However, if the screening is going to proceed over a long period of time and the production lot is large, purchasing the equipment and performing in-house screening may be more cost effective.

Cost rates for testing labs are figured in many ways. Some labs charge for thermal cycling by the day and for vibration screening by the hour, while others charge according to the screening requirements of the item. Testing lab charges for screening are very diverse. To find out what specific costs will be for screening by a testing lab, contact them directly with the item specification and SOW. They can then provide an estimate for performing the screening. This cost should be compared to the in-house screening cost development in the cost model described in Section IX to determine the most cost-effective alternative.

# SECTION IX. COST MODEL

This section contains mathematical cost models used to determine screening costs and effectiveness. The models indicate approximately how many units have to be in the production lot to allow ESS to be cost effective. Also, an estimate is derived demonstrating screening cost versus field failure cost to determine potential cost savings. For a more detailed analysis, a much more complex model is required and has already been developed; the Institute of Environmental Sciences (IES), the Rome Air Development Center (RADC), and the US Army Armaments, Munitions, and Chemical Command (AMCCOM) have developed stress screening cost analysis models for various levels of assembly. Many more parameters, however, are needed for these analyses. This model is intended to be as **simple** as possible. The model has been adapted to the LOTUS software package to assist in calculating the screening and field failure costs. The disk with the LOTUS cost model can be obtained by contacting:

Commander
Belvoir RD&E Center
ATTN: STRBE-TQE
Fort Belvoir, VA 22060-5606

Commercial: 703/664-5771
AUTOVON: 354-5771
E-mail: STRBE-TQE @
Belvoir-EMH3.ARMY.MIL

The user is encouraged to utilize the other alternative cost models if enough resources are available, and if incorporation of more parameters is desired. If these other models are not satisfactory to the user, adapting the cost model is encouraged.

## COST MODEL STRUCTURE

The cost model is composed of three sections:

- Stress Screening Cost Model
- Field Failure Cost Model
- Cost-Effectiveness Comparison

Each model progresses from a top tier equation presenting basic cost elements to a second tier that defines the major sub-elements. Next, a third level is provided that consists of a checklist and definitions of parameters used when estimating each sub-element cost.

To assist in using the cost model, flow diagrams in Figures 8 through 14 lead the user through the model.

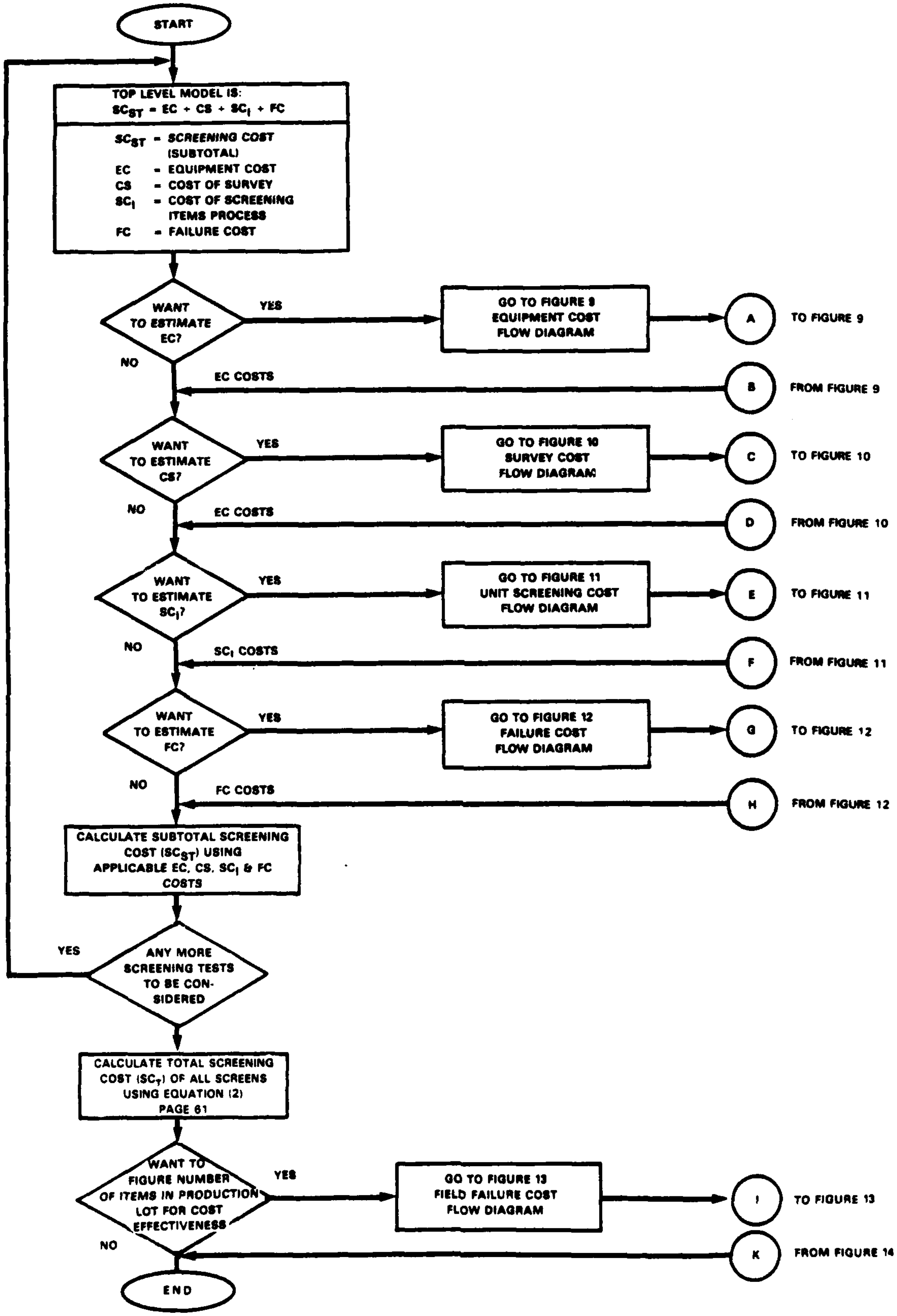


Figure 8. Top Level Cost Model

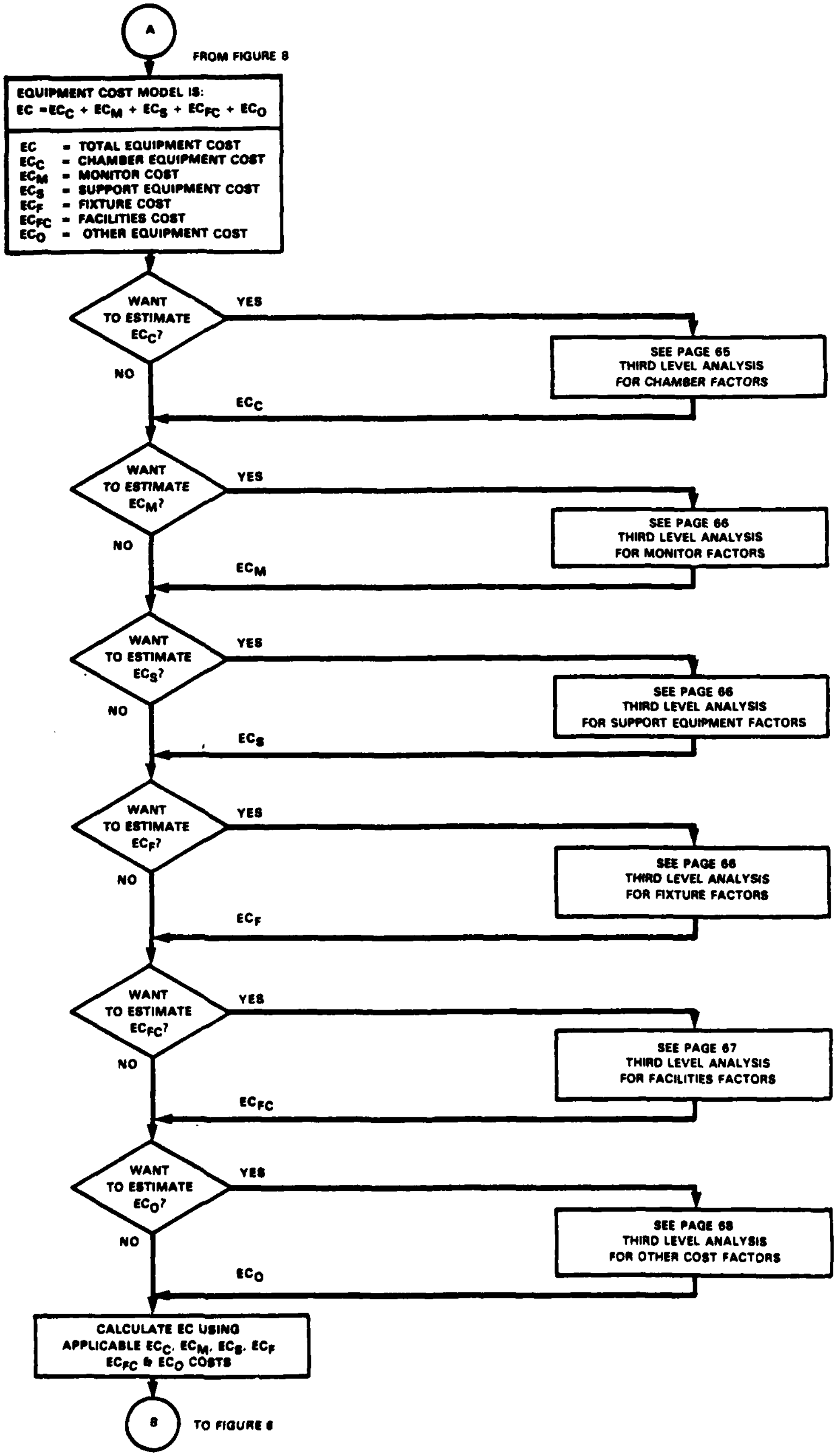


Figure 9. Equipment Cost Flow Diagram

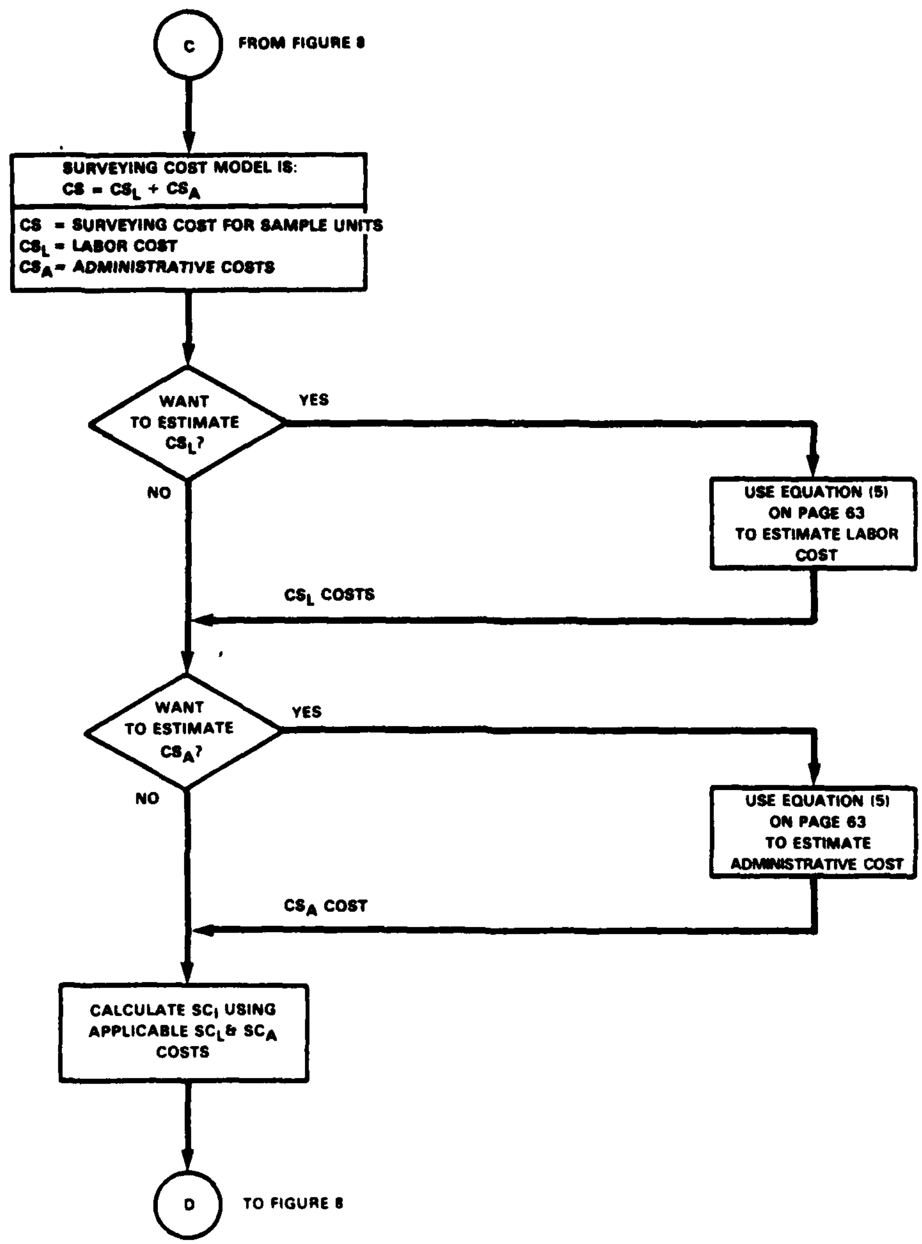


**Figure 10. Survey Cost Flow Diagram**

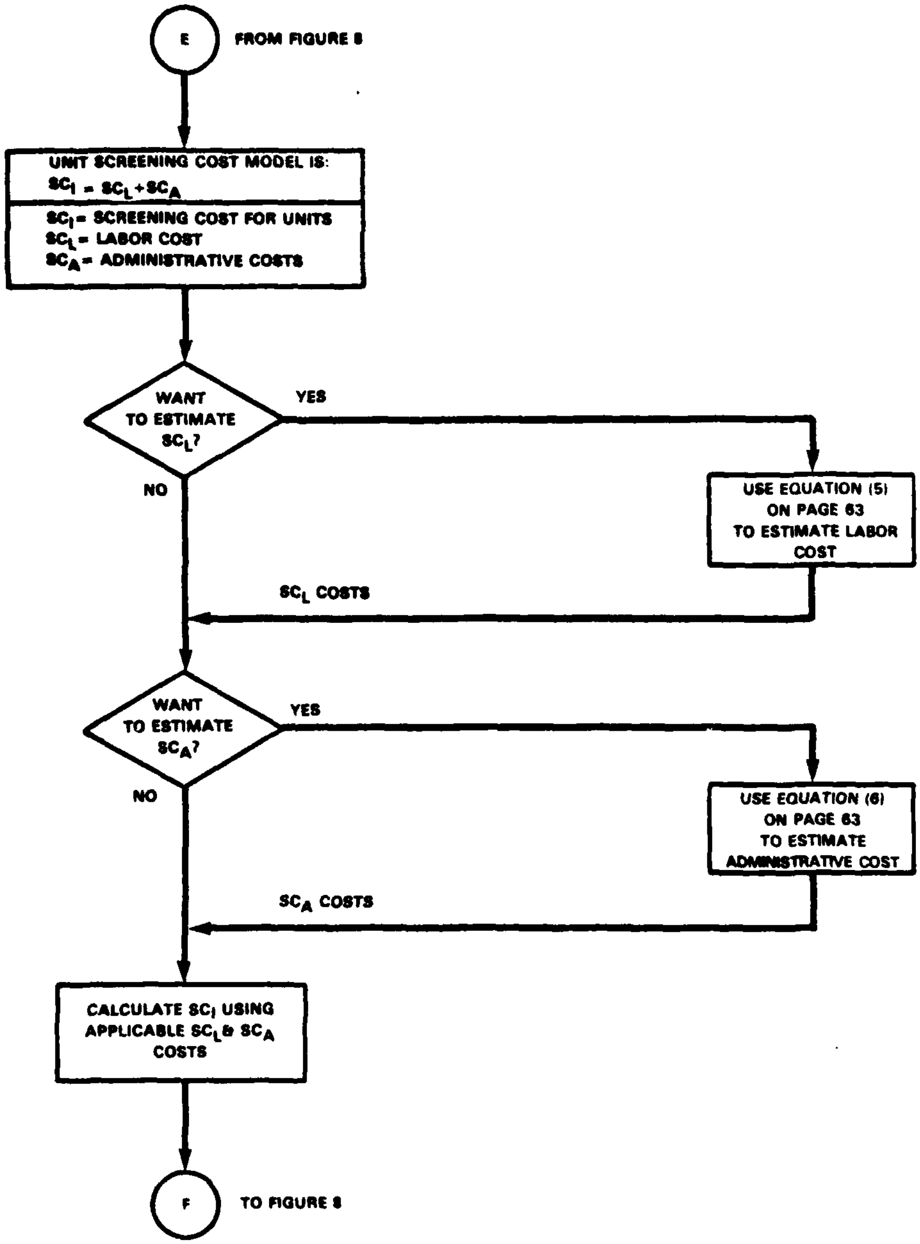


**Figure 11. Item Screening Cost Flow Diagram**

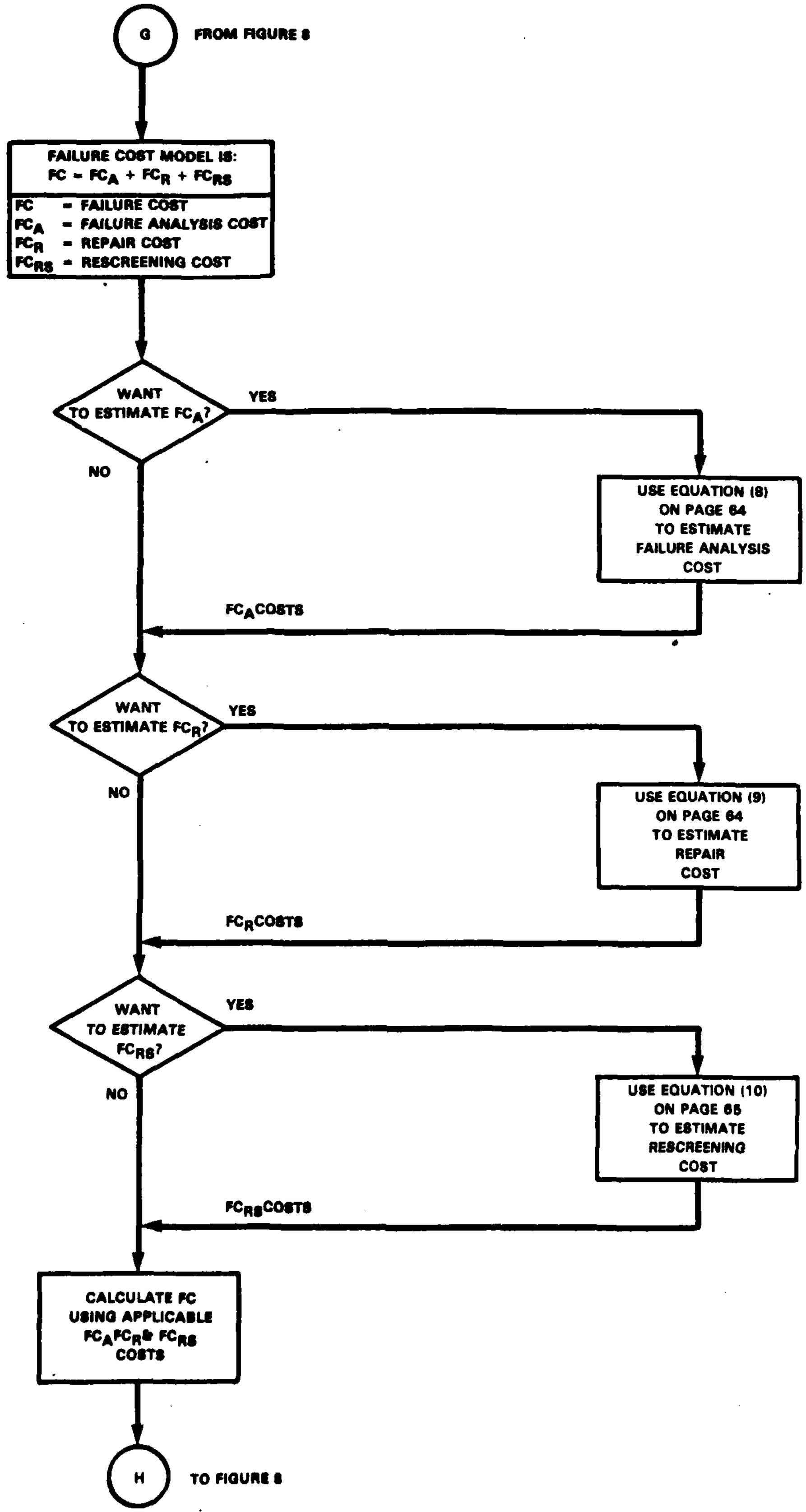


Figure 12. Failure Cost Flow Diagram

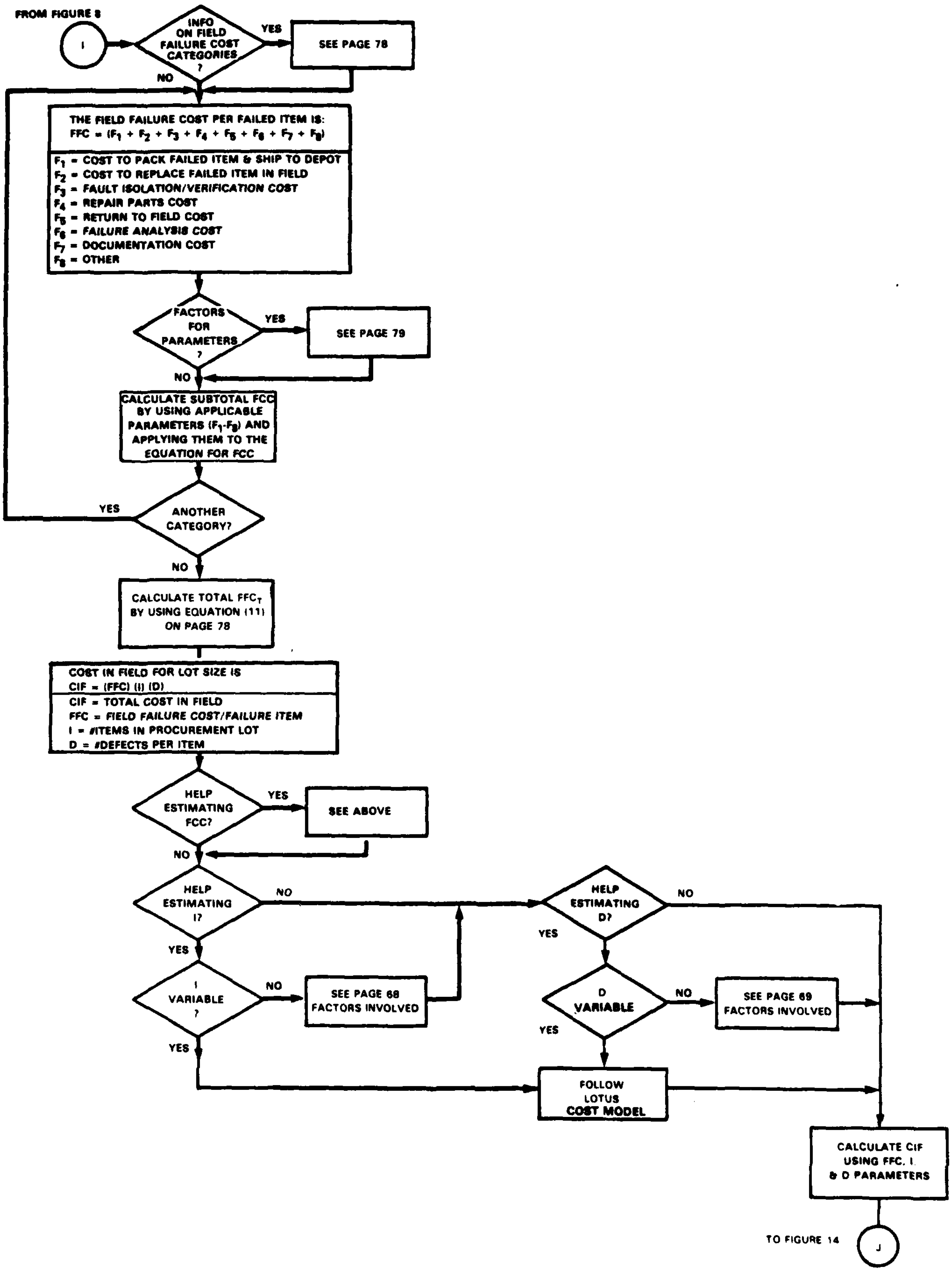


Figure 13. Cost Effectiveness Flow Diagram

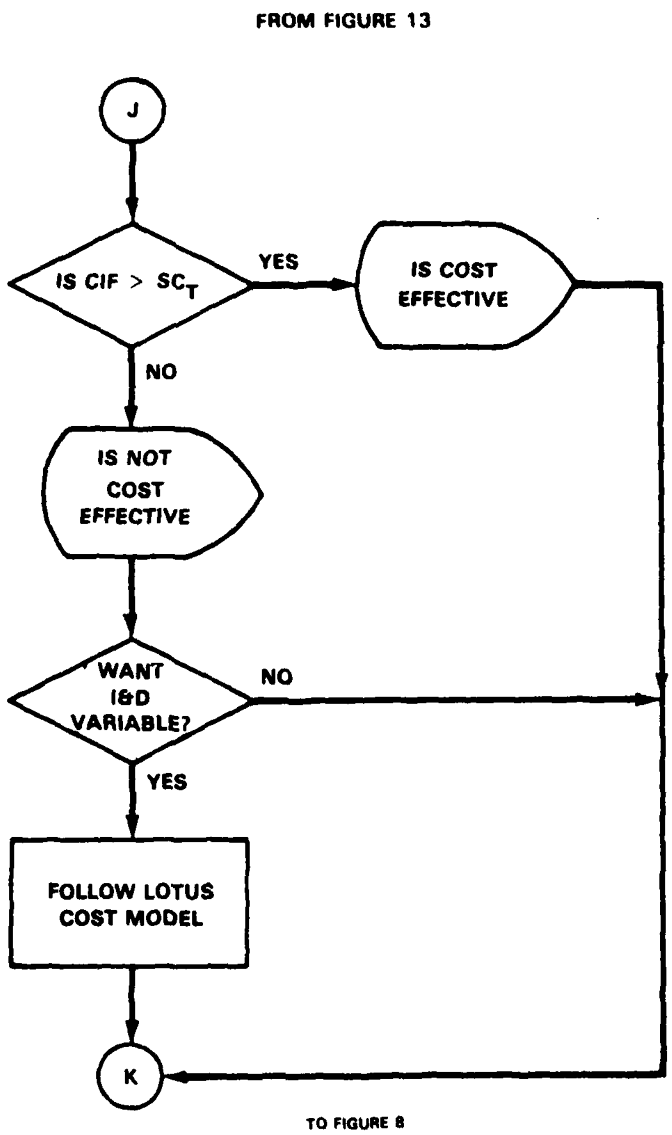


**Figure 14. Cost Effectiveness Flow Diagram**

## STRESS SCREENING COST MODEL

### Top Tier Equations for Screening

The top tier screening cost model consists of the basic statement:

$$SC_{ST} = EC + SC_I + CS + FC \qquad \text{[Equation 1]}$$

where:

| | | |
|---|---|---|
| $SC_{ST}$ | = | Screening cost (subtotal) |
| EC | = | Equipment cost |
| $SC_I$ | = | Cost of item screening process |
| CS | = | Cost of survey |
| FC | = | Failure cost of defects found during screening |

This equation is used to determine the total cost of a given screen.

The model can be easily used when performing more than one type of screening; for example, thermal cycling and random vibration. Simply follow the flow diagram for each screen and add the totals to calculate the sum of both screens ($SC_T$). Be aware that the more screens you use, the more costly the project will be. One screen is the minimum that can be done, and is the least expensive; however, two screens are usually better. For example, vibration screening implemented with thermal cycling may not be much more expensive than thermal cycling alone, since vibration cycling does not require an extensive amount of time to conduct.

When two or more screens are applied, the following equation should be used:

$$SC_T = SC_{ST_1} + SC_{ST_2} + \dots\dots\dots + SC_{ST_N} \qquad \text{[Equation 2]}$$

where:

| | | |
|---|---|---|
| $SC_T$ | = | Total screening cost of all screens |
| $SC_{ST_1}$ | = | Screening cost (subtotal of first screen) |
| $SC_{ST_2}$ | = | Screening cost (subtotal of second screen) |
| $SC_{ST_N}$ | = | Screening cost (subtotal of nth screen) |
| N | = | Number of screens |

## Second Tier Equations for Screening

The second tier breaks down the parameter of the top tier equation into its major sub-elements.

### *Equipment Cost Equation (EC)*

Equipment costs consist of five cost elements:

$$EC = EC_C + EC_M + EC_S + EC_F + EC_{FC} + EC_O \qquad \textbf{[Equation 3]}$$

where:

| | | |
|---|---|---|
| $EC$ | = | Total equipment costs |
| $EC_C$ | = | Chamber equipment costs |
| $EC_M$ | = | Cost to monitor screen performance |
| $EC_S$ | = | Support equipment cost |
| $EC_F$ | = | Fixture cost |
| $EC_{FC}$ | = | Cost of facilities |
| $EC_O$ | = | Other equipment cost |

Some models may not include all of these parameters. If "other equipment" costs are not necessary, then they not included. The equipment cost factor for equipment not used is equal to zero. Refer to page 65, Third Level Models, for factor descriptions.

### *Item Screening Cost Equation ($SC_I$)*

The item screening cost is the cost that applies only to screening the items and does not include equipment, survey or failure costs. The model is divided into two parts, *labor* cost and *administrative* costs, as shown below:

$$SC_I = SC_L + SC_A \qquad \textbf{[Equation 4]}$$

where:

| | | |
|---|---|---|
| $SC_I$ | = | Cost of item screening process |
| $SC_L$ | = | Labor cost |
| $SC_A$ | = | Administrative costs |

*Labor Cost ($SC_L$) Equation.* Screening is usually performed in sets. For example, a chamber may hold a set of 10 items at a time. A larger chamber may hold a set of 15 or more depending on the size of the items. Labor time is based on how long it takes a technician to perform the screening of one set. The labor cost, then is defined as follows:

$$SC_L = \left[ \frac{(LH + MH + UH + FH)}{IPS} LR \right] I \qquad \textbf{[Equation 5]}$$

where:

| | | |
|---|---|---|
| $SC_L$ | = | Labor costs |
| LH | = | Number of hours to load one set into the fixture |
| MH | = | Number of hours to monitor chamber while screening one set |
| UH | = | Number of hours to unload one set from the fixture |
| FH | = | Number of hours to run a postfunctional test on a set |
| IPS | = | Number of items per set |
| LR | = | Labor rate of a technician ($/hour) |
| I | = | Number of items in procurement lot |

*Administrative Cost ($SC_A$) Equation.* Administrative costs are calculated as follows:

$$SC_A = AC\,(I) \qquad \textbf{[Equation 6]}$$

where:

| | | |
|---|---|---|
| $SC_A$ | = | Total administrative costs |
| AC | = | Administrative costs associated with screening one item |
| I | = | Number of items in procurement lot |

Refer to page 68 for further explanation of item screening cost factors.

***Survey Cost (SC) Equation***

Survey costs are generally cheaper than total screening costs for a lot. The survey usually takes only a few hours (2-3). Therefore, the same costs to screen the items apply to the survey costs. The only difference will be in the number of hours the survey takes, and the number of items in the survey (see page 68). Studies have shown that a vibration survey takes approximately 5 hours and a thermal survey can take at least 24 hours.

***Failure Cost (FC) Equation***

The failure cost model relates to the costs associated with defects found during screening. The failure cost model consists of the following parameters:

$$FC = FC_A + FC_R + FC_{RS} \quad \textbf{[Equation 7]}$$

where:

| | | |
|---|---|---|
| $FC$ | = | Failure costs |
| $FC_A$ | = | Failure analysis costs |
| $FC_R$ | = | Repair costs |
| $FC_{RS}$ | = | Rescreening costs |

*Failure Analysis Cost ($FC_A$) Equation.* The failure analysis cost is calculated as follows:

$$FC_A = A\,(P)\,(D)\,(I)\,(UD) \quad \textbf{[Equation 8]}$$

where:

| | | |
|---|---|---|
| $FC_A$ | = | Cost for failure analysis of production lot |
| A | = | Cost for one full failure analysis for an unknown defect |
| P | = | Percentage of defects found needing a full analysis to find the cause of failure (decimal) |
| D | = | Number of defects per item |
| I | = | Number of items in procurement lot |
| UD | = | Percent of defects uncovered by this screen (decimal) |

*Repair Cost ($FC_R$) Equation.* The repair cost is found as follows:

$$FC_R = [\,PC + ((LR)\,(HTR))\,]\,(D)\,(I)\,(UD) \quad \textbf{[Equation 9]}$$

where:

| | | |
|---|---|---|
| $FC_R$ | = | Cost to repair all defective items |
| PC | = | Cost of parts to repair a defective item |
| LR | = | Labor rate of a repair technician ($/hour) |
| HTR | = | Number of hours to repair one defective item (decimal hours) |
| D | = | Number of defects per item |
| I | = | Number of items in procurement lot |
| UD | = | Percent of defects uncovered by this screen |

*Rescreening Cost ($FC_{RS}$) Equation.* Rescreening costs involve the same costs as the initial screening costs. Rescreening is performed in sets, with the same number of items as initial screening. The only difference is that they may be screened for a lesser number of cycles, hence a shorter time period. The cost involves the following:

$$FC_{RS} = \left[ \frac{(LH + MH_R + UH + FH)}{UPS} LR + AC \right] (D)\,(I)\,(UD) \qquad \textbf{[Equation 10]}$$

where:

| | | |
|---|---|---|
| $FC_{RS}$ | = | Cost of rescreening all failed items |
| LH | = | Number of hours to load one set into the fixture |
| $MH_R$ | = | Number of hours to monitor chamber while screening one repaired set |
| UH | = | Number of hours unload one set from the fixture |
| FH | = | Number of hours to run a postfunctional test on the rescreened items |
| UPS | = | Number of items per one set |
| LR | = | Labor rate of a technician ($/hour) |
| AC | = | Administrative costs associated with screening one defective item |
| D | = | Number of defects per item |
| I | = | Number of items in procurement lot |
| UD | = | Percent of defects uncovered by this screen |

Refer to page 69 for Failure Cost Parameter Descriptions.

## Third Tier—Parameter Descriptions for Screening Costs

The third tier parameter definitions consist of a series of descriptions to assist the user in accounting for the full range of screening cost factors.

### *Equipment Cost Parameter Descriptions*

A tabulation of ESS equipment price ranges is contained in Table 6. This table provides nominal values of current industrial equipment costs.

*$EC_C$ (chamber equipment cost).* Examples of chamber equipment are temperature chambers, vibration shaker tables, immersion tanks, etc. Factors considered when choosing the number and sizes of the chamber(s) are:

- Number of items in production lot
- Size of items
- Production rate

The set can include as many items as you like, however, the bigger the chamber, the more expensive the cost of the chamber. Purchasing more than one chamber should be considered with large procurements. This cuts down on total screening time and reduces the facility and labor costs, but increases the equipment cost.

$EC_M$ *(monitor costs).* Monitoring equipment is used to monitor the chamber(s) during operation. This allows technicians to check the operation of the chamber and items. If monitoring equipment has the capacity to document item output, then labor costs are reduced in terms of actual man-hours. Types of monitors are magnetic tape recorders, oscillographic recorders, computer printout, and strip chart recorders.

$EC_S$ *(support equipment costs).* Support equipment costs include all those extras needed to run the chamber(s) and monitor(s). Examples are:

- Interface connectors
- Cables
- Random controller for a vibration table (see Table 6 for prices).

$EC_F$ *(fixture costs).* These are the costs of the fixture(s) required to hold the items in place during screening. One fixture can usually be used for both a thermal chamber and a vibration table.

**Table 6. ESS Equipment Price Ranges**

| EQUIPMENT | DESCRIPTION | SIZE | PRICE RANGE |
|---|---|---|---|
| Agree Chamber | • Thermal Screening Chamber compatible with vibration testing equipment for combined environment testing | 32cf | $40,000-50,000 |
| | | 100cf | $55,000-60,000 |
| | • Temperature rate of change: 10°C to 20°C/minute | | |
| | • Temperature range: -73°C to +177°C | | |
| Temperature/ Humidity Chamber | • Temperature range: -68°C to 177°C | 32cf | $50,000-60,000 |
| | • Humidity range: 20% RH to 95% RH | 100cf | $65,000-75000 |
| Flexisystem Chamber | • Thermal Chamber adaptable for batch load, fixtured cart, or total automation | 32cf: | |
| | | -65°C to +125°C | $200,000-250,000 |
| | | -40°C to +125°C | $190,000-195,000 |
| | • Fixtured system | | |
| | • Temperature rate of change: 12°C to 120°C/minute | 642cf: | |
| | | -65°C to +125°C | $300,000-325,000 |
| | | -40°C to +125°C | $260,000-290,000 |
| Thermal Chamber | • Chamber for small lots<br>• Fixtured system | 24cf: | |
| | | -65°C to +125°C | $130,000-140,000 |
| | | -40°C to +125°C | $150,000-160,000 |

## Table 6. ESS Equipment Price Ranges (continued)

| | | | |
|---|---|---|---|
| Agree Compatible Vibration Equipment | • Two small vibration shaker tables and complete controller to screen one 3 lb PWA | 6 Grms | $10,000-12,000 |
| | • Vibration shaker table with amplifier | 500 force-lb random<br>600 force-lb sine | $20,000-25,000 |
| | • Vibration shaker table | 6,000 force-lb | $50,000-60,000 |
| Vibration Equipment | • Shaker with air-cooled amplifier and 2,500 lb load capacity | 9,000 lb rms random | $55,000-60,000 |
| | • Shaker with water-cooled amplifier and 10,000 lb load capacity | 9,000 lb rms random | $80,000-90,000 |
| Random Controller | • Needed to change sine wave into random wave<br>• Allows frequency range to go down to 0.5Hz | | $25,000-30,000 |
| Vibration Monitor Limiter | • Allows acceleration and displacement to be monitored and limited either together or independently | | $3,000-4,000 |
| Oscilloscope | • Monitoring equipment | | $1,500-7,000 |
| Strip Chart Recorder | • Two channel<br>• Four channel<br>• Six channel<br>• Eight channel | | $2,000-8,000 |
| Fixtures | • Holds item(s) in place for vibration and/or thermal cycling. One fixture can be used for both. (This price includes one fixture to hold six PWAs on vibration shaker and in a thermal chamber.) | Holds six PWAs | $600-800 |

*$EC_{FC}$ (cost of facilities).* This is the cost of any **new** facilities required to perform the screening. Examples would be buildings, air conditioners, and rooms. Such items are included in the total if the purchase is **specifically** done for this screening. If the facility is shared with other activities or will be put to other uses after completion of the program, a percentage of the facility cost could be used. Other costs that can be included in the facilities cost are:

- Procurement
- Installation
- Operation
- Utilities
- Repair and upkeep.

$EC_O$ *(other equipment costs).* These costs are used to include other equipment parameters besides the ones listed for this model. Many times, this parameter will be zero.

***Item Screening Cost Parameter Descriptions***

*LH (number of hours to load one set into the fixture).* Depending on the size of the chamber, the number of items in a set will vary. A large chamber will hold a larger set than a smaller chamber. It may, however, take a little longer to load and unload a larger set. Approximately 10 PCBs can be loaded in half an hour.

*MH (number of hours to monitor the chamber while screening a set).* This parameter accounts for the manual labor needed to monitor the screen. Increasing the use of automated monitoring equipment will decrease this cost. For example, if a printout is produced in the monitoring of a vibration table, the technician's monitoring hours are limited to reading the printout at the end of the screen. The same would be true for a thermal chamber monitoring system. When thermal cycling would take many hours to conduct, a monitor would become very cost-effective. If automated monitoring equipment is not used, the technician has to monitor the chamber constantly. This takes more time, and incurs more direct labor costs to the project. With large procurements, monitoring equipment may be less expensive than paying a technician to visually monitor the screen. Using monitoring equipment, approximately half an hour is needed to monitor the screening of a set of 10 PCBs.

*UH (number of hours to unload one set from the fixture).* This parameter follows the ideas expressed in LH—the number of hours to unload one set from the fixture.

*FH (number of hours to run a postfunctional test).* This test is done to ensure that the item is functioning properly after screening, or if it is not functioning properly, to validate a defect found in monitoring.

*IPS (items per set).* This parameter defines how many items can fit into a chamber at once: a set.

*LR (labor rate).* This parameter, the cost per hour, defines the current average rates for screening technicians. This rate varies depending on location. A labor rate guide for the specific area should be consulted.

*I (number of items in a procurement lot).* This parameter defines the total number of items in the procurement lot to be screened over the life of the contract.

*AC (administrative cost associated with one item).* This parameter defines the screening documentation cost. The requirement usually exists to document the techniques used to perform screening and the results of the screening. Administrative costs include:

- Monthly ESS report
- Screening plans and procedures
- Data documentation such as paper tapes and computer printouts

These costs should be combined and divided by the number of items being produced.

***Survey Cost Parameter Descriptions***

See parameter discussion on page 68.

***Failure Cost Parameter Descriptions***

*A (cost of one full failure analysis of an unknown defect).* Many times, a defect's cause can be determined by either visual inspection or testing. This parameter details the cost of analysis to find the root cause of the failure for a defect whose cause is unknown.

*P (percentage of defects found that need a full analysis to find the cause of failure).* This value, in decimal form, determines an average failure analysis cost per each defect. As stated in the explanation of *A (cost of one full failure analysis of an unknown defect),* not all defects need a full failure analysis. *P* is the percentage of defects that **do** need a full failure analysis. This value will probably be around 0.20 or 0.30, but is certainly not restricted to that.

*D (number of defects per item).* This value represents the number of inherent part defects per item. It is based on the incoming defect estimation described on page 70.

*PC (cost of parts to repair a defective item).* This cost represents the material costs associated with the replacement of failed parts. The advantages of screening at lower levels of assembly were discussed on page 2.

*LR (labor rate of a repair technician in \$/hour).* See page 68.

*HTR (number of hours to repair one defective item).* This decimal value gives the average time for a qualified repair technician to repair an item.

*LH (number of hours to load one set into the fixture for rescreening).* See page 68.

*$MH_R$ (number of hours to monitor chamber while rescreening one repaired set).* See page 68. (**Note**: Manual monitoring may take less time for rescreening since the number of cycles that the repaired item is subjected to will most likely be less.)

*UH (number of hours to unload one set).* See page 68.

*FH (number of hours to run a postfunctional test).* See page 68. (**Note**: This cost model assumes that once a defect is repaired, the amount of items that do not pass the second postfunctional test is negligible.

*UPS (units per set).* See page 68.

*AC (administrative costs).* See page 68.

***Incoming Defect Estimation***

The objective of this section is to estimate the incoming defects that are introduced into the item during its manufacture. This estimate will serve as the basis for determining if stress screening is cost effective.

The incoming defect estimation procedure, adapted from RADC-TR-87, "Guide to Environmental Stress Screening," uses a three-level equipment breakdown structure. The example given here uses the system, unit, and assembly levels for the breakdown. In most cases, the breakdown is limited to three levels of assembly. It can be adapted to cover more than the three levels if needed; the worksheets just require expansion. All three levels are not needed in some cases. If only a unit is to be screened, only the unit breakdown chart in Figure 15 and worksheet 16 in Figure 16 need to be used.

***System Breakdown***

The system to be stress screened will be broken down into system (Figure 17) and unit (Figure 15) levels. Figure 17 shows the system breakdown; in this case, into three units. The total number of defects in the system is determined by summing the defects estimates from each unit.

***Unit Defect Estimates***

For each unit identified in the System Breakdown Chart, a unit breakdown chart (Figure 15) is prepared showing the unit broken down into its assemblies. A defect estimation worksheet (Figure 16) is then completed for each assembly listed under the unit. The value for the total number of defects in each assembly is then listed in the appropriate space provided on the unit breakdown chart (Figure 15). The total number of defects in one unit is found by summing all of the assembly defect estimates. The unit total is then placed in the space provided for that unit in the system breakdown chart (Figure 17).

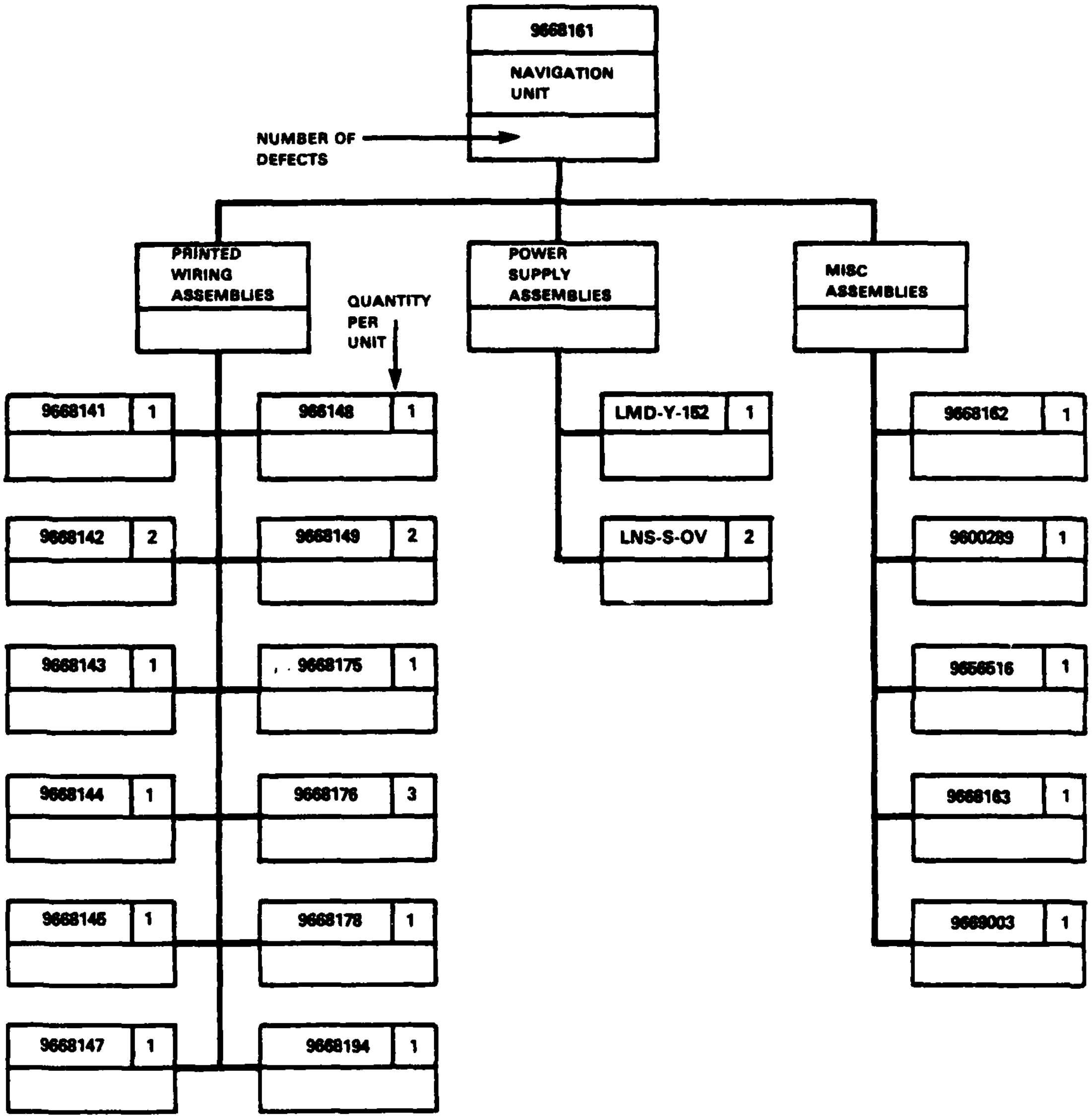


Figure 15. Unit Breakdown Chart

DEFECT ESTIMATION WORKSHEET

| Program/Project | | System Nomenclature | | Envir. |
|---|---|---|---|---|
| Unit | Assembly | Prepared by | Date | |

| Part Type | Quality Level | Quantity | Fraction Defective | Estimated Defects* |
|---|---|---|---|---|
| Microelectronic | | | | |
| Transistors | | | | |
| Diodes | | | | |
| Resistors | | | | |
| Capacitors | | | | |
| Inductive Devices | | | | |
| Rotating Devices | | | | |
| Relays | | | | |
| Switches | | | | |
| Connectors | | | | |
| Printed Wiring Boards | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Connections, Hand Solder | | | | |
| Connections, Crimp | | | | |
| Connections, Weld | | | | |
| Connections, Solderless Wrap | | | | |
| Connections, Wrapped and Soldered | | | | |
| Connections, Clip Termination | | | | |
| Connections, Reflow Solder | | | | |
| | | | Total No. of Defects | |

Figure 16. Worksheet for Estimating Number of Defects

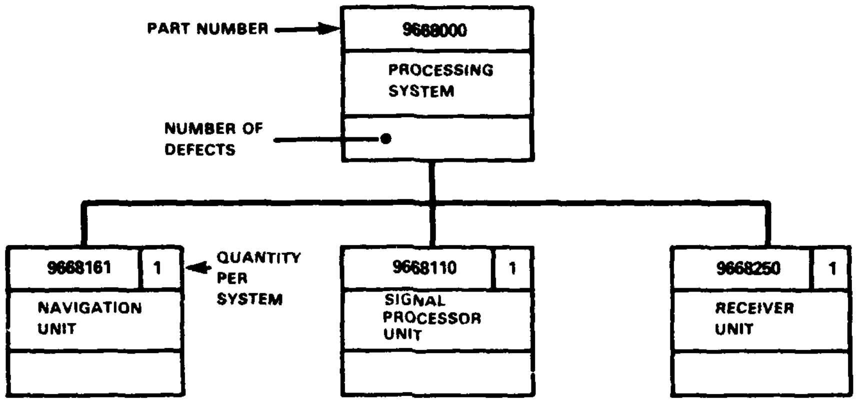


**Figure 17. System Breakdown Chart**

*Assembly Defect Estimation*

Each of the assemblies shown in the unit breakdown chart requires a worksheet, shown in Figure 16, to be completed as follows:

*Part Type.* Part types shown on the worksheet are the standard types included in MIL-HDBK-217E. Miscellaneous part types can be added as appropriate.

*Quality Level.* Enter the appropriate quality level as identified in Table 7. If quality levels are not specified, use the lowest quality level as a conservative estimate.

*Quantity.* Enter the quantity of each part type.

*Fraction Defective.* Determine the fraction defective for each part type using environmental factors and quality levels in Appendix A. Enter this number on the worksheet.

*Estimated Defects.* Determine the estimated number of defects by multiplying the quantity by the fraction defective and enter on the worksheet. Keep in mind that this number is defects per million parts.

*Totals*. Enter the total estimated number of defects on the worksheet and enter in the corresponding space of the unit breakdown chart. Again, keep in mind that this value is defects per million parts.

**Table 7. Quality Levels for Various Part Types**

| PART TYPE | QUALITY LEVELS |
|---|---|
| Microelectronic Devices | S, B, B-0, B-1, B-2, C, C-1, D, D-1 |
| Transistors | JANTXV, JANTX, JAN, LOWER, PLASTIC |
| Diodes | JANS, JANTXV, JANTX, JAN, LOWER, PLASTIC |
| Resistors | S, R, P, M, MIL-SPEC, LOWER |
| Capacitors | S, R, P, M, L, MIL-SPEC, LOWER |
| Transformers | MIL-SPEC, LOWER |
| Coils | S, R, P, M, MIL-SPEC, LOWER |
| Relays | MIL-SPEC, LOWER |
| Switches | MIL-SPEC, LOWER |
| Connectors | MIL-SPEC, LOWER |
| Printed Wiring Boards | MIL-SPEC, LOWER |

## Example

The following example demonstrates an incoming defect estimation. The example illustrates a communications system that is to be stress screened. The system is comprised of nine units, as shown in Figure 18. Each unit is then further broken down into assembly levels as shown in Figure 19. Only the processor unit breakdown is illustrated in this example. The printed wiring assemblies (PWAs) contained in this unit are shown in Table 8. Figure 20 shows the defect estimation for one of the assemblies in Table 8, the Interface Assy-1, part number 9664074. A Defect Estimation Worksheet is needed for each assembly in the communication system. (If only this assembly is to be screened, this defect estimation worksheet is all that is needed).

Once all of the Defect Estimation Worksheets are completed, assembly totals are entered on the Unit Breakdown Chart (Figure 19) and unit totals are entered onto the System Breakdown Chart (Figure 18). In this example, it is estimated that each system produced will have approximately 1.414 defects. The total shown in Figure 18 is defects per million parts. If the processor unit is screened alone, the defect estimate would be 0.769 defects per processor unit. The number of defects per system is used to arrive at the estimated number of field failures. The number of field failures is multiplied by the average cost of failure (see page 78) to get the total cost of all field failures. This cost is then compared to the total screening costs to determine cost-effectiveness of ESS.

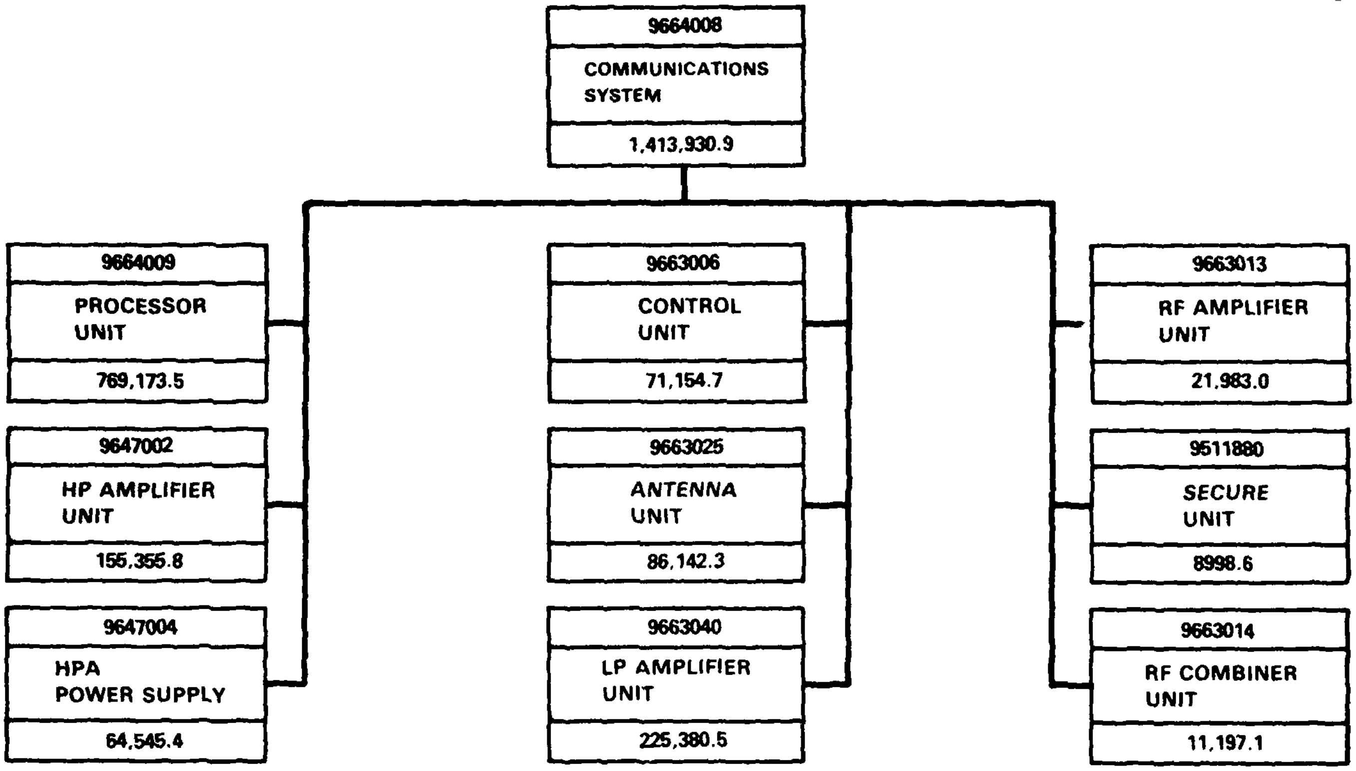


**Figure 18. System Breakdown Chart for a Communications System**

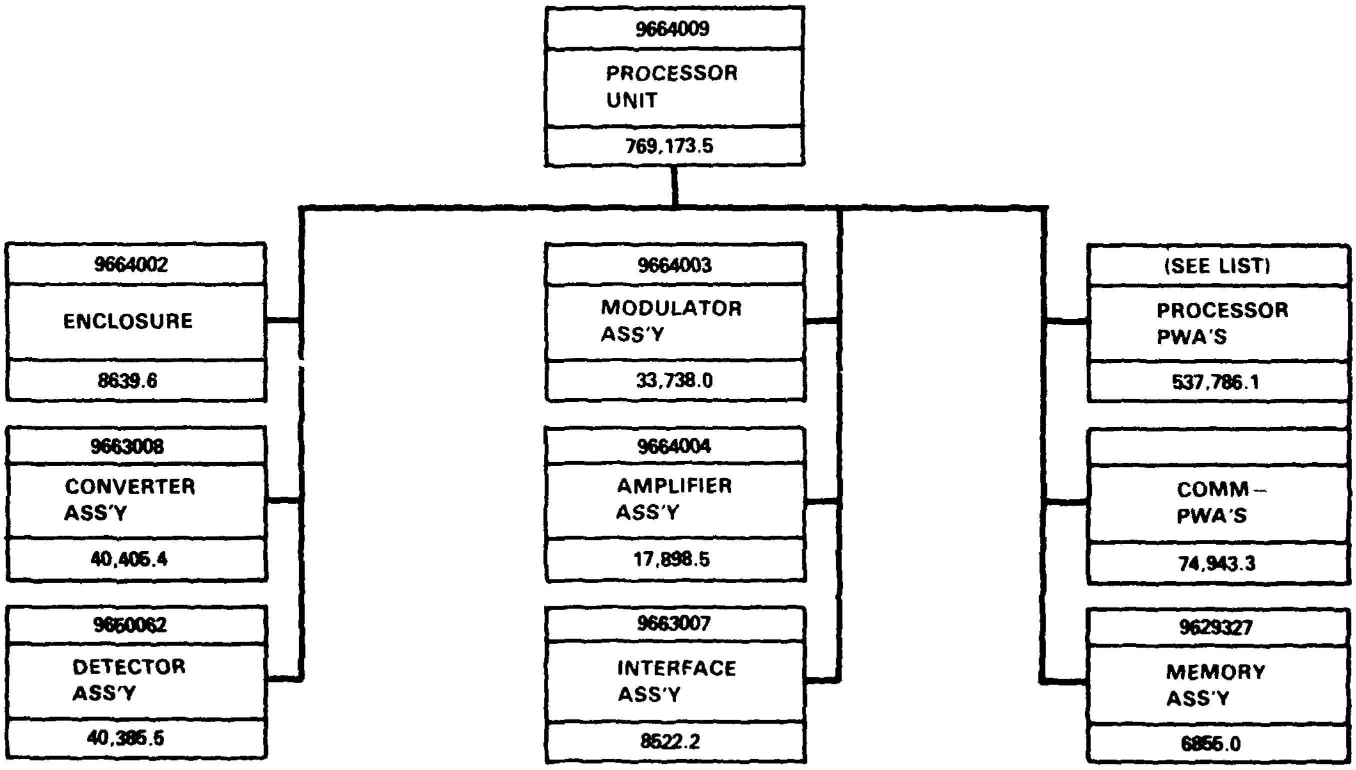


**Figure 19. Processor Unit Breakdown to the Assembly Level**

## Table 8. List of Processor Unit PWAs

| QTY | PART NUMBER | NOMENCLATURE | ESTIMATED DEFECTS* |
|---|---|---|---|
| 1 | 9664060 | Sequencer Assembly | 13,771.8 |
| 1 | 9664061 | Timing Assembly-1 | 21,256.2 |
| 1 | 9664062 | Timing Assembly-2 | 19,829.0 |
| 1 | 9664063 | Event Sequencer Assembly | 13,864.4 |
| 1 | 9664064 | Timing Control Assembly | 12,990.2 |
| 1 | 9664065 | Interleave Assembly | 22,791.6 |
| 1 | 9664066 | Interleave Timing Assembly | 11,446.8 |
| 1 | 9664067 | Delay Assembly-A | 26,098.2 |
| 1 | 9664068 | Demodulator Assembly | 60,096.5 |
| 1 | 9664069 | Tracker Assembly | 5,328.6 |
| 1 | 9664070 | Delay Assembly-B | 20,811.0 |
| 1 | 9664071 | Input Buffer Assembly | 25,174.6 |
| 1 | 9664072 | Output Buffer Assembly | 17,298.8 |
| 1 | 9664073 | Formatter Assembly | 21,785.9 |
| 1 | 9664074 | Interface Assembly-1 | 6,160.9 |
| 1 | 9664075 | Clock Control Assembly | 20,371.8 |
| 4 | 9664076 | Correlator Assembly | 50.998.4 |
| 1 | 9664077 | Arithmetic/Memory Assembly | 14,083.4 |
| 1 | 9664078 | Address Select Assembly | 25,234.4 |
| 1 | 9664079 | Interface Assembly-2 | 4,395.4 |
| 1 | 9664080 | Timing Assembly-3 | 2,117.0 |
| 1 | 9664081 | Detector Assembly | 33,008.3 |
| 1 | 9664082 | Frequency Selector Assembly | 5,083.2 |
| 1 | 9664083 | Interface Assembly-3 | 16,379.1 |
| 1 | 9664084 | Fault Isolation Assembly | 13,842.4 |
| 1 | 9664085 | Frequency Control Assembly | 5,327.2 |
| 1 | 9664086 | Timing Assembly-4 | 20,921.0 |
| 1 | 9664087 | Quantizer Assembly | 24,216.6 |
| 1 | 9664088 | Arithmetic Assembly | 2,662.8 |
| | | **Total Defects** | **537,786.1** |

* per $10^6$

DEFECT ESTIMATION WORKSHEET

| Program/Project | | System Nomenclature | | Envir. |
|---|---|---|---|---|
| Communications Distribution Program | | Communications System 9664008 | | AIF |
| Unit | Assembly | Prepared by | Date | |
| Processor Unit 9664009 | Interface Assy-1 9664074 | A.E. Saari | 3/21/85 | |

| Part Type | Quality Level | Quantity | Fraction Defective | Estimated Defects* |
|---|---|---|---|---|
| Microelectronic | B-0 | 49 | 87.0 | 4263.0 |
| Transistors | | | | |
| Diodes | JANTX | 1 | 46.9 | 46.9 |
| Resistors | ER-M | 18 | 23.8 | 428.4 |
| Capacitors | ER-M | 1 | 115.3 | 115.3 |
| Inductive Devices | | | | |
| Rotating Devices | | | | |
| Relays | | | | |
| Switches | | | | |
| Connectors | M/S | 1 | 168.0 | 168.0 |
| Printed Wiring Boards | M/S | 1 | 1139.3 | 1139.3 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Connections, Hand Solder | | | | |
| Connections, Crimp | | | | |
| Connections, Weld | | | | |
| Connections, Solderless Wrap | | | | |
| Connections, Wrapped and Soldered | | | | |
| Connections, Clip Termination | | | | |
| Connections, Reflow Solder | | | | |
| *per $10^6$ | | | Total No. of Defects | 6160.9 |

**Figure 20. Completed Worksheet for a Sample Assembly**

## FIELD FAILURE COST MODEL

The field failure costs detail the cost of a failed item as it experiences on of three conditions. This model covers three conditions that deal with an item when it fails:

*No Failure.* In some cases, an item is labeled "failed," even though it has not. Operator error is the biggest cause of this category. This occurs approximately 20 percent of the time. In this case, the "percent approximate (PA)" would be 0.20.

*Discard.* This category applies when the failed item is beyond repair. When an item is destroyed, it is beyond repair. This value is typically 0.20.

*Repairable.* This category applies when the failed item is repairable. The PA for this category will have the highest percent in most cases, usually 0.60.

### Top Tier Field Failure Cost Equation

To find the weighted average based on the costs and the percentages of the three categories previously described, the following equation is used to average field failure cost per failed item:

$$FFC_T = (PA_1)\ (FFC_1) + (PA_2)\ (FFC_2) + (PA_3)\ (FFC_3) \qquad \textbf{[Equation 11]}$$

where:

| | | |
|---|---|---|
| $FFC_T$ | = | Average field failure cost per failed item |
| $FFC_1$ | = | Field failure cost per failed item for "no failure" |
| $FFC_2$ | = | Field failure cost per failed item for "discard" |
| $FFC_3$ | = | Field failure cost per failed item for "repairable" |
| $PA_1$ | = | Approximate percentage of "no failures" |
| $PA_2$ | = | Approximate percentage of "discards" |
| $PA_3$ | = | Approximate percentage of "repairables" |

### Second Tier Field Failure Cost Model

The following equation can be used to calculate each of the three field failure categories. Some of the parameters will not be used for some of the conditions. The third tier cost section below explains this in more detail.

$$FFC = F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8 \quad \textbf{[Equation 12]}$$

where:

| | | |
|---|---|---|
| FFC | = | Field failure cost per failed item for each condition |
| $F_1$ | = | Cost to pack failed item and ship to depot |
| $F_2$ | = | Cost of temporary replacement in field |
| $F_3$ | = | Fault isolation/verification costs |
| $F_4$ | = | Repair parts costs |
| $F_5$ | = | Return to field costs |
| $F_6$ | = | Failure analysis costs |
| $F_7$ | = | Documentation costs |
| $F_8$ | = | Other costs |

**Note:** For total cost in field, use the following equation:

$$CIF = FFC_T \times I \times D \quad \textbf{[Equation 13]}$$

where:

| | | |
|---|---|---|
| CIF | = | Cost in field (total for all defects) |
| I | = | Number of items in procurement lot |
| D | = | Number of defects estimated per item |
| $FFC_T$ | = | Average field failure cost per item |

### Third Tier Failure Cost Parameter Descriptions

*$F_1$ (cost to pack failed item and ship to depot).* This cost will involve the following:

- Packing cost
- Shipping and handling charges.

In the case of the "discard" item, this cost may or may not be zero. If failure analysis is desired, the item will have to be shipped back.

$F_2$ *(cost of temporary replacement in field).* This cost will be the same for all three cases (or conditions) suggested for the field failure costs. In most cases, you will always have to replace the item in the field whether you are waiting for the failed item to be repaired or waiting for a new item to be shipped to you. The only time this cost will be zero is when necessity of the item is not critical, and does not need an immediate replacement. When a replacement is needed, the cost will be prorated based on usage of the item. For example, if the life of a $2,000 item is 10 years (120 months), and you only use it for 6 months before you receive the repaired item, the cost of the replacement is calculated as follows:

$$\text{Cost} = \frac{\text{usage time (in months)}}{\text{life of item (in months)}} \times \text{cost of item}$$

$$\text{Cost} = \frac{6 \text{ months}}{120 \text{ months}} \times \$2{,}000 = \$100$$

The cost for the example is, therefore, $100.

$F_3$ *(fault isolation/verification costs).* This cost involves the following:

- Labor to test the item to validate a failure
- Labor to repair the item.

If the item is discarded, this cost is zero.

$F_4$ *(repair parts costs).* This value will be much greater than the parts cost value of parameter PC on page 69, unless "no failure" of the item was found. If no failure was found, this cost will be zero. If the failed item is "discarded," the cost for this parameter is the cost for a new item. If the item is "repairable," this value is the cost for whatever needs to be repaired or replaced on the item.

$F_5$ *(return to field costs).* This cost parameter follows parameter $F_1$. In most cases, this cost will be the same. In the case of the "discarded" item, this cost covers the shipment of the new replacement item to the field.

$F_6$ *(failure analysis costs).* This cost will be zero for the cases of "no failure" and the "discard" item. For the item that is "repairable," this cost will follow the basis of $FC_A$ described on page 64. the number of defects found in each failed item will be equal to one. Keep in mind that not all failed items will be subjected to a failure analysis.

$F_7$ *(documentation costs).* This cost includes everything mentioned for cost parameter AC on page 68; however, cost parameter AC is onl; for documentation at one place. For any of the categories, the failed item will have to be documented in the field, at the depot, for shipping and handling, and again when it or its replacement is back in the field. This cost will be more than the administrative costs described on page 68.

*$F_8$ (other costs).* This cost covers any other costs that need to be accounted for, but were not mentioned by any of the seven parameters listed previously.

*PA (percent approximate).* This parameter describes the percent of time that one of the conditions occurs. See page 78.

*D (defects per item).* See page 69.

## COMPARISON FOR COST EFFECTIVENESS

To determine cost effectiveness based on parts defects alone, simply compare the total costs found for stress screening and field failures. If the cost to run all screens ($SC_T$ from equation 2) **is less than** the cost to repair all defects once they are in the field (CIF from equation 13), then cost effectiveness has been achieved. Even if the numbers are very close in value, ESS is advised. The estimates developed for field failure costs are conservative since they do not take into account the defects introduced by assembly and workmanship errors. ESS will also be justified by considering other benefits, such as earlier defect identification and corrective action.

## LOTUS COST MODEL

The cost model has been adapted to the LOTUS software package. The disk can be obtained by contacting:

Commander
Belvoir RD&E Center
ATTN: STRBE-TQE
Fort Belvoir, VA 22060-5606

Commercial: 703/664-5771
AUTOVON: 354-5771
E-mail: STRBE-TQE @
Belvoir-EMH3.ARMY.MIL

The program is designed to assist the user in calculating the screening and field failure costs, and comparing them. Some knowledge of the LOTUS software is needed to begin the computer cost model. A default cost model can be seen in Appendix C. This model will always be kept a file name "DEFAULT." The following steps will help you accurately use the LOTUS cost model.

1. Boot up LOTUS 1-2-3.

2. Place your cost model disk into the data disk drive when prompted. Follow LOTUS directions.

3. To retrieve the default cost model, type /FR. There will be three files listed to chose from: DEFAULT, ESS1, and ESS2. Choose DEFAULT. When saving your modified cost model, name it ESS1 or ESS2. Never save a changed cost model under DEFAULT. This should always be the original.

4. You will now see the beginning of the cost model. There is a special menu at the top of the screen. It allows you to do the following:

   - Retrieve another cost model.
   - Save the cost model and the chart currently on the screen as ESS1 or ESS2.
   - Print the current cost model (CPRINT).
   - Print the current cost chart (CCHART).
   - View the cost chart associated with the customized cost model (VIEW).
   - View and save the current graph associated with model filed as ESS1 (1GRAPH). The graph will show the crossover point at the number of defects needed for the given lot size where the stress screen becomes cost effective.
   - View and save the current graph associated with model filed as ESS2 (2GRAPH)
   - Quit and go to ready mode.

Select "QUIT" to enter the ready mode where you can now move around the screen using the arrow keys. Ready mode also allows you to change the default values within the brackets to fit the cost model. Remember, all responses in the brackets of the *default model* are *default values*. Change them to fit your screens. The default cost model displays costs associated with screening printed wiring assemblies within a unit valued at $800 with a 10-year life, an 8-month replacement period, and a median defect estimate of 0.7. In this example, the units are screened using thermal cycling and random vibration. **Your screens and values may be different**. All parameter considerations can be found in the third tier cost parameter description (pages 65 and 79).

5. To print either of the stored graphs, you will have to exit LOTUS 1-2-3, and use the LOTUS Printgraph system. Graphs will already have been saved under 1GRAPH and 2GRAPH. Graphs are saved each time you view them in LOTUS 1-2-3.

# APPENDIX A
# FRACTION DEFECTIVE TABLES

| | |
|---|---|
| AIC | Airborne Inhabited Cargo |
| AIT | Airborne Inhabited Trainer |
| AIB | Airborne Inhabited Bomber |
| AIA | Airborne Inhabited Attack |
| AIF | Airborne Inhabited Fighter |
| AUC | Airborne Uninhabited Cargo |
| AUT | Airborne Uninhabited Trainer |
| AUB | Airborne Uninhabited Bomber |
| AUA | Airborne Uninhabited Attack |
| AUF | Airborne Uninhabited Fighter |
| ARW | Airborne Rotary Wing |
| CL | Cannon Launch |
| GB | Ground Benign |
| GF | Ground Fixed |
| GM | Ground Mobile |
| ML | Missile Launch |
| MFF | Missile Free Flight |
| MFA | Airbreathing Missile Flight |
| MP | Manpack |
| NS | Naval Sheltered |
| NU | Naval Unsheltered |
| NUU | Naval Undersea Unsheltered |
| NSB | Naval Submarine |
| NH | Naval Hydrofoil |
| SF | Space Flight |
| USL | Undersea Launch |

## Table A-1. Fraction Defective, Microelectronic Devices (Defects/$10^6$)

| ENVIRONMENT | QUALITY LEVEL | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S | B | B-0 | B-1 | B-2 | C | C-1 | D | D-1 |
| GB | 9.2 | 18.3 | 36.6 | 54.9 | 119.0 | 146.4 | 237.9 | 320.3 | 640.6 |
| GF | 19.4 | 38.7 | 77.4 | 116.1 | 251.6 | 309.6 | 503.2 | 677.3 | 1,354.6 |
| GM | 27.5 | 55.1 | 110.1 | 165.2 | 357.9 | 440.5 | 715.8 | 963.6 | 1,927.2 |
| MP | 25.6 | 51.2 | 102.4 | 153.6 | 332.9 | 409.7 | 665.8 | 896.3 | 1,792.5 |
| NSB | 26.6 | 53.1 | 106.3 | 159.4 | 345.4 | 425.1 | 690.8 | 929.9 | 1,859.9 |
| NS | 26.6 | 53.1 | 106.3 | 159.4 | 345.4 | 425.1 | 690.8 | 929.9 | 1,859.9 |
| NU | 34.7 | 69.5 | 139.0 | 208.5 | 451.7 | 556.0 | 903.5 | 1,216.2 | 2,432.5 |
| NH | 35.7 | 71.4 | 142.8 | 214.3 | 464.3 | 571.4 | 928.5 | 1,249.9 | 2,499.9 |
| NUU | 37.6 | 75.3 | 150.5 | 225.8 | 489.3 | 602.2 | 978.6 | 1,317.3 | 2,634.6 |
| ARW | 48.2 | 96.4 | 192.9 | 289.3 | 626.9 | 771.6 | 1,253.8 | 1,687.8 | 3,375.6 |
| AIC | 19.4 | 38.7 | 77.4 | 116.1 | 251.6 | 309.6 | 503.2 | 677.3 | 1,354.6 |
| AIT | 21.8 | 43.5 | 87.0 | 130.5 | 282.9 | 348.9 | 565.7 | 761.5 | 1,523.1 |
| AIB | 31.4 | 62.8 | 125.5 | 188.3 | 408.0 | 502.1 | 815.9 | 1,098.4 | 2,196.7 |
| AIA | 26.6 | 53.1 | 106.3 | 159.4 | 345.4 | 425.1 | 690.8 | 929.9 | 1,859.9 |
| AIF | 36.2 | 72.4 | 144.8 | 217.2 | 470.5 | 579.1 | 941.0 | 1,266.8 | 2,533.5 |
| AUC | 21.8 | 43.5 | 87.0 | 130.5 | 282.9 | 348.9 | 565.7 | 761.5 | 1,523.1 |
| AUT | 26.6 | 53.1 | 106.3 | 159.4 | 345.4 | 425.1 | 690.8 | 929.9 | 1,859.9 |
| AUB | 43.4 | 86.8 | 173.6 | 260.5 | 564.3 | 694.6 | 1,128.7 | 1,519.4 | 3,038.8 |
| AUA | 36.2 | 72.4 | 144.8 | 217.2 | 470.5 | 579.1 | 941.0 | 1,266.8 | 2,533.5 |
| AUF | 50.6 | 101.3 | 202.5 | 303.8 | 658.2 | 810.1 | 1,316.4 | 1,772.0 | 3,544.0 |
| SF | 11.7 | 23.3 | 46.6 | 69.9 | 151.5 | 186.4 | 303.0 | 407.9 | 815.7 |
| MFF | 26.1 | 52.2 | 104.4 | 156.5 | 339.2 | 417.4 | 678.3 | 913.1 | 1,826.2 |
| MFA | 33.3 | 66.6 | 133.2 | 199.8 | 433.0 | 532.9 | 866.0 | 1,165.7 | 2,331.4 |
| USL | 60.3 | 120.5 | 241.0 | 361.5 | 783.3 | 964.0 | 1,566.6 | 2,108.8 | 4,217.7 |
| ML | 69.9 | 139.8 | 279.5 | 419.3 | 908.4 | 1,118.0 | 1,816.8 | 2,445.7 | 4,891.3 |
| CL | 1,065.9 | 2,131.8 | 4,263.7 | 6,395.5 | 13,857.0 | 17,054.8 | 27,714.0 | 37,307.4 | 74,614.7 |

## Table A-2. Fraction Defective, Transistors (Defects/$10^6$)

| ENVIRONMENT | QUALITY LEVEL | | | | |
|---|---|---|---|---|---|
| | JANTXV | JANTX | JAN | LOWER | PLASTIC |
| GB | 10.9 | 21.9 | 109.3 | 546.6 | 1,093.2 |
| GF | 34.6 | 69.2 | 346.0 | 1,730.2 | 3,460.4 |
| GM | 98.8 | 189.5 | 947.7 | 4,738.5 | 9,477.0 |
| MP | 65.2 | 130.4 | 651.8 | 3,259.0 | 6,518.0 |
| NSB | 54.3 | 108.7 | 543.3 | 2,716.5 | 5,433.1 |
| NS | 54.3 | 108.7 | 543.3 | 2,716.5 | 5,433.1 |
| NU | 109.6 | 219.1 | 1,095.7 | 5,478.3 | 10,956.6 |
| NH | 99.7 | 199.4 | 997.0 | 4,985.1 | 9,970.2 |
| NUU | 104.6 | 209.3 | 1,046.3 | 5,231.7 | 10,463.4 |
| ARW | 139.2 | 278.3 | 1,391.6 | 6,957.8 | 13,915.6 |
| AIC | 52.9 | 105.7 | 528.5 | 2,642.6 | 5,285.1 |
| AIT | 80.0 | 160.0 | 799.8 | 3,998.8 | 7,997.5 |
| AIB | 178.6 | 357.2 | 1,786.1 | 8,930.5 | 17,860.9 |
| AIA | 104.6 | 209.3 | 1,046.3 | 5,231.7 | 10,463.4 |
| AIF | 203.3 | 406.5 | 2,032.7 | 10,163.4 | 20,326.8 |
| AUC | 80.0 | 160.0 | 799.8 | 3,998.8 | 7,997.5 |
| AUT | 129.3 | 258.6 | 1,292.9 | 6,464.6 | 12,929.2 |
| AUB | 301.9 | 603.8 | 3,019.0 | 15,095.1 | 30,190.1 |
| AUA | 178.6 | 357.2 | 1,786.1 | 8,930.5 | 17,860.9 |
| AUF | 326.6 | 653.1 | 3,265.6 | 16,328.0 | 32,656.0 |
| SF | 8.0 | 15.9 | 79.7 | 398.6 | 797.3 |
| MFF | 65.2 | 130.4 | 651.8 | 3,259.0 | 6,518.0 |
| MFA | 89.8 | 179.7 | 898.4 | 4,491.9 | 8,983.9 |
| USL | 183.5 | 367.1 | 1,835.4 | 9,177.0 | 18,354.1 |
| ML | 208.2 | 416.4 | 2,082.0 | 10,410.0 | 20,819.9 |
| CL | 3,408.9 | 6,817.7 | 34,088.7 | 170,443.3 | 340,886.7 |

## Table A-3. Fraction Defective, Diodes (Defects/$10^6$)

| ENVIRONMENT | QUALITY LEVEL | | | | | |
|---|---|---|---|---|---|---|
| | JANS | JANTXV | JANTX | JAN | LOWER | PLASTIC |
| GB | 1.2 | 5.9 | 11.8 | 59.2 | 296.2 | 592.3 |
| GF | 1.7 | 8.6 | 17.2 | 86.0 | 430.0 | 860.0 |
| GM | 4.3 | 21.16 | 43.2 | 216.2 | 1,080.8 | 2,161.5 |
| MP | 3.2 | 16.1 | 32.2 | 160.8 | 803.8 | 1,607.7 |
| NSB | 1.9 | 9.4 | 18.9 | 94.3 | 471.5 | 943.1 |
| NS | 1.9 | 9.4 | 18.9 | 94.3 | 471.5 | 943.1 |
| NU | 4.9 | 24.4 | 48.8 | 243.8 | 1,219.2 | 2,438.5 |
| NUU | 4.7 | 23.5 | 46.9 | 234.6 | 1,173.1 | 2,346.2 |
| ARW | 6.0 | 29.9 | 59.8 | 299.2 | 1,496.2 | 2,992.3 |
| AIC | 3.8 | 18.8 | 37.7 | 188.5 | 942.3 | 1,884.6 |
| AIT | 4.7 | 23.5 | 46.9 | 234.6 | 1,173.1 | 2,346.2 |
| AIB | 6.5 | 32.7 | 65.4 | 326.9 | 1,634.6 | 3,269.2 |
| AIA | 5.6 | 28.1 | 56.2 | 280.8 | 1,403.8 | 2,807.7 |
| AIF | 7.5 | 37.3 | 74.6 | 373.1 | 1,865.4 | 3,730.8 |
| AUC | 5.6 | 28.1 | 56.2 | 280.8 | 1,403.8 | 2,807.7 |
| AUT | 6.5 | 32.7 | 65.4 | 326.9 | 1,634.6 | 3,269.2 |
| AUB | 10.2 | 51.2 | 102.3 | 511.5 | 2,557.7 | 5,115.4 |
| AUA | 8.4 | 41.9 | 83.8 | 419.2 | 2,096.2 | 4,192.3 |
| AUF | 10.2 | 51.2 | 102.3 | 511.5 | 2,557.7 | 5,115.4 |
| SF | 1.2 | 5.9 | 11.8 | 59.2 | 296.2 | 592.3 |
| MFF | 3.2 | 16.1 | 32.2 | 160.8 | 803.8 | 1,607.7 |
| MFA | 4.1 | 20.7 | 41.4 | 206.9 | 1,034.6 | 2,069.2 |
| USL | 7.6 | 38.2 | 76.5 | 382.3 | 1,911.5 | 3,823.1 |
| ML | 8.6 | 42.8 | 85.7 | 428.5 | 2,142.3 | 4,284.6 |
| CL | 128.4 | 641.9 | 1,283.8 | 6,419.2 | 32,096.2 | 64,192.3 |

## Table A-4. Fraction Defective, Resistors (Defects/$10^6$)

| ENVIRONMENT | QUALITY LEVEL S | R | P | M | MIL-SPEC | LOWER |
|---|---|---|---|---|---|---|
| GB | 0.4 | 1.2 | 3.7 | 12.3 | 61.4 | 184.2 |
| GF | 0.6 | 2.0 | 6.1 | 20.3 | 101.7 | 305.2 |
| GM | 1.5 | 5.1 | 15.4 | 51.5 | 257.4 | 772.3 |
| MP | 1.7 | 5.7 | 17.2 | 57.2 | 286.2 | 858.7 |
| NSB | 0.9 | 3.1 | 9.2 | 30.7 | 153.6 | 460.9 |
| NS | 1.0 | 3.4 | 10.1 | 33.6 | 168.1 | 504.2 |
| NU | 2.6 | 8.7 | 26.2 | 87.2 | 436.2 | 1,308.5 |
| NH | 2.6 | 8.7 | 26.2 | 87.2 | 436.2 | 1,308.5 |
| NUU | 2.8 | 9.3 | 27.9 | 93.0 | 465.0 | 1,395.0 |
| ARW | 3.5 | 11.6 | 34.8 | 116.1 | 580.3 | 1,740.9 |
| AIC | 0.6 | 2.1 | 6.3 | 20.9 | 104.6 | 313.9 |
| AIT | 0.7 | 2.4 | 7.1 | 23.8 | 119.0 | 357.1 |
| AIB | 1.3 | 4.4 | 13.2 | 44.0 | 219.9 | 659.8 |
| AIA | 1.2 | 4.1 | 12.3 | 41.1 | 205.5 | 616.6 |
| AIF | 1.8 | 5.8 | 17.5 | 58.4 | 292.0 | 876.0 |
| AUC | 1.4 | 4.7 | 14.1 | 46.9 | 234.4 | 703.1 |
| AUT | 1.3 | 4.4 | 13.2 | 44.0 | 219.9 | 659.8 |
| AUB | 2.8 | 9.3 | 27.9 | 93.0 | 465.0 | 1,395.0 |
| AUA | 2.8 | 9.3 | 27.9 | 93.0 | 465.0 | 1,395.0 |
| AUF | 3.7 | 12.2 | 36.5 | 121.8 | 609.1 | 1,827.4 |
| SF | 0.3 | 0.9 | 2.6 | 8.8 | 44.1 | 132.3 |
| MFF | 1.7 | 5.8 | 17.3 | 57.8 | 289.1 | 867.4 |
| MFA | 2.3 | 7.6 | 22.7 | 75.7 | 378.5 | 1,135.5 |
| USL | 4.7 | 15.6 | 46.9 | 156.4 | 782.1 | 2,346.3 |
| ML | 5.4 | 17.9 | 53.8 | 179.5 | 897.4 | 2,692.2 |
| CL | 88.4 | 294.7 | 884.1 | 2,947.0 | 14,735.0 | 44,205.0 |

## Table A-5. Fraction Defective, Capacitors (Defects/$10^6$)

| | QUALITY LEVEL | | | | | | |
|---|---|---|---|---|---|---|---|
| ENVIRONMENT | S | R | P | M | L | MIL-SPEC NON-ER | LOWER |
| GB | 1.2 | 3.8 | 11.5 | 38.4 | 115.3 | 115.3 | 384.4 |
| GF | 1.8 | 6.2 | 18.4 | 61.5 | 184.5 | 184.5 | 615.0 |
| GM | 9.0 | 30.0 | 89.9 | 299.8 | 899.4 | 899.4 | 2,998.1 |
| MP | 12.7 | 42.3 | 126.8 | 422.8 | 1,268.4 | 1,268.4 | 4,228.1 |
| NSB | 5.8 | 19.2 | 57.7 | 192.2 | 576.6 | 576.6 | 1,921.9 |
| NS | 6.3 | 21.1 | 63.4 | 211.4 | 634.2 | 634.2 | 2,114.1 |
| NU | 14.3 | 47.7 | 143.0 | 476.6 | 1,429.9 | 1,429.9 | 4,766.2 |
| NH | 18.4 | 61.5 | 184.5 | 615.0 | 1,845.0 | 1,845.0 | 6,150.0 |
| NUU | 20.8 | 69.2 | 207.6 | 691.9 | 2,075.6 | 2,075.6 | 6,918.7 |
| ARW | 27.7 | 92.2 | 276.7 | 922.5 | 2,757.5 | 2,767.5 | 9,225.0 |
| AIC | 3.5 | 11.5 | 34.6 | 115.3 | 345.9 | 345.9 | 1,153.1 |
| AIT | 3.5 | 11.5 | 34.6 | 115.3 | 345.9 | 345.9 | 1,153.1 |
| AIB | 5.8 | 19.2 | 57.7 | 192.2 | 576.6 | 576.6 | 1,921.9 |
| AIA | 3.5 | 11.5 | 34.6 | 115.3 | 345.9 | 345.9 | 1,153.1 |
| AIF | 6.9 | 23.1 | 69.2 | 230.6 | 691.9 | 691.9 | 2,306.2 |
| AUC | 8.6 | 28.8 | 86.5 | 288.3 | 864.8 | 864.8 | 2,882.8 |
| AUT | 9.2 | 30.7 | 92.2 | 307.5 | 922.5 | 922.5 | 3,075.0 |
| AUB | 11.5 | 38.4 | 115.3 | 384.4 | 1,153.1 | 1,153.1 | 3,843.7 |
| AUA | 9.2 | 30.7 | 92.2 | 307.5 | 922.5 | 922.5 | 3,075.0 |
| AUF | 17.3 | 57.7 | 173.0 | 576.6 | 1,729.7 | 1,729.7 | 5,765.6 |
| SF | 0.9 | 3.1 | 9.2 | 30.7 | 92.2 | 92.2 | 307.5 |
| MFF | 12.7 | 42.3 | 126.8 | 422.8 | 1,268.4 | 1,268.4 | 4,228.1 |
| MFA | 17.3 | 57.7 | 173.0 | 576.6 | 1,729.7 | 1,729.7 | 5,765.6 |
| USL | 36.9 | 123.0 | 369.0 | 1,230.0 | 3,690.0 | 3,690.0 | 12,300.0 |
| ML | 41.5 | 138.4 | 415.1 | 1,383.7 | 4,151.2 | 4,151.2 | 13,837.5 |
| CL | 703.4 | 2,344.7 | 7,034.1 | 23,446.9 | 70,340.6 | 70,340.6 | 234,468.6 |

## Table A-6. Fraction Defective, Inductive Devices (Defects/$10^6$)

| | QUALITY LEVEL | |
|---|---|---|
| ENVIRONMENT | MIL-SPEC | LOWER |
| GB | 537.2 | 1,790.7 |
| GF | 1,222.9 | 4,076.4 |
| GM | 2,142.0 | 7,140.1 |
| MP | 1,996.1 | 6,653.8 |
| NSB | 1,135.4 | 3,784.6 |
| NS | 1,222.9 | 4,076.4 |
| NU | 2,433.8 | 8,112.7 |
| NH | 2,725.6 | 9,085.3 |
| NUU | 3,017.4 | 10,058.0 |
| ARW | 3,892.7 | 12,975.8 |
| AIC | 1,047.8 | 3,492.8 |
| AIT | 1,266.7 | 4,222.3 |
| AIB | 1,266.7 | 4,222.3 |
| AIA | 1,266.7 | 4,222.3 |
| AIF | 1,704.4 | 5,681.2 |
| AUC | 1,339.6 | 4,465.4 |
| AUT | 1,339.6 | 4,465.4 |
| AUB | 1,485.5 | 4,951.7 |
| AUA | 485.5 | 4,951.7 |
| AUF | 1,850.3 | 6,167.5 |
| SF | 537.2 | 1,790.7 |
| MFF | 1,996.1 | 6,653.8 |
| MFA | 2,579.7 | 8,599.0 |
| USL | 5,059.9 | 16,866.2 |
| ML | 5,643.4 | 18,811.5 |
| CL | 89,385.3 | 297,951.1 |

### Table A-7. Fraction Defective, Rotating Devices

| ENVIRONMENT | FRACTION DEFECTIVE (DEFECTS/$10^6$) |
|---|---|
| GB | 5,935.2 |
| GF | 11,663.1 |
| GM | 30,168.5 |
| MP | 27,965.5 |
| NSB | 14,967.6 |
| NS | 16,289.4 |
| NU | 34,574.6 |
| NH | 38,980.6 |
| NUU | 43,386.7 |
| ARW | 56,604.8 |
| AIC | 12,544.3 |
| AIT | 13,645.8 |
| AIB | 15,848.8 |
| AIA | 13,645.8 |
| AIF | 23,559.4 |
| AUC | 14,747.3 |
| AUT | 18,051.9 |
| AUB | 20,254.9 |
| AUA | 18,051.9 |
| AUF | 25,762.5 |
| SF | 5,935.2 |
| MFF | 27,965.5 |
| USL | 74,229.1 |
| ML | 83,041.2 |
| CL | ******* |

## Table A-8. Fraction Defective, Relays (Defects/$10^6$)

| ENVIRONMENT | QUALITY LEVEL MIL-SPEC | LOWER |
|---|---|---|
| GB | 142.5 | 210.9 |
| GF | 231.4 | 388.8 |
| GM | 635.1 | 1,784.5 |
| MP | 1,510.8 | 4,384.3 |
| NSB | 621.4 | 1,716.0 |
| NS | 621.4 | 1,716.0 |
| NU | 1,031.9 | 2,673.9 |
| NH | 2,263.4 | 6,642.0 |
| NUU | 2,400.2 | 6,915.7 |
| ARW | 3,221.2 | 9,652.3 |
| AIC | 450.3 | 724.0 |
| AIT | 484.5 | 1,100.3 |
| AIB | 758.2 | 1,442.4 |
| AIA | 587.2 | 1,100.3 |
| AIF | 758.2 | 1,784.5 |
| AUC | 621.4 | 1,442.4 |
| AUT | 689.8 | 1,784.5 |
| AUB | 1,100.3 | 2,810.7 |
| AUA | 758.2 | 2,126.5 |
| AUF | 1,100.3 | 3,152.8 |
| SF | 142.5 | 210.9 |
| MFF | 1,510.8 | 4,384.3 |
| MFA | 2,058.1 | 5,684.2 |
| USL | 4,315.8 | 13,073.1 |
| ML | 4,931.6 | 14,441.4 |
| CL | N/A | N/A |

## Table A-9. Fraction Defective, Switches (Defects/$10^6$)

| ENVIRONMENT | QUALITY LEVEL MIL-SPEC | LOWER |
|---|---|---|
| GB | 1.4 | 24.4 |
| GF | 2.4 | 44.0 |
| GM | 8.8 | 158.4 |
| MP | 12.8 | 230.6 |
| NSB | 5.3 | 95.5 |
| NS | 5.3 | 95.5 |
| NU | 12.2 | 220.3 |
| NUU | 20.3 | 364.7 |
| ARW | 27.1 | 488.4 |
| AIC | 5.4 | 96.6 |
| AIT | 5.4 | 96.6 |
| AIB | 9.4 | 168.8 |
| AIA | 9.4 | 168.8 |
| AIF | 12.2 | 220.3 |
| AUC | 6.5 | 117.2 |
| AUT | 6.5 | 117.2 |
| AUB | 12.2 | 220.3 |
| AUA | 12.2 | 220.3 |
| AUF | 15.1 | 271.9 |
| SF | 1.4 | 24.4 |
| MFF | 12.8 | 230.6 |
| MFA | 17.4 | 313.1 |
| USL | 36.9 | 663.7 |
| ML | 41.5 | 746.2 |
| CL | 688.3 | 12,388.6 |

## Table A-10. Fraction Defective, Connectors (Defects/$10^6$)

| ENVIRONMENT | QUALITY LEVEL MIL-SPEC | LOWER |
|---|---|---|
| GB | 73.7 | 97.3 |
| GF | 83.2 | 248.1 |
| GM | 417.7 | 1,204.6 |
| MP | 427.1 | 827.7 |
| NSB | 219.8 | 408.3 |
| NS | 276.3 | 544.9 |
| NU | 639.2 | 1,298.9 |
| NH | 639.2 | 1,251.8 |
| NUU | 686.3 | 1,346.0 |
| ARW | 921.9 | 1,770.1 |
| AIC | 120.9 | 497.8 |
| AIT | 168.0 | 497.8 |
| AIB | 238.7 | 733.4 |
| AIA | 215.1 | 733.4 |
| AIF | 332.9 | 969.0 |
| AUC | 262.2 | 733.4 |
| AUT | 403.6 | 733.4 |
| AUB | 497.8 | 969.0 |
| AUA | 474.3 | 969.0 |
| AUF | 733.4 | 1,440.2 |
| SF | 73.7 | 97.3 |
| MFF | 427.1 | 827.7 |
| MFA | 592.1 | 1,157.5 |
| USL | 1,204.6 | 2,382.7 |
| ML | 1,393.1 | 2,759.6 |
| CL | 21,335.8 | 45,733.8 |

**Table A-11. Fraction Defective, Printed Wiring Boards (Defects/$10^6$)**

| ENVIRONMENT | QUALITY LEVEL MIL-SPEC | LOWER |
|---|---|---|
| GB | 425.0 | 4,250.0 |
| GF | 690.3 | 6,903.2 |
| GM | 1,792.4 | 17,925.3 |
| MP | 1,629.2 | 16,291.5 |
| NSB | 1,057.7 | 10,576.9 |
| NS | 1,302.6 | 13,026.0 |
| NU | 2,670.0 | 26,700.3 |
| NH | 2,874.1 | 28,741.2 |
| NUU | 3,078.2 | 30,782.2 |
| ARW | 4,098.7 | 40,986.9 |
| AIC | 731.1 | 7,311.4 |
| AIT | 1,139.3 | 11,393.2 |
| AIB | 1,853.7 | 18,536.5 |
| AIA | 1,567.9 | 15,679.2 |
| AIF | 2,261.8 | 22,618.4 |
| AUC | 1,751.6 | 17,516.1 |
| AUT | 3,282.3 | 32,823.1 |
| AUB | 5,323.3 | 53,232.5 |
| AUA | 4,302.8 | 43,027.8 |
| AUF | 7,364.2 | 73,641.9 |
| SF | 425.0 | 4,250.0 |
| MFF | 1,996.5 | 19,965.2 |
| MFA | 2,670.0 | 26,700.3 |
| USL | 5,527.3 | 55,273.5 |
| ML | 6,139.6 | 61,396.3 |
| CL | 102,267.9 | ******* |

## Table A-12. Fraction Defective, Connections (Defects/$10^6$)

CONNECTION TYPE

| ENVIRONMENT | HAND SOLDER | WELD | SOLDERLESS WRAP | WRAPPED AND SOLDERED | CLIP TERM | REFLOW SOLDER | CRIMP AUTO | CRIMP MANUAL UPPER | CRIMP MANUAL STD. | CRIMP MANUAL LOWER |
|---|---|---|---|---|---|---|---|---|---|---|
| GM | 12. | 0.2 | 0.02 | 1. | 1. | 0.3 | 1.2 | 1.2 | 2.5 | 24.8 |
| GF | 26. | 0.5 | 0.03 | 1. | 1. | 0.7 | 2.6 | 2.6 | 5.2 | 52.0 |
| GM | 90. | 1.7 | 0.12 | 5. | 4. | 2.4 | 9.0 | 9.0 | 18.1 | 180.8 |
| MP | 90. | 1.7 | 0.12 | 5. | 4. | 2.4 | 9.0 | 9.0 | 18.1 | 180.8 |
| NSB | 43. | 0.8 | 0.06 | 2. | 2. | 1.1 | 4.3 | 4.3 | 8.7 | 86.7 |
| NS | 54. | 1.0 | 0.07 | 3. | 3. | 1.4 | 5.4 | 5.4 | 10.9 | 109.0 |
| NU | 123. | 2.4 | 0.16 | 7. | 6. | 3.3 | 12.3 | 12.3 | 24.5 | 245.1 |
| NH | 136. | 2.6 | 0.18 | 7. | 6. | 3.6 | 13.6 | 13.6 | 27.2 | 272.4 |
| NUU | 149. | 2.9 | 0.20 | 8. | 7. | 3.9 | 14.9 | 14.9 | 29.7 | 297.1 |
| ARW | 198. | 3.8 | 0.27 | 11. | 9. | 5.3 | 19.8 | 39.6 | 39.6 | 396.2 |
| AIC | 31. | 0.6 | 0.04 | 2. | 1. | 0.8 | 3.1 | 3.1 | 6.2 | 61.9 |
| AIT | 56. | 1.1 | 0.07 | 3. | 3. | 1.5 | 5.6 | 5.6 | 11.1 | 111.4 |
| AIB | 68. | 1.3 | 0.09 | 4. | 3. | 1.8 | 6.8 | 6.8 | 13.6 | 136.2 |
| AIA | 62. | 1.2 | 0.08 | 3. | 3. | 1.6 | 6.2 | 6.8 | 12.4 | 123.8 |
| AIF | 93. | 1.8 | 0.12 | 5. | 4. | 2.5 | 9.3 | 9.3 | 18.6 | 185.7 |
| AUC | 37. | 0.7 | 0.05 | 2. | 2. | 1.0 | 3.7 | 3.7 | 7.4 | 74.3 |
| AUT | 74. | 1.4 | 0.10 | 4. | 3. | 2.0 | 7.4 | 7.4 | 14.9 | 148.6 |
| AUB | 93. | 1.8 | 0.12 | 5. | 4. | 2.5 | 9.3 | 9.3 | 18.6 | 185.7 |
| AUA | 87. | 1.7 | 0.12 | 5. | 4. | 2.5 | 9.3 | 9.3 | 18.6 | 185.7 |
| AUF | 118. | 2.3 | 0.16 | 6. | 5. | 3.1 | 11.8 | 11.8 | 23.5 | 235.2 |
| SF | 12. | 0.2 | 0.02 | 1. | 1. | 0.3 | 1.2 | 2.5 | 2.5 | 24.8 |
| MFF | 90. | 1.7 | 0.12 | 5. | 4. | 2.4 | 9.0 | 9.0 | 18.1 | 180.8 |
| MFA | 124. | 2.4 | 0.17 | 7. | 6. | 3.3 | 12.4 | 12.4 | 24.8 | 247.6 |
| USL | 272. | 5.2 | 0.37 | 15. | 13. | 7.2 | 27.2 | 27.2 | 54.5 | 544.8 |
| ML | 310. | 6.0 | 0.42 | 17. | 14. | 8.2 | 31.0 | 31.0 | 61.9 | 619.0 |
| CL | 5,200. | 100.0 | 7.00 | 280. | 240. | 138.0 | 520.0 | 520.0 | 1,040.0 | 10,400.0 |

# APPENDIX B
# SELECTION OF SOW, DD FORM 1423 AND DATA ITEM DESCRIPTIONS

Based on the previous processes of defect determination—stress type and magnitude determination, criticality assessment and cost analysis—certain ESS activities are appropriate. For each type of stress screen, a narrative requirement must appear in the statement of work, accompanied by an initial baseline intensity of the stress.

All projects having any ESS elements must have contract requirements for implementation of an ESS program, preparation of an ESS plan, ESS procedures and ESS performance reports. Other activities are determined by the types of stress being applied and the amount of funding available. Thermal cycling requires a thermal survey (if funding permits) and a requirement of performance of thermal cycling. Random vibration requires a vibration survey (if funding permits) and a requirement to perform random vibration at a given intensity.

Any contract requirement for ESS must be accompanied by certain parameters specified by the procuring activity. The type of stress screens to be performed and the intensity of the stress must be specified. This includes random vibration frequency range, power spectral density, axis of vibration, duration of vibration or number of thermal cycles, temperature extremes, temperature rate-of-change, and other factors that must be evaluated by the procuring activity to generate effective contract clauses and statements of work.

Table B-1 provides a listing of the sample statements of work that can be invoked in hardware contracts. They are to be tailored to specific needs and may be modified to eliminate redundant requirements with other quality or reliability statements of work.

**Table B-1. Selection of Statement of Work, DD Form 1423 and Data Item Description**

| ACTIVITY | DID # | MIL-STD TASK # | PAGE |
|---|---|---|---|
| Implement ESS Program | | MIL-STD-785, Task 301 | 41 |
| Prepare ESS Plan | DI-R-8XXX85 | Defined in SOW | 42 |
| Prepare ESS Procedures | | In SOW | 44 |
| Prepare ESS Performance Reports | DI-RELI-80249 | MIL-STD-785, Task 301<br>MIL-STD-781, Task 401 | 47 |
| Perform Thermal Survey | DI-RELI-80247 | MIL-STD-781D, Task 201, Paragraph 201.2.1 | 21 |
| Perform Vibration Survey | DI-RELI-80248 | MIL-STD-781D, Task 201, Paragraph 201.2.2 | 33 |
| Perform Parts Screening | | MIL-STD-883, Methods 1015, 2020, 2003, 5009, 2012, and 1014 | 7 |
| Perform Thermal Cycling | | | 13 |
| Perform Random Vibration | | | 25 |

# APPENDIX C
# ENVIRONMENTAL STRESS SCREENING COST MODEL

Place the proper amount in the brackets provided after each question. Default values are listed in the brackets for most of the questions. If you do not wish to use the default value, change it simply by putting in your value over the existing default value within the brackets. Never leave brackets empty. If the question does not pertain to your evaluation, place a zero (0) in the brackets. If a word or phrase is desired by the question, place the appropriate phrase within the brackets.

## PART 1

The first part of this cost model allows the user to see the following cost model elements:

- Range of defects per item
- Number of defects in lot size according to the incoming defect estimation
- Total screening cost for each defect estimation
- Screening cost per item for each defect estimation
- Screening cost per defect for each defect rate.

1. What is the title you wish to use for this cost model (i.e., item name, company name, etc.) [The BRDEC Cost Model]

The following costs relate to two different screens. Two columns of brackets denote the two screens. Default values given here under columns A and B relate to thermal cycling and random vibration, respectively. Where there is only one set of brackets, the cost for both screens "A" and "B" is the same.

| | A | B |
|---|---|---|
| 2. What are the screen names? | [Thermal] | [Vibration] |
| 3. What is the cost for the following screening equipment? | | |
| – Chamber cost | [ $40,000 ] | [ $55,000 ] |
| – Monitoring equipment cost | [ $4,000 ] | [ $4,000 ] |
| – Support equipment cost | [ $0 ] | [ $30,000 ] |
| – Fixture cost | [ $500 ] | [ $0 ] |
| – Facilities cost | [ $0 ] | [ $0 ] |
| – Any other costs | [ $0 ] | [ $0 ] |
| —Totals— | $44,500 | $89,000 |

4. What are the values for the following survey parameters?

| | A | B |
|---|---|---|
| – Accelerometer cost | [ $0 ] | [ $300 ] |
| – Survey time (hours) | [ 24.00 ] | [ 4.00 ] |
| – Technician labor rate ($/hr) | [ $50 ] | [ $50 ] |
| —Survey Costs— | $1,200 | $500 |

5. What are the values for the following item screening parameters?

| | A | B |
|---|---|---|
| – # Items in the lot | [ 5,000 ] | [ 5,000 ] |
| – # Items in one set | [ 10 ] | [ 10 ] |
| – # Hours to load one set | [ 0.5 ] | [ 0.5 ] |
| – # Hours to manually monitor chamber while screening one set | [ 0.5 ] | [ 0.2 ] |
| – # Hours to unload one set | [ 0.2 ] | [ 0.2 ] |
| – # Hours to run functional test on one set | [ 2 ] | [ 2 ] |
| – Technician labor rate ($/hr) | [ $50 ] | [ $50 ] |
| – Administrative cost associated with screening one item | [ $4 ] | [ $4 ] |
| —Totals for Screening— | $100,000 | $92,500 |
| —Screening Cost Per Item— | $20 | $19 |

| | A | B |
|---|---|---|
| 6. What are the values for the following failure parameters? | | |
| **Analysis Parameters** | | |
| – Cost for one full failure analysis of an unknown defect ($) | | [ $ 1,000 ] |
| – Percentage of defects found that need a full analysis to find the cause of failure (decimal) | | [ 0.20 ] |
| – Range for number of defects estimated per item (Place the first value of the range in column "A" and the last value of the range in the range in column "B" | [ 0 ] | [ 0.3 ] |
| – Estimated defect per item step | | [ 0.02 ] |
| – Percent of total defects that will be uncovered by screen "A" and screen "B," respectively | [ 0.8 ] | [ 0.2 ] |
| —Failure Cost Per Defect— | | $200 |
| **Repair Parameters** | | |
| – Average parts cost to repair defective item ($) | | [ $0 ] |
| – Repair technician labor rate ($/hr) | | [ $50 ] |
| – # Hours to repair one defective item (X.XX) | | [ 1.00 ] |
| —Total Repair Cost Per Defect— | | $50 |

**Rescreening Parameters**

(These values may be the same as the screening values. Differences may occur when no rescreening is done or the cycles are reduced, hence shortening the monitoring time.)

| | A | B |
|---|---|---|
| – # Hours to load one repaired set into fixture (X.XX) | [ 0.50 ] | [ 0.50 ] |
| – # Hours to monitor chamber while screening one repaired set (X.XX) | [ 0.25 ] | [ 0.25 ] |
| – # Hours to unload one repaired set from the fixture (X.XX) | [ 0.20 ] | [ 0.20 ] |
| – # Hours to run a functional test on the rescreened items (X.XX) | [ 1.00 ] | [ 1.00 ] |
| – Administrative cost ($) | [ $4 ] | [ $4 ] |
| —Rescreening Cost Per Defect— | $13.75 | $13.00 |

**PART 2**

The second part of this cost model illustrates the field failure costs and will display the cost per field failure.

| | A | B |
|---|---|---|
| 7. What is the cost of one item? | [ $800 ] | |
| 8. What is the life of the item (months)? | [ 120 ] | |
| 9. If a temporary replacement item is to be used in the field during the repair period, how long will the replacement item be used? (months) | [ 8 ] | |

The following parameters are categorized into three different areas dealing with the return of the item. Suggested categories are placed in the brackets as defaults.

| | A | B | C |
|---|---|---|---|
| 10. What are the field failure categories | [No Failure] | [ Discard ] | [ Repaired ] |
| 11. What is the percent estimate for each of the field failure categories occurring? | [ 0.2 ] | [ 0.2 ] | [ 0.6 ] |
| 12. What are the following failure costs per item? | | | |
| – Cost to pack item and ship to depot | [ $100.00 ] | [ $100.00 ] | [ $100.00 ] |
| – Cost to replace item in field while out of supply pipeline | [ $53.33 ] | [ $53.33 ] | [ $53.33 ] |
| – Fault isolation/verification | [ $25.00 ] | [ $0.00 ] | [ $25.00 ] |
| – Repair parts | [ $0.00 ] | [ $800.00 ] | [ $200.00 ] |
| – Cost to ship item back to field | [ $100.00 ] | [ $100.00 ] | [ $100.00 ] |
| – Failure analysis cost for one item | [ $0.00 ] | [ $0.00 ] | [ $200.00 ] |
| – Administrative cost | [ $75.00 ] | [ $75.00 ] | [ $75.00 ] |
| —Totals— | $353.33 | $1,128.33 | $753.33 |

Using a weighted average based on the above totals and percentages,
the cost per field failure is ..............................................................$748.33

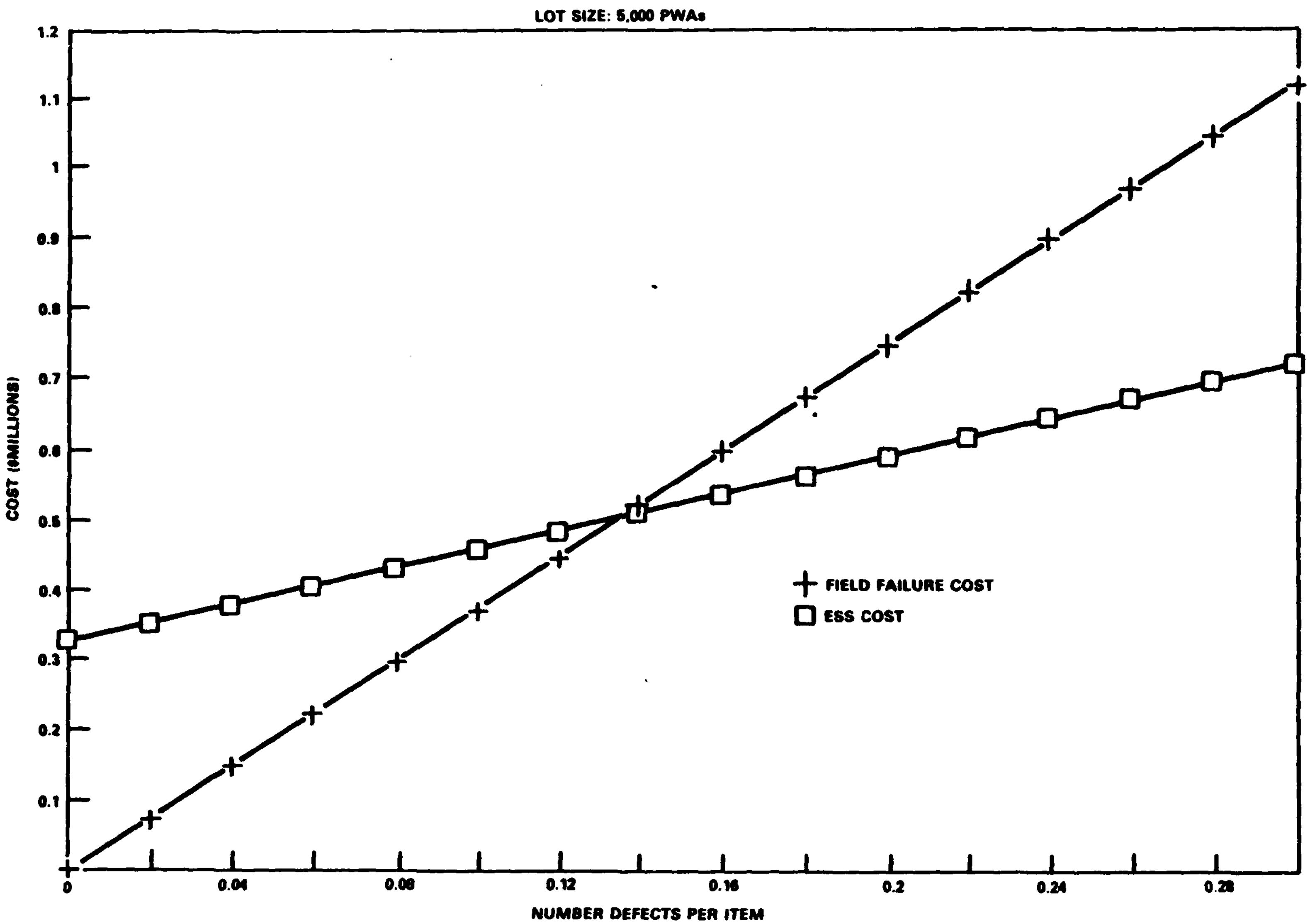


Figure C-1. Sample Cost Effectiveness Graph

## Table C-1. BRDEC Cost Model

LOT SIZE = 5,000

| # DEFECTS PER ITEM | TOTAL # DEFECTS | THERMAL SCR COST | VIBRATION SCR COST | TOTAL SCR COST | SCR COST PER ITEM | COST PER DEFECT | TOTAL FIELD FAILURE COST |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.0 | $145,700 | $182,000 | $327,700 | $66 | ERR | $0 |
| 0.02 | 100.0 | $166,822 | $187,266 | $354,088 | $71 | $3,541 | $74,833 |
| 0.04 | 200.0 | $187,945 | $192,531 | $380,476 | $76 | $1,902 | $149,667 |
| 0.06 | 300.0 | $209,067 | $197,797 | $406,864 | $81 | $1,356 | $224,500 |
| 0.08 | 400.0 | $230,190 | $203,062 | $433,252 | $87 | $1,083 | $299,333 |
| 0.10 | 500.0 | $251,312 | $208,328 | $459,640 | $92 | $919 | $374,167 |
| 0.12 | 600.0 | $272,434 | $213,594 | $486,028 | $97 | $810 | $449,000 |
| 0.14 | 700.0 | $293,557 | $218,859 | $512,416 | $102 | $732 | $523,833 |
| 0.16 | 800.0 | $314,679 | $224,125 | $538,804 | $108 | $674 | $598,667 |
| 0.18 | 900.0 | $335,802 | $229,390 | $565,192 | $113 | $628 | $673,500 |
| 0.20 | 1,000.0 | $356,924 | $234,656 | $591,580 | $118 | $592 | $748,333 |
| 0.22 | 1,100.0 | $378,046 | $239,922 | $617,968 | $124 | $562 | $823,167 |
| 0.24 | 1,200.0 | $399,169 | $245,187 | $644,356 | $129 | $537 | $898,000 |
| 0.26 | 1,300.0 | $420,291 | $250,453 | $670,744 | $134 | $516 | $972,833 |
| 0.28 | 1,400.0 | $441,414 | $255,718 | $697,132 | $139 | $498 | $1,047,667 |
| 0.30 | 1,500.0 | $462,536 | $260,984 | $723,520 | $145 | $482 | $1,122,500 |

# REFERENCES

## MILITARY SPECIFICATIONS AND STANDARDS


MIL-T-27E, *General Specifications for Transformers and Inductors (Audio, Power, and High Power Pulse),* 4 April 1985.

MIL-STD-202F, *Test Methods for Electronic and Electrical Component Parts*, 1 April 1980.

MIL-STD-105, *Sampling Procedures and Tables for Inspection by Attributes*, March 1964.

MIL-STD-750C, *Test Methods for Semiconductor Devices*, February 1983.

MIL-STD-242G, *Electronic Equipment Parts Selected Standards*, 17 September 1981.

MIL-STD-781D, *Reliability Testing for Engineering Development, Qualification and Production.*

MIL-STD-785B, *Reliability Program for Systems and Equipment Development and Production,* 3 July 1986.

MIL-STD-810D, *Environmental Test Methods and Engineering Guidelines*, July 1986.

MIL-STD-883C, *Test Methods and Procedures for Microelectronics*, 29 May 1987.

MIL-STD-19500G, *Semiconductor Devices, General Specification for,* 11 March 1985.

MIL-HDBK-217E, *Reliability Prediction of Electronic Equipment*, 27 October 1986.

DI-RELI-80247, *Thermal Survey Report*

DI-RELI-80248, *Vibration Survey Report*

DI-RELI-80249, *Environmental Stress Screening Report*

## FOOTNOTES

1. "R&M 2000 Enviornmental Stress Screening," IEEE Transactions on Reliability, Vol. R-36, August 1987.

2. "Environmental Stress Screening Guidelines for Assemblies," Institute of Environmental Sciences, September 1984.

3. NAVMAT-9492, "Navy Manufacturing Screening Program," Department of the Navy, May 1979.

4. "Random Vibration Screening of Six Militarized Avionic Computers," Journal of the Institute of Environmental Sciences, March-April 1982.

## OTHER REFERENCES

AMC-R-702-25, "AMC Environmental Stress Screening Program," 29 May 1987.

RADC TR-87, "Guide to Environmental Stress Screening."

DOD HDBK-344 (USAF), "Environmental Stress Screening (ESS) of Electronic Equipment," 20 October 1986.

# DISTRIBUTION FOR REPORT 2477

| No. Copies | Addressee |
|---|---|
| | **Department of Defense** |
| 1 | Director, Technical Information<br>Defense Advanced Research Projects Agency<br>1400 Wilson Blvd<br>Arlington, VA 22209 |
| 1 | Director<br>Defense Nuclear Agency<br>ATTN: TITL<br>Washington, DC 20305 |
| 12 | Defense Technical Information Center<br>Cameron Station<br>Alexandria, VA 22314 |
| 5 | Commander<br>US Army Materiel Command<br>ATTN: AMCQA<br>5001 Eisenhower Ave<br>Alexandria, VA 22333-0001 |
| 2 | Commander<br>US Army Armament Munitions and Chemical Command<br>ATTN: AMSMC-QA<br>Dover, NJ 07801-5000 |
| 3 | Commander<br>US Army Troop Support Command<br>ATTN: AMSTR-Q<br>4300 Goodfellow Blvd<br>St. Louis, MO 63120 |
| 3 | Commander<br>US Army Natick RD&E Center<br>ATTN: STRNC-EP<br>Natick, MA 01760-5014 |
| 2 | Commander<br>US Army LABCOM<br>ATTN: AMSLC-PA<br>Adelphi, MD 20783 |
| 2 | Commander<br>US Army Communication Electronics Command<br>ATTN: AMSEL-PA<br>Fort Monmouth, NJ 07703-5000 |
| 2 | Commander<br>US Army Aviation Systems Command<br>ATTN: AMSAV-Q<br>4300 Goodfellow Blvd<br>St. Louis, MO 63120-1798 |
| 1 | Commander<br>US Army Depot System Command<br>ATTN: AMSDS-Q<br>Chambersburg, PA 17201-4170 |
| 2 | Commander<br>US Army Missile Command<br>ATTN: AMSMI-Q<br>Redstone Arsenal, AL 35898-5290 |
| 2 | Commander<br>US Army Tank-Automotive Command<br>ATTN: AMSTA-Q<br>Warren, MI 48090 |
| 2 | Commander<br>US Army Test and Evaluation Command<br>ATTN: AMSTE-AD<br>Aberdeen Proving Ground, MD 21005 |
| 2 | Commander<br>US Army Logistics Management Center<br>ATTN: AMXMC-ACM-MA<br>Fort Lee, VA 23801-6042 |
| 2 | Director<br>US AMC Intern Training Center<br>ATTN: AMXMC-ITC<br>Texarkana, TX 75507 |
| 2 | Director<br>US Army Management Engineering Training Activity<br>ATTN: AMXOM-DO<br>Rock Island, IL 61299-7040 |
| 1 | Chief<br>Product Assurance and Test Field Activity<br>ATTN: AMXQA<br>Lexington, KY 40511-5105 |

| No. Copies | Addressee |
|---|---|
| 2 | Director<br>US Army Materiel Systems Analysis Agency<br>ATTN: AMXSY-R<br>Aberdeen Proving Ground, MD 21005-5071 |
| | **Department of the Army** |
| 1 | Commander, HQ TRADOC<br>ATTN: ATEN-ME<br>Fort Monroe, VA 23651 |
| 1 | HQDA (DAMA-AOA-M)<br>Washington, DC 20310 |
| 1 | HQDA (DAEN-RDL)<br>Washington, DC 20314 |
| 1 | HQDA (DAEN-MPE-T)<br>Washington, DC 203014 |
| 1 | Commander<br>US Army Missile Command<br>ATTN: DRSMI-RR<br>Redstone Arsenal, AL 35809 |
| 1 | Director<br>US Army Materiel Systems Analysis Agency<br>ATTN: DRXSY-CM<br>Aberdeen Proving Ground, MD 21005 |
| 1 | Director<br>US Army Ballistic Research Laborotory<br>ATTN: DRDAR-TSD-S (STINFO)<br>Aberdeen Proving Ground, MD 21005 |
| 1 | Commandant<br>Belvoir Research, Development and Engineering Center<br>Fort Belvoir, VA 22060 |
| 1 | Commander, STRBE-Z<br>Deputy Commander, STRBE-ZD<br>Technical Director, STRBE-ZT<br>Assoc Tech Dir (E&A), STRBE-ZTE<br>Assoc Tech Dir (R&D), STRBE-ZTR<br>Executive Officer, STRBE-ZX<br>Sergeant Major, STRBE-ZM<br>Advanced Systems Concepts Dir, STRBE-H<br>Program Planning Div, STRBE-HP<br>Foreign Intelligence Div, STRBE-HF<br>Systems and Concepts Div, STRBE-HC<br>CIRCULATE |
| 1 | Dir, Resource Management Dir, STRBE-C<br>Dir, Information Management Dir, STRBE-B<br>Dir, Facilities and Support Dir, STRBE-W<br>Dir, Product Assurance & Engr Dir, STRBE-T<br>Dir, Combat Engineering Dir, STRBE-J<br>Dir, Logistics Support Dir, STRBE-F<br>Dir, Materials, Fuels & Lubricants Lab, STRBE-V |
| 10 | PA&E Dir, STRBE-T |
| 50 | PA Div, STRBE-TQE |
| 3 | Tech Reports Ofc, STRBE-BPG |
| 5 | Security Ofc (for liaison officers), STRBE-S |
| 2 | Tech Lib, STRBE-BT |
| 1 | Pubic Affairs Ofc, STRBE-I |
| 1 | Ofc of Chief Counsel, STRBE-L |

**AMC LIBRARIES**

| No. Copies | Addressee |
|---|---|
| 1 | US Army Aberdeen Proving Ground<br>ATTN: STEAP-IM-AL<br>Aberdeen Proving Ground, MD 21005-5001 |
| 1 | Director, US Army Ballistic Research Lab<br>ATTN: AMXBR-OD-ST<br>Aberdeen Proving Ground, MD 21005-5066 |
| 1 | HQ, US Army TECOM<br>ATTN: AMSTE-TO-F<br>Aberdeen Proving Ground, MD 21005-5055 |
| 1 | DIR, US Army Laboratory Command<br>Materials Technology Laboratory<br>ATTN: SLCMT-IML<br>Watertown, MA 02172-0001 |
| 1 | CDR, USA Communication & Electronic CMD<br>ATTN: AMSEL-ME-PSL<br>Ft. Monmouth, NJ 07703-5007 |
| 1 | HQ, US Army CECOM<br>ATTN: AMSEL-LG-JA<br>Ft. Monmouth, NJ 07703-5010 |
| 1 | CDR, US Army Aviation Systems Command<br>ATTN: AMSAV-DIL<br>4300 Goodfellow Blvd, East 2<br>St. Louis, MO 63120-1798 |
| 1 | CDR, US Army Armament, Munitions & Chemical Command<br>ATTN: AMSMC-IMP-L<br>Rock Island, IL 61299-6000 |

| No. Copies | Addressee | No. Copies | Addressee |
|---|---|---|---|
| 1 | CDR, US Army Missile Command<br>ATTN: AMSMI-RPR<br>Redstone Scientific Information Ctr<br>Redstone Arsenal, AL 35898-5241 | 1 | CDR, US Army Yuma Proving Ground<br>ATTN: STEYP-IM-AT<br>Yuma, AZ 85365-9102 |
| 1 | CDR, US Army Missile Command<br>ATTN: AMSMI-YDL<br>Redstone Arsenal, AL 35898-5500 | 1 | CMDT, USA School of Engineering & Logistics<br>ATTN: AMXMC-SEL-L<br>Red River Army Depot<br>Texarkana, TX 75507-5000 |
| 1 | Director, White Sands Missile Range<br>ATTN: STEWS-TE-TL<br>White Sands Missile Range, NM 88002-5029 | 1 | CDR, Letterkenny Army Depot<br>ATTN: SDSLE-SWIM<br>Chambersburg, PA 17201-4150 |
| 1 | CDR, White Sands Missile Range<br>ATTN: STEWS-DP-ML<br>White Sands Missile Range, NM 88002-5039 | 1 | CDR, New Cumberland Army Depot<br>ATTN: SDSNC-D-DA<br>New Cumberland, PA 17070-5001 |
| 1 | HQ, US Army Materiel Command<br>ATTN: AMCDMA-ML<br>5001 Eisenhower Ave<br>Alexandria, VA 22333-0001 | 1 | CDR, Seneca Army Depot<br>ATTN: SDSSE-TR<br>Romulus, NY 14541-5110 |
| 1 | CDR, US Army Tank Automotive Command<br>ATTN: AMSTA-TSL<br>Warren, MI 48397-5000 | 1 | CDR, Sierra Army Depot<br>ATTN: SDSSI-CSB<br>Herlong, CA 96113-5110 |
| 1 | CDR, Automated Logistics Mgmt Systems Acty<br>ATTN: AMXAL-AAG<br>PO Box 1578<br>St. Louis, MO 63188-1578 | 1 | CDR, Sharpe Army Depot<br>ATTN: SDSSH-AMW-MSA<br>Lathrop, CA 95331-5124 |
| 1 | US Army Armament RD&E Center<br>ATTN: SMCAR-TSS<br>Bldg 59<br>Dover, NJ 07801-5001 | 1 | CDR, Tobyhanna Army Depot<br>ATTN: SDSTO-DA-T<br>Tobyhanna, Pa 18466-5099 |
| 1 | CDR, USA Aviation Research & Technology Acty<br>Applied Technology Directorate<br>ATTN: SAVDL-ATL-TSC<br>Bldg 401<br>Ft. Eustis, VA 23604-5577 | 1 | CDR, Tobyhanna Army Depot<br>ATTN: SDSTO-TM<br>Tobyhanna, PA 18466-5097 |
| 1 | US Army Natick RD&E Center<br>ATTN: STRNC-ML<br>Natick, MA 01760-5000 | 1 | CDR, Sacremento Army Depot<br>ATTN: SDSSA-AAD-W<br>Sacramento, CA 95813-5009 |
| 1 | US Army Tank Automotive Command<br>ATTN: AMSTA-TSL<br>Warren, MI 48090-5000 | 1 | CDR, Corpus Christi Army Depot<br>ATTN: SDSSC-AAR<br>Corpus Christi, TX 78419-6020 |
| 1 | CDR, US Army Armament RD&E Center<br>Benet Weapons Lab<br>ATTN: SMCAR-CCB-TL<br>Watervliet Arsenal<br>Watervliet, NY 12189-5000 | 1 | US Army Foreign Science & Technology Ctr<br>ATTN: AMXST-IS3<br>220 7th St. NE<br>Charlottesville, VA 22901-5396 |

| No. Copies | Addressee |
|---|---|
| | **OTHER ARMY LIBRARIES** |
| 1 | DIR. USA TRADOC Systems Analysis Acty<br>ATTN: ATAA-SL (TECH LIB)<br>White Sands Missile Range, NM 88002 |
| 1 | US Army Aviation School Library<br>PO Drawer 0<br>Ft. Rucker, AL 36360 |
| 1 | USMA<br>ATTN: Mr. Egon Weiss, Librarian<br>West Point, NY 10996 |
| 1 | Commandant, US Army Engineer School<br>ATTN: Library<br>Ft. Belvior, VA 22060 |
| 1 | US Army Humphrey's Engr. Supt Activity<br>ATTN: Library Branch<br>Ft. Belvoir, VA 22060 |
| 1 | Engineer Topographic Lab<br>ATTN: STINFO<br>Ft. Belvior, VA 22060 |
| 1 | Pentagon Library<br>ATTN: Chief, Readers Services Branch<br>The Pentagon, RM 1A518<br>Washington, DC 20310 |
| 1 | US Army Corps of Engineers<br>ATTN: DAEN-ASI-(Tech Library)<br>20 Massachusetts Ave. NW<br>Room 3119<br>Washington, DC 20314 |
| 1 | US Army Operational Test &<br>Evaluation Agency<br>ATTN: Tech Library<br>5600 Columbia Pike, RM 503<br>Falls Church, VA 22401 |
| | **DOD LIBRARIES** |
| 1 | Naval Mine Warfare Engineering Acty<br>Code 322<br>Yorktown, VA 23691 |
| 1 | CDR, Naval Facilities Engineering Command<br>ATTN: Library<br>200 Stovall St<br>Alexandria, VA 22332 |

| No. Copies | Addressee |
|---|---|
| 1 | David W. Taylor Naval Ship RD&E Center<br>Library Div, Code 5220<br>Bethesda, MD 20084 |
| 1 | Naval Air Systems Command<br>ATTN: Tech Library<br>Air 00D4<br>Washington, DC 20361 |
| 1 | Naval Surface Weapons Center<br>ATTN: Tech Library<br>Dahlgren, VA 22448 |
| 1 | Naval Research lab<br>ATTN: Tech Library<br>Washington, DC 20375 |
| 1 | Naval Surface Weapons Center<br>ATTN: Tech Library<br>Silver Spring, MD 20910 |
| 1 | Naval Sea Systems Command<br>Library Documentation Branch<br>Sea 9661<br>Washington, DC 20362 |
| 1 | Naval Ship System Engineering Station<br>Technical Library<br>Code 011F<br>Bldg 619<br>Philadelphia, PA 19112 |
| 1 | Naval Training Equipment Center<br>ATTN: Technical Library<br>Orlando, FL 32813 |
| 1 | HQ, USMC<br>Marine Corps Technical Library<br>Code LMA-1<br>Washington, DC 20314 |
| 1 | Air Force Systems Command<br>Technical Information Center<br>HQ AFSC/MPSLT<br>Andrews AFB, DC 20334 |
| 1 | HQ AF Engineering & Services Center<br>Tech Library FL 7050<br>Tyndall AFB, FL 32403 |

| No. Copies | Addressee |
|---|---|
| 1 | Defense Systems Management College<br>ATTN: Library<br>Bldg. 205<br>Ft. Belvoir, VA 22060 |
| 1 | Director, Defense Nuclear Agency<br>ATTN: TITL<br>Washington, DC 20305 |

## OTHER FEDERAL LIBRARIES

| No. Copies | Addressee |
|---|---|
| 1 | Geological Survey Library (GIS)<br>National Center, Stop 950<br>12201 Sunrise Valley Drive<br>Reston, VA 22092 |
| 1 | National Bureau of Standards (NBS)<br>E01 Administration Building<br>Washington, DC 20234 |
| 1 | Dept of Transportation Library<br>FOB 10A, M494-6<br>800 Independence Ave. SW<br>Washington, DC 20591 |