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**MIL-HDBK-2164A
19 June 1996
SUPERSEDING
MIL-HDBK-2164(SH)
16 January 1996**

**DEPARTMENT OF DEFENSE
HANDBOOK
ENVIRONMENTAL STRESS SCREENING
PROCESS
FOR
ELECTRONIC EQUIPMENT**



**THIS HANDBOOK IS FOR GUIDANCE ONLY. DO NOT CITE THIS DOCUMENT
AS A REQUIREMENT.**

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FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

3. The current emphasis on quality, reliability and hardware design integrity has resulted in efforts to provide a sound and inherently reliable design. The increased complexity and density of packaging of contemporary electronic equipment amplifies the ever present problems of detecting and correcting latent manufacturing defects. The occurrence of a malfunction incurs extremely high maintenance costs after the equipment has been deployed. It is also important that laboratory testing be extensive enough to prevent failure that would result in loss of life or mission.

4. This handbook provides guidelines that will help in the Environmental Stress Screening (ESS) of electronic equipment so that latent defects may be located and eliminated before the equipment is accepted. It has been written in compliance with the DoD Acquisition Reform Initiatives (ARI), Single Process Initiative (SPI), and the latest series of DoD acquisition directives.

5. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 03R42, 2531 Jefferson Davis Highway, Arlington, VA 22242-5160, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

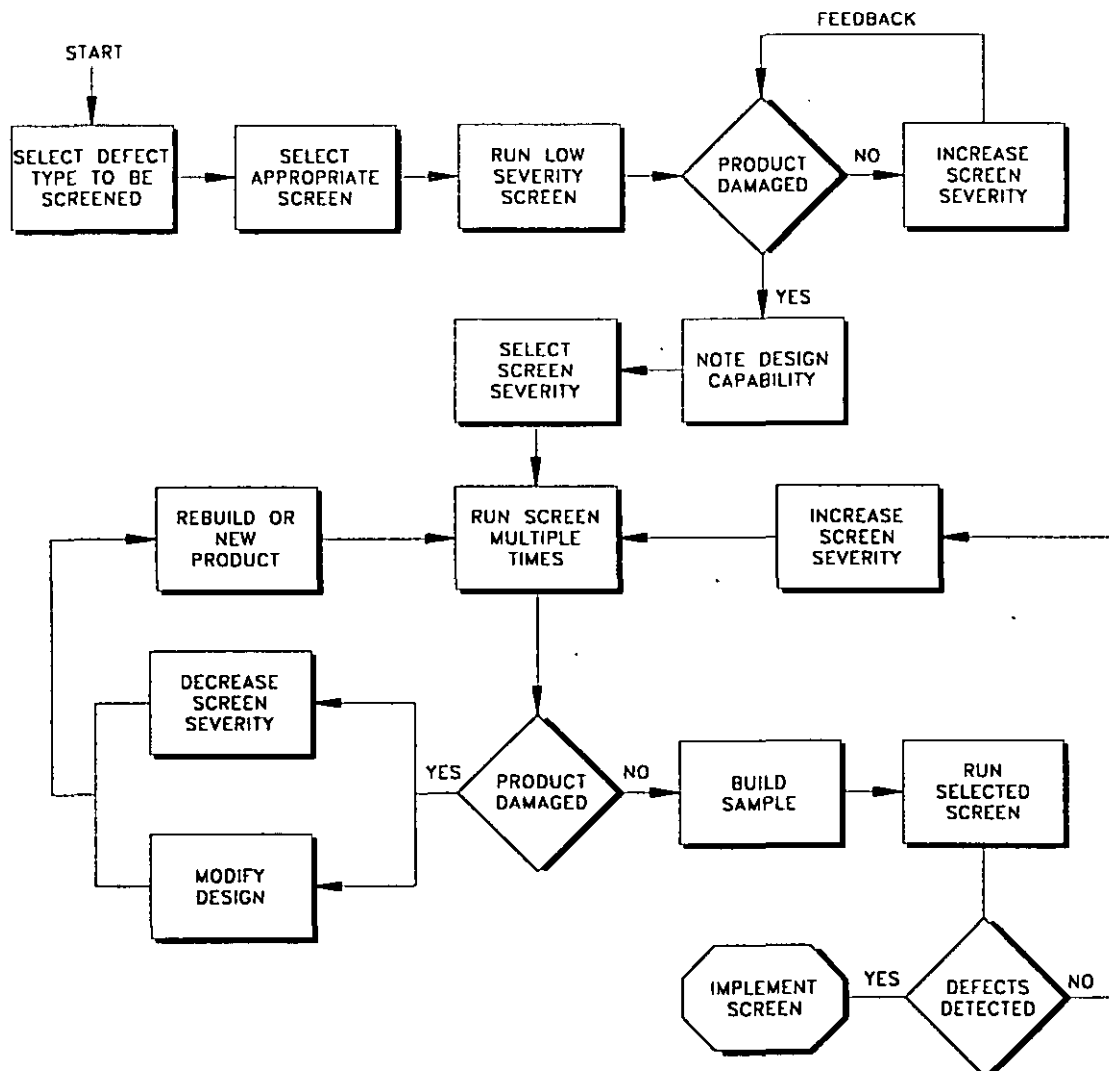
1.1 Purpose. This handbook provides guidelines for Environmental Stress Screening (ESS) of electronic equipment, including environmental screening conditions, durations of exposure, procedures, equipment operation, actions taken upon detection of defects, and screening documentation. These guidelines provide for a uniform ESS process that may be utilized for effectively disclosing manufacturing defects in electronic equipment caused by poor workmanship and faulty or marginal parts. It will also identify design problems if the design is inherently fragile or if qualification and reliability growth tests were too benign or not accomplished. The most common stimuli used in ESS are temperature cycling and random vibration. A viable ESS program must be dynamic; the screening program must be actively managed, and tailored to the particular characteristics of the equipment being screened. It should be noted that there are no universal screens applicable to all equipment.

ESS is part of a viable engineering development, manufacturing corrective action and overhaul process rather than a test in the normal accept/reject sense. Guidance in developing a screen can be found in figure 1. Those participating in the effort, including the contractor should never be led to believe that a "failure" is bad and would be held against them. ESS is intended to stimulate defects, not to simulate the operating environment, and therefore, factory failures are encouraged. The root causes of ESS failures need to be found and corrected before there is a complete process. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

1.2 Application to products. The process described herein may be applied to electronic assemblies, equipment and systems, in six broad categories as distinguished according to their field service application:

<u>Category</u>	<u>Service Application</u>
1	Fixed ground equipment
2	Mobile ground vehicle equipment
3	Shipboard equipment
3A	• Sheltered
3B	• Exposed
4	Jet aircraft equipment
5	Turbo-propeller and rotary-wing aircraft Equipment
6	Air launched weapons and assembled external stores

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FIGURE 1. Screen Development Process

1.2.1 Large, heavy items. When applying these guidelines to large, heavy items, the following should be considered:

- Potential fatigue of the item
- Adequate environmental inputs
- Availability of suitable environmental generation facilities
- Technical validity of screening at lower assembly levels, i.e., drawers, chassis

1.2.2 Contractual responsibility considerations. Navy-approved detailed screening procedures are used to verify contractual requirements.

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Acquisition authorities are cautioned from advising contractors on how to obtain desired results. They should confine the contractual requirements to performance requirements, rather than dictating the manufacturing method. Appendix A contains guidance concerning screening duration, reduced screening and sampling. Appendix B covers some considerations useful in formulating a troubleshooting plan to address ESS failures, while Appendix C contains guidance that will assist the Navy program manager in understanding Environmental Stress Screening, including the Department of the Navy Single Process Initiative, and provides guidance in the preparation of contractual acquisition documentation.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following standard and handbook form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

STANDARD

DEPARTMENT OF DEFENSE

MIL-STD-1235 - Single- and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes Functional Curves of the Continuous Sampling Plans

HANDBOOK

DEPARTMENT OF DEFENSE

MIL-HDBK-781 - Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

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2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein.

TRI-SERVICE TECHNICAL BRIEF 002-93-08 - Environmental Stress Screening Guidelines

(Application for copies should be addressed to The Office of the Assistant Secretary of the Navy (Research, Development, and Acquisition) Product Integrity, 2211 Jefferson Davis Highway, Arlington, VA 22244.)

2.3 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS, and supplement thereto.

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI/NCSL Z540-1 - General Requirements for Calibration Laboratories and Measuring Test Equipment

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

INSTITUTE OF ENVIRONMENTAL SCIENCES (IES)

Environmental Stress Screening Guidelines, 1981

Environmental Stress Screening Guidelines for Assemblies, March 1990

Environmental Stress Screening Guidelines for Parts, September 1985

(Application for copies should be addressed to the Institute of Environmental Sciences, 940 East Northwest Highway, Mt. Prospect, IL 60056-3444)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS AND ACRONYMS

3.1 Definitions. Definitions applicable to this handbook are:

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- Assembly/Module - A number of parts joined together to perform a specific function and capable of disassembly, e.g., a printed circuit board.
- Chamber - Cabinet in which hardware is placed in order to apply stress to it.
- Defect - The causative element that results in a failure.
- Environmental Stress Screening - ESS of a product is a process which involves the application of one or more specific types of environmental stresses for the purpose of precipitating to hard failure, latent, intermittent, or incipient defects or flaws which would otherwise cause product failure in the use environment. The stress may be applied either in combination or in sequence on an accelerated basis, but within product design capabilities.
- ESS failure - Failures occurring in the defect-free screening that cannot be classified as non-ESS failures as defined below. ESS failures include those due to defective manufacturing processes and defective components.

NOTE: In the event that several component parts of the same type fail during the screening, each one should be considered a separate ESS failure, unless it can be shown that one failure caused one or more of the others.

- Latent Defect - An inherent or induced weakness, not detectable by ordinary means, which will either be precipitated to early failure under environmental stress screening conditions or eventually fail in the intended use environment.
- Levels of product Definitions relating to levels of product are as specified:
 - a. Electronic Unit. An item which can be removed and replaced within the end item, such as a weapon replaceable assembly (WRA) or line replaceable unit (LRU).
 - b. System. A group of electronic units, interconnected, which provide a specific function, for example, a radar system or navigation system.
- Non-ESS failure - The following failures are non-ESS failures:

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- a. Failures directly attributable to improper installation in the screening facility.
- b. Failures of screening instrumentation or monitoring equipment (other than the Built In Test (BIT) function), except where it is part of the delivered item.
- c. Failures resulting from operator error in setting up, or in screening the equipment.
- d. Failures attributable to an error in, or interpretation of, the screening procedures.
- e. Dependent failures.
- f. Failures occurring during repair.
- g. Failures clearly attributable to the environmental generation screening equipment overstress condition.

Part	-	One piece, or two or more pieces joined together which are not normally subject to disassembly without destruction of designed use. Parts, components, and devices are synonymous.
Thermal Survey	-	The measurement of thermal response characteristics at points of interest within an equipment when temperature extremes are applied to the equipment.
Vibration Survey	-	The measurement of vibration response characteristics at points of interest within an equipment when vibration excitation is applied to the equipment.

3.2 Acronyms used in this handbook.

a.	ARI	-	Acquisition Reform Initiatives
b.	BIT	-	Built In Test
c.	COTS	-	Commercial-Off-The-Shelf
d.	ESS	-	Environmental Stress Screening
e.	FAR	-	Federal Acquisition Regulations
f.	FRACAS	-	Failure Reporting and Corrective Action System
g.	IRIG	-	Inter-Range Instrument Group
h.	LRU	-	Line Replaceable Unit
i.	MTBF	-	Mean Time Between Failure
j.	NDI	-	Nondevelopmental Item
k.	PDF	-	Pre Defect-Free
l.	SPC	-	Statistical Process Control

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m. WRA - Weapon Replaceable Assembly

4. GENERAL GUIDELINES

4.1 General. ESS screenings are usually accomplished in accordance with the guidelines of MIL-HDBK-781 to ensure that hardware is free of manufacturing defects. Design and manufacturing practice calls for the application of environmental stress screening to:

- All material acquisitions that include electrical, electronic, electro-optical, electromechanical or electro-chemical components in program definition and risk reduction, engineering and manufacturing development, and production, fielding/deployment, and operational phases
- Reprocurements and to the procurement of spare and repair parts where the cost of ESS implementation can be amortized economically
- Depot overhaul programs where opportunities exist for substantial cost savings
- Nondevelopmental items such as commercial-off-the-shelf (NDI-COTS) and domestic or foreign military (NDI-Military) items only to the extent ESS was implemented and documented during the previous production
- Systems, equipment, and spares that have been specifically designed to receive ESS

4.2 Screening conditions. The following conditions should be required for all ESS:

a. ESS may be applied at any manufacturing level, from piece parts to end items. It is intended to screen defects in a manner that is not harmful to properly manufactured material. Hardware proven to be too fragile may be excluded because screening environments may be too harmful, but rationale for exclusion should be included in appropriate documentation such as a stress screening plan.

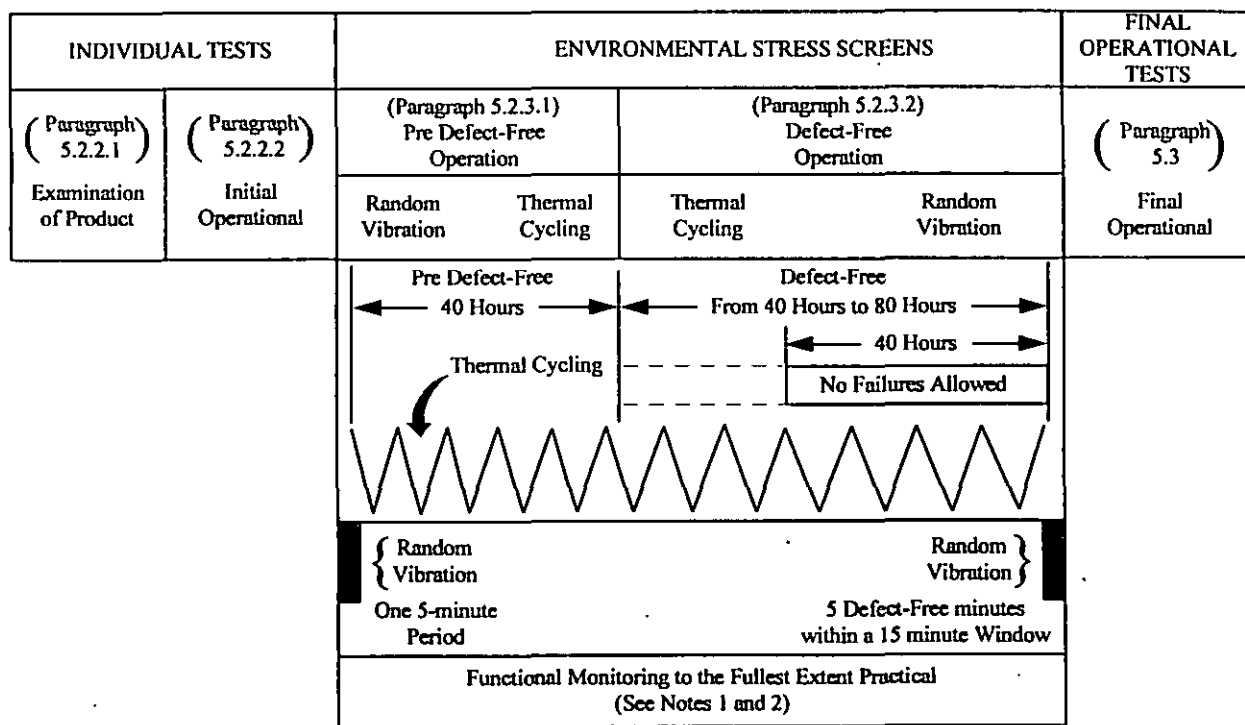
b. All screening should be accomplished in accordance with the applicable guidelines specified herein.

c. There should be evidence of quality control acceptance of all required inspection or test activity prior to the start of any contractual environmental stress screening, and at each time maintenance is performed.

d. All testing should be completed prior to packaging the equipment.

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e. The conditions specified should be applied in the sequence indicated in figure 2.



Notes:

1. During the last four thermal cycles and throughout the random vibration portion of the defect-free period, 100% repetitive functional monitoring should be accomplished.
2. Where sufficient parameters are monitored (with contractor concurrence) during environmental screening, the final operational test should not be considered as part of the defect-free requirement. However, if, in the contractor's opinion, the monitoring of functions is inadequate, then the final operational test should be part of the defect-free period and any disclosed defect should require a rerun of the entire defect-free test (subject to the window limitations).

FIGURE 2. Environmental Stress Screening Constituents

f. Equipment should be installed initially in the environmental chamber and then operated to ensure satisfactory performance of both the equipment to be screened and the screening facility. The time to verify the facility compatibility with the equipment should not be counted as screening time.

g. When a failure has occurred and the defect isolated and corrected, the equipment should be operated and its performance monitored to ensure proper diagnosis and correction.

h. Unless otherwise stated, the equipment's performance should be verified before and after each environmental screening. Continuous functional monitoring is performed in accordance with Notes 1 and 2 of figure 2.

i. During all equipment operation, functional parameters, such as voltage and current, should be maintained at specified nominal values.

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j. The BIT capabilities of the equipment should be utilized to the maximum extent to aid in the performance monitoring. BIT should not be the sole means of monitoring performance.

k. Anticipation of failure should not be justification for maintenance; for example, if an output is observed to be degrading but is still within specification limits, no replacement or adjustment may be permitted unless such adjustments are normally made manually.

1. Failures detected during screening should be counted as if they occurred in the defect-free period if the equipment used to monitor the performance characteristics during the screening was not capable of detecting that failure. Refer to figure 2, Notes 1 and 2.

4.2.1 General environmental guidelines. Unless otherwise specified, measurements and screenings should be made at the conditions in 4.2.1.1 through 4.2.1.5.

4.2.1.1 Standard ambient. Ambient measurements and checks (e.g., pre- and post-screening) are conducted at room ambient conditions as follows:

Temperature:	25°C ± 10°C (77°F ± 18°F)
Relative humidity:	Uncontrolled room ambient
Atmospheric pressure:	Uncontrolled site pressure

4.2.1.2 Controlled ambient. When the ambient conditions must be closely controlled, the following should be maintained:

Temperature:	23°C ± 2°C (73°F ± 3.6°F)
Relative humidity:	50 percent ± 5 percent
Atmospheric Pressure:	Ideal: 96.45kPa (Range 86.45-162.45)
	Ideal: 725 mmHg (Range 655-775)
	Ideal: 28.5 inHg (Range 25.5-30.5)

4.2.1.3 Thermal screening tolerances. The screened item should be totally surrounded by an envelope of air except at necessary support points. The temperature gradient throughout this envelope, which is measured close to the screened item, should be within ± 2°C (±3.6°F) of the screening temperature and not exceed 1°C per meter or a maximum of 2.2°C total with equipment nonoperating.

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4.2.1.4 Vibration testing tolerances. The acceleration power spectral density of the screening control signal should not deviate from the specified guidelines by more than ± 3 dB over the entire test frequency range between 20 Hz and 1,000 Hz and should not deviate by more than ± 6 dB in the screening frequency range between 1,000 and 2,000 Hz. However, deviations of -6 dB in the screening control signal may be granted for frequencies greater than 500 Hz due to fixture resonance, screened item resonance, or facility limitations. The cumulative bandwidth over which the reductions are allowed cannot be greater than 100 Hz between 500 Hz and 1,000 Hz and 300 Hz between 1,000 Hz and 2,000 Hz. In no case should the acceleration power spectral density be more than -6 dB below the specified guidelines. No deviation should be granted for frequencies below 500 Hz. Tolerance levels in terms of dB are defined as:

$$\text{dB} = 10 \log_{10} \frac{W_1}{W_0}$$

where

W_1 - measured acceleration power spectral density in g^2/Hz units

W_0 - specified level in g^2/Hz units

Confirmation of these tolerances should be made by the use of an analysis system with the following characteristics:

<u>Frequency Range</u>	<u>Maximum Filter Bandwidth</u>
20 to 200 Hz	25 Hz
200 to 1000 Hz	50 Hz
1000 to 2000 Hz	100 Hz

4.2.1.5 Time. Elapsed time should be measured with an accuracy of ± 1 percent.

4.2.2 Accuracy of screening instrumentation calibration. The accuracy of instruments and screening equipment used to control or monitor the screening parameters should be calibrated in predetermined intervals and then verified prior to and following each screening. All instruments and screening equipment used in conducting the screenings specified herein should be calibrated to national standards, such as ANSI/NCSS Z540-1.

4.3 Screening facilities. Screening facilities and apparatus used in conducting the screenings contained in this handbook should be capable of meeting the conditions specified.

4.3.1 Screening chamber. The screening chamber should conform to the following:

- a. The screened item should be as recommended in 4.2.1.3.

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b. The heat source of the screening facility should be so located that radiant heat from the source will not fall directly on the screened item.

c. Unless otherwise suggested, thermocouples or equivalent temperature sensors utilized to determine or control the chamber temperature should be located centrally within the chamber, in the supply airstream, or in the return airstream, whichever provides the specified screening conditions at the item to be screened. The thermocouples or temperature sensors should be baffled or otherwise protected against radiation effects.

d. The conditioned air flow should be suitably baffled to provide uniform air flow around the item. If multiple items are screened, they should be so spaced as to provide free circulation between the items and the chamber walls.

4.3.2 Vibration apparatus. Any vibration generating machinery capable of satisfying the random vibration guidelines contained herein is acceptable. The equipment should be capable of maintaining the input as defined herein throughout the duration of the exposure.

4.3.3 Quality of air for supplementary cooled equipment. The successful implementation of the rapid thermal cycle for supplementary cooled equipment is in part dependent upon the close control of certain parameters associated with the cooling air. The two most critical of these parameters are absolute moisture content and the temperature of the air. As the air temperature is specified, the only uncontrolled parameter is the absolute moisture content.

The chamber is cycled between -54°C and $+71^{\circ}\text{C}$ for most electronic equipment. As the chamber is programmed to fall below room ambient (approximately $+25^{\circ}\text{C}$), the probability of reaching the dew point of unconditioned, room ambient air is very high. This condition is not acceptable as it represents a non-identifiable damage potential which provides no benefits in terms of detecting workmanship defects.

The air used for supplementary cooling must be temperature conditioned and dried to the point where its dew point is below -54°C . If this absolute humidity condition is not met, moisture will condense out of the cooling air and remain within the equipment as either free water or ice depending upon the chamber temperature. A closed loop system is recommended. This system recirculates the same dry air through a temperature conditioning unit into the equipment.

4.4 General instrumentation guidelines. Instrumentation should be in accordance with the following guidelines:

a. Real time on line data should be obtained for all critical performance parameters.

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b. Continuous permanent records of all environmental screening conditions should be provided.

c. Transducer installation should be in accordance with the following:

(1) Location should be selected to permit accurate measurement of the screened article environment.

(2) The transducer characteristics should not affect the screened article.

(3) Control accelerometers should be mounted mechanically.

(4) Response accelerometer attachment methods should be compatible with the maximum levels and frequencies expected during the screening.

d. All instrumentation should be calibrated prior to supplying power to environmental screening equipment.

e. To permit as complete an evaluation as possible of specific screened item performance under the various specified screening conditions, all relevant critical screening signals should be recorded. This will permit post-screening analysis to supplement the real-time monitoring and can allow the accumulation of trend data on critical screening parameters.

f. Screening records should be maintained for the screened item. All discrepancies, including those attributed to screening equipment, input power, and procedural errors, including their disposition, should be included in the records.

4.5 Vibration screening guidelines. The following guidelines, tolerances and data handling techniques should be applied to vibration screening.

4.5.1 Screening fixture. Screening fixtures should be designed to eliminate or minimize fixture resonances in the frequency range up to 2,000 Hz. The fixture characteristics should be verified using sinusoidal vibration to establish resonance and transmissibility factors. Only one such evaluation is necessary for a given fixture and equipment combination. Sinusoidal transmissibility should be such that the vibration input in the axis of applied vibration at any specimen mounting point should be within ± 3.0 dB of that specified over the entire frequency band from 10-2,000 Hz. Sinusoidal crosstalk (vibration input in either axis orthogonal to the axis of applied vibration) should not exceed the input. Resonances whose total accumulation bandwidth do not exceed 300 Hz may be allowed in the band from 500 to 2,000 Hz provided they do not deviate more than ± 6 dB from the input level.

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4.5.1.1 Fixture checkout. During fixture checkout a dynamic mockup should be used to avoid accumulation of stress cycles on the equipment. If actual equipment is used, the vibration input should be limited to low levels.

4.5.2 Control excitation. The vibration input should be controlled at one or more points by accelerometers located on the equipment at a point or points as near as possible to the fixture and equipment or fixture and support structure interface. Exact locations of control accelerometers must be carefully considered. The control accelerometer(s) should be attached with positive mechanical fastening (bolt or stud), not using cement alone. The accelerometer's sensitive axis should be directed parallel to the direction of excitation.

4.6 Performance monitoring guidelines. The overall effectiveness of ESS is dependent upon the completeness of the performance monitoring before, during and after the environmental exposures. Prior to the environmental exposure, all functional parameters should be verified and, to the extent possible, quantified. This benchmark data is utilized throughout the subsequent screening phases to identify failures or degraded performance. The successful application of this technique depends upon the accurate assessment of equipment performance in terms of both permanent and intermittent failures.

4.7 Failure reporting, analysis, and corrective action system (FRACAS). A closed loop system that collects data on, analyses, and records timely corrective action is recommended for all failures that occur during ESS. The FRACAS should cover all screening items, interfaces between items, instrumentation, facilities, screening procedures, screening personnel, and operating instructions. ESS is an essential tie to the design and manufacturing processes during development and to statistical process control (SPC) of the manufacturing processes during production and depot repair.

4.7.1 Failures during pre defect-free screening. If an equipment failure occurs during the pre defect-free screening, correction may be accomplished immediately or deferred until the end of the period. However, if the failure adversely affects the ability to monitor the equipment's operation, then correction should be made immediately.

4.7.2 Failures during defect-free screening. If a failure occurs during the first 40 hours of the defect-free screening, corrective action should be taken. However, if a failure occurs after 40 hours of screening have elapsed, the screening should be terminated and the equipment not be submitted for ESS compliance until a positive corrective action plan is developed (see 4.7).

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4.7.3 Rescreening. Rescreening of failed equipment should be initiated only after adequate investigative analysis and correction have been accomplished.

4.8 Sampling. Initially, ESS is applied to 100% of the units manufactured, including repaired units. By using a closed loop feedback system, determination will be possible to determine if the screening program should be modified.

5. DETAILED ENVIRONMENTS

5.1 Environmental stresses. The environmental stresses defined herein have been selected based on their proven effectiveness in screening manufacturing defects. The levels and durations of exposure have been established to assure adequate stimulation without incurring fatigue damage or degradation of good equipment.

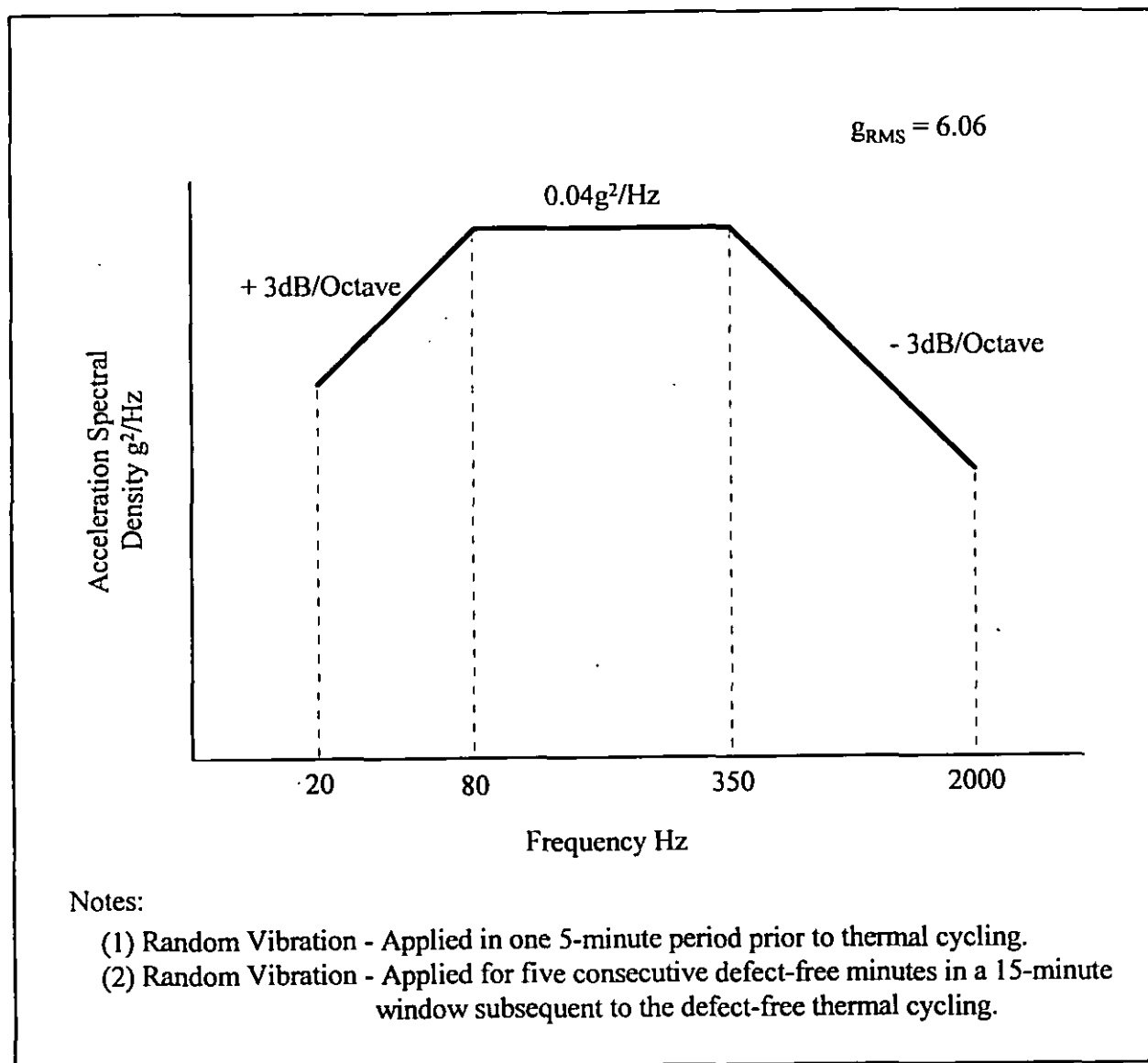
5.1.1 Random vibration spectrum. Figure 3 depicts a typical random vibration spectrum that should be applied, as an input, to the equipment to be screened with the equipment hard mounted to the screening fixture and shaker system. In order to avoid any potential fatigue or peak level damage due to resonances, it may be necessary to notch the spectrum at points of severe ($Q \geq 10$) resonant frequencies. These resonances should be obtained from data accumulated during development screenings, or by conducting a low level time sweep. This spectrum could severely overstress good hardware. Vibration parameters should be tailored to the response characteristics of the item being screened.

5.1.1.1 Applied axis determination. Generally, random vibration applied in a single axis effectively screens defects found in electronic equipment. Crosstalk (vibration set up in the two axes not directly being excited) does in fact also provide some stimulation of defects sensitive or unique to a particular axis. In certain cases it may be necessary to apply vibration in more than one axis to provide adequate screening.

The selection of a single axis or multiple axes is dependent upon the physical construction and component layout as well as the susceptibility or sensitivity to vibration of the hardware. The following guidelines should be employed in defining which axis will be selected:

- If the electronic equipment contains printed circuit cards and these cards are arranged predominantly parallel to each other, then the vibration input should be perpendicular to the plane of the cards to assure maximum deflection and stimulation.
- Vibration screenings are conducted during the development program. The acquired data should be reviewed to determine the axis of major resonances and transmissibilities (Q) values.

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FIGURE 3. Random Vibration Spectrum

5.1.2 Temperature cycling. In order to conduct the ESS thermal cycling exposure as effectively as possible, it is necessary to maximize the number of temperature reversals. It should be noted that it is the frequency of thermally induced stress reversals (minimization of soaks) as well as the temperature extremes which are the principal parameters associated with disclosure of thermally sensitive manufacturing defects. The ESS profiles illustrated in figure 4 have been developed to accomplish this and should be used when performing thermal cycling screenings.

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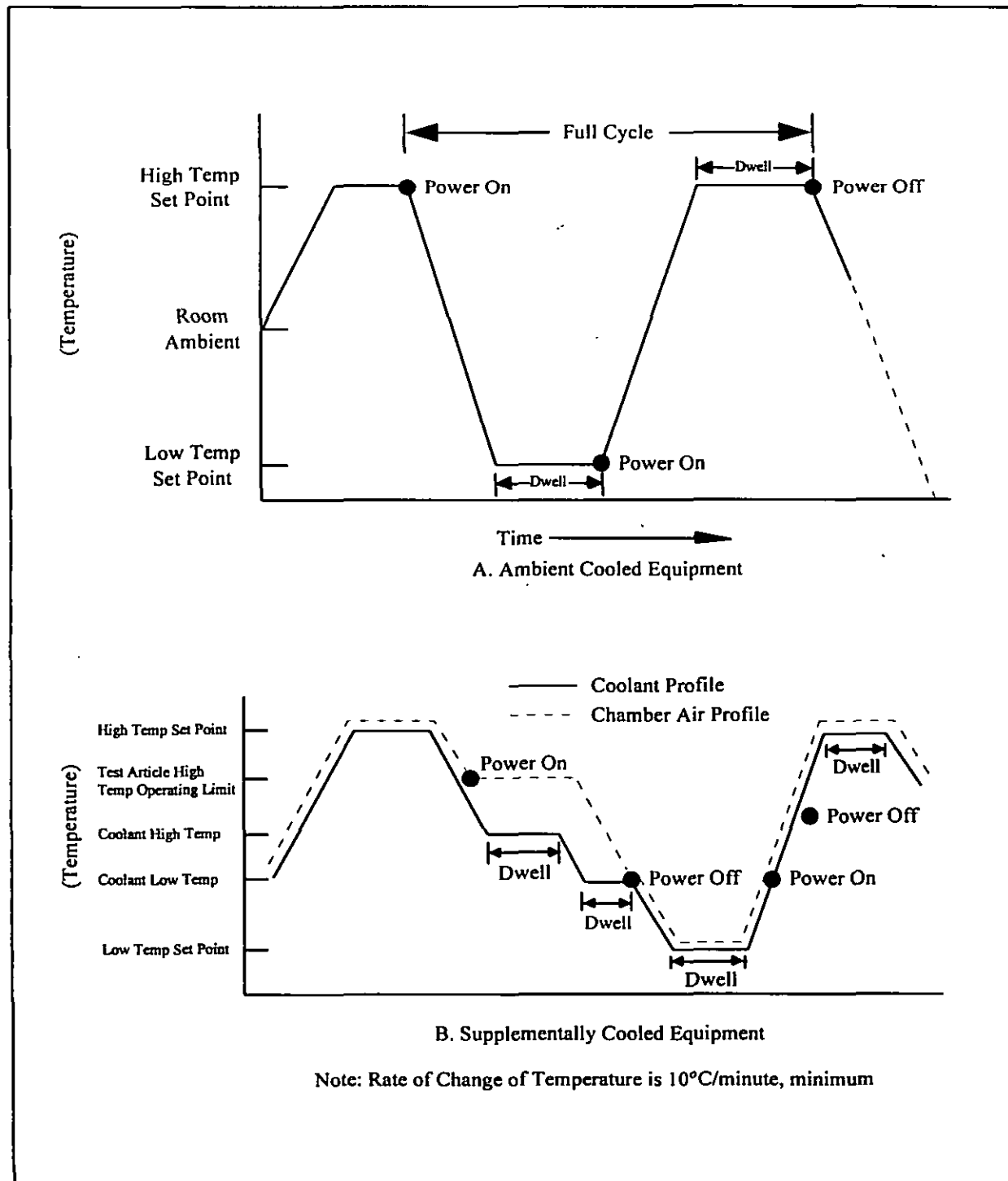


Figure 4 - Temperature Cycling Profile for Ambient Cooled and Supplementally Cooled Equipment

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A minimum of ten thermal cycles should be performed in order to eliminate most latent workmanship defects in complex electronic equipment. The applicable equipment specification will dictate chamber air temperature extremes (high and low set points).

5.1.2.1 Thermal survey. The thermal survey establishes inputs for the thermal cycling profile of the equipment, and varies slightly according to the method by which the equipment is cooled.

5.1.2.1.1 Procedure for ambient-cooled equipment. Steps a through k should be followed for thermal surveys of ambient cooled equipment.

a. Attach thermocouples to components identified by thermal analysis of the equipment as being representative of the various types and locations within the equipment. Replace all equipment covers and properly seal, if applicable.

b. Install the item to be screened in the temperature chamber at room ambient temperature. Verify equipment operation and then turn the equipment power off.

c. After turning the equipment power back on, set the chamber temperature to the equipment high temperature limit (high set point - see paragraph 5.1.2), and allow the chamber air temperature to increase to the high set point at an average rate of 10°C per minute, minimum. If the chamber cannot provide the rate of temperature change required, auxiliary heating means should be employed. The average rate should be computed for the total chamber temperature excursion.

d. Turn off the equipment power when the chamber air reaches the high temperature operating limit, and continue heating the chamber air until the high temperature set point is reached. If the operating limit is the same as the high set point, leave the equipment power on.

e. Maintain the chamber temperature at the high set point until 2/3 of the thermocouples reach within 10°C of the maximum operating temperature. Record the time between the chamber reaching the high operating temperature set point and 2/3 of the thermocouples reaching within 10°C of the maximum operating temperature (high temperature dwell time).

f. Turn off the equipment power if left on in step d.

g. Set the chamber to the equipment low temperature limit (low set point) (see 5.1.2) and reduce the chamber temperature at an average rate of 10°C per minute. If the chamber is not capable of an average rate of 10°C per minute, minimum, auxiliary cooling means should be employed. The average rate should be computed for the total chamber temperature excursion.

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h. Maintain the chamber air at the low set point until 2/3 of the thermocouples reach within 10°C of the low set point. Record the low temperature dwell time.

i. Repeat steps c through h, then repeat steps c, d and e. These steps will result in three high temperature dwells and two low temperature dwells. The average of the last two high temperature dwells and the average of the two low temperature dwells are the recommended dwell periods.

j. Turn off the equipment power if on, and lower the chamber air temperature to room ambient. Allow the equipment to stabilize at room ambient temperature.

k. Set up the chamber automatic controls with the temperature-time profile determined in steps c through j. Repeat two cycles to verify repeatability of the profile. Note that the time for one cycle should be three hours and 20 minutes. In the event that the cycle duration exceeds this, the increased time should be added to the low temperature dwell time.

5.1.2.1.2 Procedure for supplementally cooled equipment. Steps a through k should be followed for thermal surveys of supplementally cooled equipment (refer to Figure 4B).

a. Attach thermocouples to components identified by thermal analysis of the equipment as being representative of the various types and locations within the equipment. Replace all equipment covers and properly seal, if applicable.

b. Install the equipment in the temperature chamber at room ambient temperature. Verify proper operation of the article to be screened and the supplementary cooling system. If the coolant specifications permit, the equipment power should remain on for the next step.

c. Set the chamber temperature to the equipment high temperature limit (high temperature set point) and increase the chamber ambient temperature at an average rate of 10°C per minute, minimum. Simultaneously raise the coolant temperature with the chamber ambient temperature until the high temperature set point is reached. The equipment should be powered until the high temperature operating limit is reached, and then the screened article power should then be turned off.

d. Continue to raise the chamber ambient and coolant temperatures until the high temperature set point is reached. Maintain this temperature until 2/3 of the thermocouples are within 10°C of the equipment high temperature limit. The time period between when the chamber reaches the high temperature set point and when 2/3 of the thermocouples indicate within 10°C of the equipment high temperature limit is the high temperature dwell time.

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e. At the end of the high temperature dwell period, reduce both the chamber ambient air and the coolant temperatures at 10°C per minute, minimum. Continue to reduce the chamber ambient and equipment coolant temperatures before turning on the equipment power.

f. Continue reducing the chamber ambient and equipment coolant temperatures until the specified coolant minimum temperature for equipment operation is reached. At this point, turn off equipment power, and continue reducing both ambient temperature to the low temperature set point.

g. Maintain the low set point temperatures until 2/3 of the thermocouples indicate within 10°C of the set point, and record the time period between when the chamber reaches the low temperature set point and when 2/3 of the thermocouples indicate within 10°C of this set point. This is the low temperature dwell time.

h. At the end of the low temperature dwell period, turn on the equipment power if permitted by the equipment specification, and increase both the chamber ambient and equipment coolant temperatures at an average rate of 10°C per minute, minimum. If the equipment specification prohibits equipment power on below a given temperature level, wait until the specified temperature is reached before turning on the equipment power. When room ambient temperature has been reached, one thermal cycle has been completed.

i. Repeat steps c through h for a second full cycle, recording the time it takes to perform each step. Due to the start-up point being at ambient, the initial high temperature dwell period defined in d is invalid and should be ignored. Note: Determination of the equipment coolant high and low temperature plateau time periods are described in 5.1.2.2.2.

j. Turn off the equipment power and allow the equipment to stabilize at room temperature.

k. Set up the chamber automatic controls with the temperature-time profile determined in step i (the second cycle). Perform two cycles to verify repeatability of the profile.

5.1.2.2 Thermal screenings. The thermal cycling portion of the ESS should be applied during both the pre defect-free and the defect free segments of the overall screening.

5.1.2.2.1 Ambient cooled equipment. The equipment should be subjected to the temperature cycles developed in paragraph 5.1.2.1.1. as illustrated in figure 4A.

5.1.2.2.2 Supplementally cooled equipment. Each equipment should be subjected to the temperature profile cycling illustrated in Figure 4B. Overall duration for one cycle should be three hours and 20 minutes, to

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provide at least 12 thermal cycles during each pre defect-free and defect-free screenings. Using the results obtained from the thermal survey, (see paragraph 5.1.2.1.2) determine the duration of the high temperature operating dwell. First, subtract the total of the up and down excursion times and the high and low temperature dwell times from the overall cycle time. During the remaining time, the equipment should be operated for 10 minutes maximum at the equipment coolant low temperature plateau and the remainder of the time at the equipment coolant high temperature plateau.

5.2 Total ESS program. The total ESS program includes a physical inspection, functional tests and periods of environmental exposure designed to stimulate latent defects without incurring equipment fatigue damage. Figure 2 presents the overall screening flow which should be used to verify that an equipment is ready for operational use.

5.2.1 Documentation. Documentation for the data acquisition should include the following information:

- Screen identification
 - program name
 - item name screening section
 - tape recorder
 - tape speed
 - engineer/person administering screening
 - date/time
 - excitation system
- Channel information
 - accelerometer identification
 - accelerometer serial number
 - accelerometer sensitivity
 - charge amplifier gain
 - charge amplifier serial number
- Run information
 - run identification
 - frequency range and level of excitation
 - IRIG (Inter-Range Instrument Group) time/tape footage, beginning and end of run
 - IRIG time/tape footage, beginning and end of full level vibration

5.2.2 Individual tests. Each equipment under ESS should be subjected to:

5.2.2.1 Examination of product. Each equipment should be examined during appropriate stages of manufacture and assembly to ensure proper workmanship has been applied.

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5.2.2.2 Initial operational test. An equipment operational test should be performed, and data should be recorded. The test procedure should include measurements required for a quantitative assessment of all functional parameters including BIT functional performance parameters. Verification of BIT operational capability should be included to the extent possible by external equipment adjustment and without insertion of faults. GO/NO GO evaluation should not be acceptable except for BIT. The record of pretest data should be retained for use as a reference during subsequent ESS.

5.2.3 Environmental screening. Equipment submitted for screening should be subjected to a fixed duration pre defect-free screening and defect-free screening. The equipment operation should be continuously monitored, and all functional parameters exercised repeatedly at the highest rate attainable. The mechanization of the functional check-out and its speed of repeatability should represent a major task in the overall formulation of the ESS program. All vibration screening should be conducted with the equipment hard mounted regardless of whether or not it is to be installed on vibration isolators in its use environment.

5.2.3.1 Fixed duration pre defect-free (PDF) screening. Each equipment should be exposed to random vibration and thermal cycling periods as depicted in figure 2. Since the purpose of this screening is to eliminate latent manufacturing defects, all defects detected during this screening should be recorded and repaired, but should not count against the acceptance of the equipment.

5.2.3.1.1 Vibration. With the power on, the equipment should be exposed to one five-minute burst of random vibration in the axis deemed most susceptible to vibratory excitation. Failures occurring during this five-minute screening should be accrued (if possible) and corrected at the conclusion of the five-minute period (See Appendix B). The random vibration spectrum should be:

20-80 Hz at 3 dB/octave rise

80-350 Hz at $0.04g^2/\text{Hz}$

350-2,000 Hz at 3 dB/octave rolloff

5.2.3.1.2 Thermal cycling. With the power on, the equipment should be subjected to a thermal cycling screening for a period of 40 hours in accordance with the appropriate cycle depicted in figure 4. The required number of thermal cycles may be interrupted for repair actions.

The thermal limits (high and low temperature extremes of chamber air) for cycling, are those values of temperature defined by the equipment specifications.

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Vibration and thermal cycling screenings are not to be applied concurrently, but can be applied in the sequence defined in figure 2, that is vibration, then thermal cycling, and again vibration.

5.2.3.2 Defect-free (pf) screening. After completion of the fixed duration pre defect-free screening, each equipment should undergo a defect-free screening under the same environmental conditions as in the pre defect-free screening. The operating equipment (power on) should be subjected to 40 consecutive defect-free hours under thermal cycling conditions within an overall screening period of 80 hours maximum. After completion of the 40-hour defect-free thermal cycling requirement, the equipment should withstand five continuous minutes of random vibration without failure within a maximum screening time of 15 minutes. An equipment which does not successfully complete the defect-free period within either allowable window should not be submitted for ESS compliance and requires corrective action as described in 4.7.2 and 4.7.3.

5.3 Final functional operational test. Upon the successful completion of the defect-free ESS phase, a final functional test should be performed at room ambient conditions. This functional test should fully verify the satisfactory operation of the equipment in accordance with the parameters specified in the prime item specification. Operational measurements should be compared with those obtained during the benchmark testing referred to in 4.6, and evaluated based upon the specified acceptable functional limits.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.

6.1 Intended use. This document provides guidance for establishing, documenting and implementing an ESS program.

6.2 Subject term (key word) listing.

Random vibration
Temperature cycling
Thermal cycling
Thermal survey
Vibration screening

Custodians:

Navy - SH
Air Force - 17

Preparing activity:

NAVY - SH
(Project RELI-0082)

Review activities:

Air Force - 84
DESC - AS
DLA - ES

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APPENDIX A

ESS DURATION, REDUCED SCREENING AND SAMPLING

A.1 SCOPE

A.1.1 Scope. This appendix describes the approach, ground rules and assumptions used to optimize the times for pre defect-free (p_{DF}) and subsequent defect-free (p_{DP}) screening under environmental conditions, and define ground rules and techniques for reduced screening and sampling.

A.1.2 Purpose. The purpose of this appendix is to present the background that led to the screening times stipulated in the main body of the handbook, and define statistical plans for reduced screening and sampling options.

A.2 APPLICABLE DOCUMENTS

A.2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones needed in order to fully understand the information provided by this handbook.

A.2.2 Government documents.

A.2.2.1 Specifications, standards, and handbooks. The following standard and handbook form a part of this appendix to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

STANDARD

DEPARTMENT OF DEFENSE

MIL-STD-1235	-	Single and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes With Functional Curves of the Continuous Sampling Plans
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HANDBOOK

DEPARTMENT OF DEFENSE

MIL-HDBK-781	-	Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production
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(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the

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Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue,
Philadelphia, PA 19111-5094.)

A.3 ASSUMPTIONS

A.3.1 Environmental effects. The underlying assumption is that the environments are the primary precipitators of the manufacturing defects independent of the inherent life characteristic of the device to be screened. That is, for a constant number of defects incorporated in the device due to improper manufacturing and processing techniques, these defects will appear in the first "T" hours of the pre defect-free (T_{PDF}) screening at a rate which will be constant, independent of the MTBF of the device.

A.3.2 Defect-free verification. The time on screening after an environmental fixed duration exposure, is the defect free portion of the screening (T_{DF}). This test is designed to verify the assumption of A.3.1, and any defects thereafter become inconsequential since they become part of the random life process.

A.4 ANALYSIS

A.4.1 Setting duration for pre defect-free (pdf) screening. A minimum number of hours or cycles are defined by the environmental profile for the screening, and should be a given value independent of the complexity or inherent life of the device.

A.4.2 Cycles vs. dwell time. Although the number of pdf hours are constant, the dwell time in each cycle is a function of the stress loading on the device. Therefore the cycles on one device may represent t_1 hours of dwell time, while it would represent t_2 hours on another device. In all cases during pdf and defect-free screening, the time dimension will always be in hours of cycling.

A.4.3 Time on screening derivation. Assuming that environmental factors are adequate and the production units are of known design integrity, the ESS duration can be described by the classical failure rate ("bathtub") curve shown in figure A-1, where:

λ_0 (Initial value) is the failure rate due to early manufacturing defects

λ_M (Minimum acceptable) is the failure rate to be achieved, as a minimum, to verify that early defect failures have been eliminated.

λ_S (Specified value) is the failure rate operationally achievable.

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T_{PDF} Duration of environmental cycling necessary to achieve α percent defective or less for lot or unit acceptance.

T_{DF} Defect free time (equipment must operate without failure) after T_{PDF} necessary to verify λ_M with a probability of acceptance P_A .

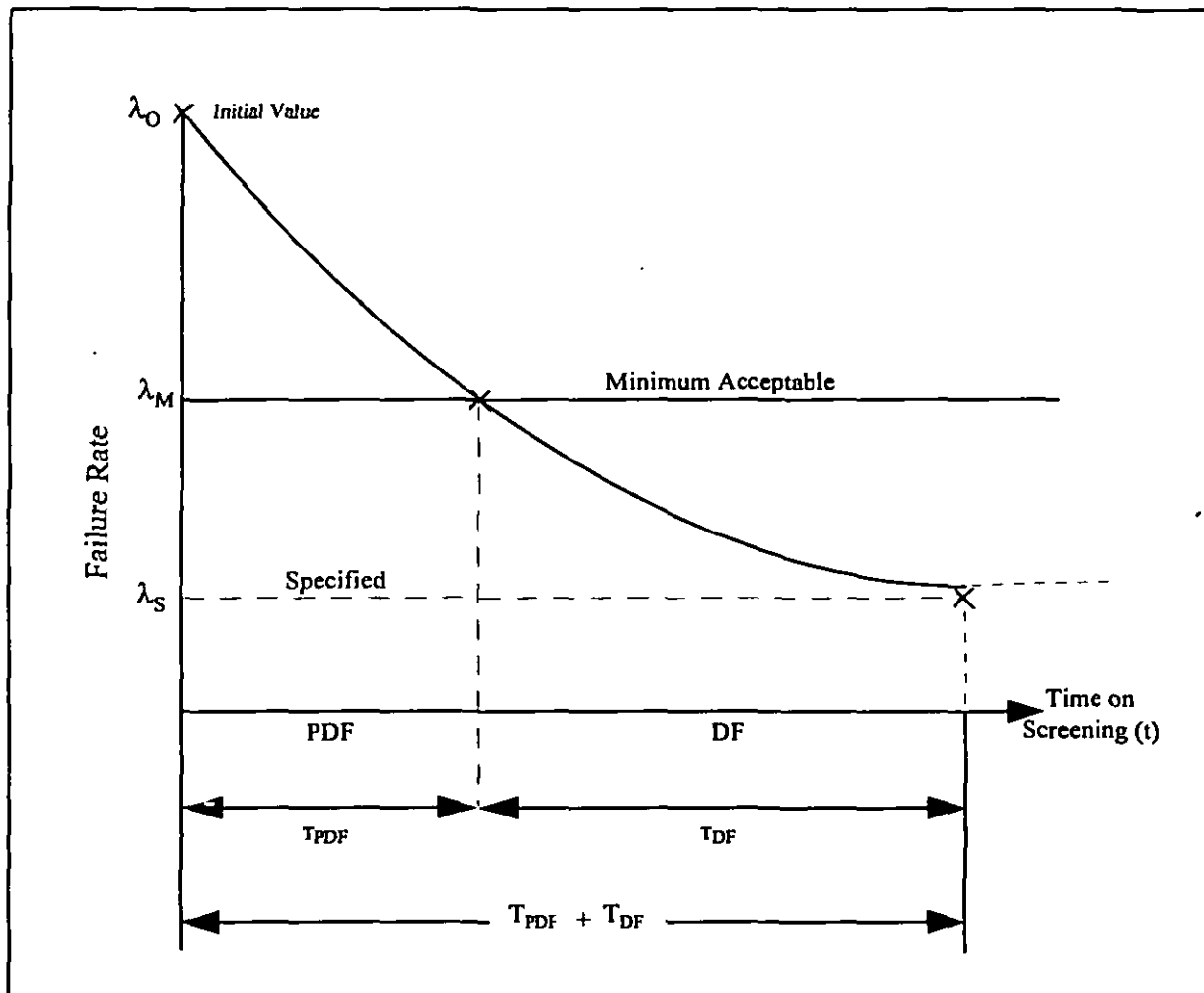


Figure A-1 ESS Characteristics Curve

These parameters and the growth rate function of the curve can be expressed by the logistics curve form:

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$$\lambda(t) = (\lambda_0 - \lambda_s)e^{-kt} + \lambda_s \quad (1)$$

where:

$$K = \frac{1}{T} \ln \frac{1}{\alpha} \quad (\text{growth rate parameter}) \quad (1A)$$

$$\alpha = \frac{\lambda_M - \lambda_s}{\lambda_0 - \lambda_s} \quad (\text{percent defective remaining after } T \text{ hours}) \quad (1B)$$

$$T = T_{PDF} \quad (\text{ESS duration}) \quad (1C)$$

t = time on screening.

The DF time (T_{DF}) can be defined from the Probability of Acceptance (P_A) relationship developed in MIL-HDBK-781 and is expressed as:

$$P_A = \left(e^{-\frac{T_{DF}}{\theta_s}} \right) \left(1 + \frac{W - T_{DF}}{\theta_s} \right); W \leq 2T_{DF} \quad (2)$$

Where P_A is the probability of a unit passing ESS screening given that the desired operational MTBF (θ_s), and the defect-free time is allowable in a window (W). By setting the window not to exceed $2 \times T_{DF}$ reduces equation (2) to:

$$P_A = \left(e^{-\frac{T_{DF}}{\theta_s}} \right) \left(1 + \frac{T_{DF}}{\theta_s} \right) \quad (3)$$

The object is to establish a defect free duration to give a very high probability of passing the DF portion of the screening in the order of >90%, if the equipment has in fact been adequately corrected after P_{DF} and is approaching the minimum acceptable value.

The most important facets of these relationships are that the initial screening durations (T_{PDF} and T_{DF}) can be derived independent of historical data and, by means of statistical sampling and quality monitoring techniques, results can be verified against lot acceptance criteria based on an allowable percent defective (α) and probability of acceptance (P_A). Solving (1) in terms of T_{PDF} and T_{DF} provides the proportionality

$$T_{PDF} = \frac{T_{DF} \ln \frac{1}{\alpha}}{\ln(\theta_0 / \alpha)} \quad (4)$$

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From the expression (1B), the initial value $\theta_0 = (1/\lambda_0)$, can be expressed as a function of the percent defective (α):

$$\lambda_0 = \frac{\lambda_M - \lambda_s}{\alpha} + \lambda_s \quad (5)$$

Expressing the minimum acceptable rate (λ_M) in terms of a 2:1 discrimination ratio of specified (λ_s) simplifies (5) to:

$$\lambda_0 = \frac{\lambda_s (1 + \alpha)}{\alpha} \quad \text{or} \quad \theta_0 = \frac{\alpha \theta_s}{(1 + \alpha)} \quad (6)$$

Equation (3) can now be transformed to:

$$P_A = \left(e^{-\frac{T_{DF}(\alpha)}{(1 + \alpha)\theta_0}} \right) \left(1 + \frac{T_{DF}(\alpha)}{(1 + \alpha)\theta_0} \right) \quad (7)$$

This now provides a complete correlation between the time required in P_{DF} to precipitate manufacturing defects at some rate θ_0 , and the probability of accepting the device in DF.

A.4.4 Time on screening criteria.

A.4.4.1 Screening duration. The criteria for screening duration is that it be fixed for all devices independent of their life characteristics, and that the $T_{PDF} = T_{DF}$. To satisfy the assumptions of A.3.1 and A.3.2, θ_0 for all cases will be relatively small and constant, and is estimated from equation (4) as $\theta_0 = 1$, when $T_{PDF} = T_{DF}$.

A.4.4.2 Probability of acceptance (P_A). The probability of acceptance for the DF portion of the screening is set at $\geq 90\%$ to ensure a low probability of rejection if, in fact, the defects have been adequately corrected after PDF. This also minimizes the chance of random failure effects. The DF screening objective is not to verify reliability.

A.4.4.3 Percent defective data (α). Within the constraints of the P_A , and solving equation (7) for values of α and T_{PDF} establishes that α must be in the range of 1% and $T_{PDF} = T_{DF}$ in the range of 50 hours or less to satisfy the criteria of A.4.4.1 and A.4.4.2, as shown in table A-I.

A.4.5 PDF Time (T_{PDF}). From the environmental profile guidelines; paragraph 5.2.1.1, the optimum number of hours of cycling for all devices will be on the order of $T_{PDF} = 40$ hours.

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TABLE A-IValues of P_A for Various α and $T_{PDF} = T_{DF}$. $T_{PDF} = T_{DF}$ (Hours)

<u>α</u>	<u>30</u>	<u>40</u>	<u>50</u>
1%	96%	95%	91%
2%	88%	81%	74%
3%	78%	68%	57%
4%	66%	55%	43%
5%	58%	43%	31%

A.4.6 DF Time (T_{DF}). The defect free portion of the screening, set at the same length and environmental cycling profile as the PDF, $T_{DF} = 40$ hours, which is to be obtained sequentially within an overall window of 80 hours. The probability of acceptance (P_A) will be 95% for a percent defective rate (α) of 1.0% (0.01).

It should be cautioned that, for devices whose design MTBF (θ_s) is less than 25 hours, the probability of random failures occurring significantly decreases to below 50%. This is illustrated in table A-II which provides the probability of rejection due to random failure (P_r) over the DF period for various levels of MTBF (θ_s).

TABLE A-II

Probability of Rejections Due to Random Failure
for Various Values of θ_s .

<u>θ_s (Hrs)</u>	<u>P_r</u>
≤ 25	$> 50\%$
50	20%
200	2%
500	0.3%
> 1000	0%

A.4.7 Screening duration. The recommended duration for all units screened is:

- $T_{(PDF)} = 40$ hours of cycling
- $T_{(DF)} = 40$ hours of cycling
- DF Window = 80 hours of cycling

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A.5 REDUCED SCREENING AND SAMPLING

A.5.1 Reduced screening limits. Reduced screening means a reduction in the number of units screened or a reduction of the initial criteria. The baseline screening durations for PDF and DF will not be altered, nor will the criteria for a ESS, or an acceptable product. Any reduced screening should be in accordance with sampling plans and procedures approved by the procuring activity. The criteria for reduced screening comes from the fact that, if a large number of continuous units or lots screened have no defects during PDF, then θ_0 is very large and P_A approaches 100%.

A.5.2 Screening options. The options in a through c apply.

a. 100% screening. Each unit of product should be submitted for ESS screening.

b. Sampling plans. It is recommended that sampling plans, including selections and criteria for the samples, be prepared in accordance with MIL-STD-1235. In all cases, both the PDF and DF segments of the ESS should be defect free to satisfy the criteria for instituting a sampling plan. A single failure in either PDF or DF portion of the screening could be cause for rejection.

c. Reduced DF accountability. In conjunction with options a or b, all defects should be noted during the early stages of the PDF, and provided failures are corrected as they occur, the DF may begin before the PDF time has elapsed; that is, the DF time may start at the beginning of the PDF if no product operational failure occurs, or the DF may begin after repair of a product operational failure in PDF. As a minimum, there should be 40 continuous hours of defect-free screening within a maximum of 120 screening hours. In order to satisfy option (b), no failure can occur during PDF, and the DF portion should be waived.

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APPENDIX B

ESS TROUBLESHOOTING PLAN

B.1 SCOPE

B.1.1 Scope. This appendix covers some considerations useful in formulating a troubleshooting plan to address ESS failures.

B.1.2 Purpose. The purpose of this appendix is to ensure that adequate planning is accomplished prior to ESS to minimize the environmental effects on the equipment to be screened during the pre defect-free and defect free periods.

B.2 APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

B.3 TROUBLESHOOTING CONSIDERATIONS

B.3.1 Content. A detailed troubleshooting plan should be formulated prior to the start of ESS. This plan may be a part of, or a supplement to, the screening procedure. The plan should be coordinated with the performance monitoring procedures, utilize Built-In-Test to the fullest extent possible, and take full advantage of all data resulting from performance monitoring, including trend data.

B.3.2 Considerations. In preparing the plan the following should be considered.

B.3.2.1 Identification. Recognizing that failures may degrade the ability to monitor the performance of the equipment, conventional fault isolation and identification techniques may not be appropriate. It may be advantageous or even necessary to perform functional screenings on a module or a subassembly while exposing it to a specified environment. The troubleshooting procedures should address this possibility, not only in terms of powering, operating and monitoring the article, but also in terms of applying the required environment(s).

B.3.2.2 Monitoring. Equipment performance should be monitored during the application of specific environments. When a failure occurs which would mask other functions, the screening should be stopped and troubleshooting procedures initiated to identify and correct the defective item.

B.3.2.3 Temperature cycling. If the failure is intermittent, the environmental stimuli at the time of the failure should be noted and troubleshooting procedures relating to the environment followed. Given that the failure is associated with thermal cycling and the point in the cycle at which the failure first appeared is known, troubleshooting should be initiated while applying that thermal stress. If the specific failure

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point is not known, or if the initial attempt is unsuccessful, complete thermal cycles may be applied until the failure is reproduced and its origin identified. It should be noted that, in practical terms, as many additional thermal cycles as are necessary can be applied without affecting the equipment's useful life.

B.3.2.4 Vibration. Unlike thermal cycling, the maximum time that a unit can be exposed to the specified spectrum of random vibration, without significantly affecting its useful life, is severely limited. With the unit operational and its performance monitored, it should be exposed to the specified spectrum of random vibration at the lowest g_{RMS} level which will cause the noted failure to reappear and allow identification of its origin. In the event that the failure cannot be duplicated at reduced levels, the criticality of the failure should be examined and a judgment made as to the advisability of continuing the effort, considering the risk of fatigue damage associated with the application of reasonably high vibration levels for extended periods of time.

To minimize the accumulation of equivalent random vibration screening time, during diagnostic screening the vibration should be reduced to the lowest feasible level. The total equivalent time for all acceptance and diagnostic vibration screening should not exceed 20 minutes at the full ($0.04g^2/Hz$) level. Equivalent screening time is given by the following expression:

$$\left(\frac{0.04g^2/Hz}{EQUIV} \right)^3 = \frac{T}{20}$$

Where EQUIV is the equivalent g^2/Hz level and T is the allowable time in minutes.

RMS Level (g_{RMS})	PSD Level (g^2/Hz)	Equivalent Screening Time (minutes)
6.0	0.04	20
5.2	0.03	47
4.24	0.02	160
3.0	0.01	1280

EXAMPLE:

Screening	(g^2/Hz) Level	Allowable Exposure	Ratio of Allowable Exposure	Equivalent Screening Time
Pre Defect-Free	.04	5 minutes	5/20 or 0.25	5.0 minutes
Defect-Free	.04	4 minutes	4/20 or 0.20	4.0 minutes
Diagnostic	.02	20 minutes	20/160 or 0.125	2.5 minutes
Diagnostic	.01	20 minutes	20/1280 or .016	.31 minute
Pre Defect-Free	.04	5 minutes	5/20 or 0.25	5.0 minutes
			Total = 0.841	16.81 minutes

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NAVY PROGRAM MANAGEMENT GUIDANCE

C.1 SCOPE

C.1.1 Scope. This appendix covers some considerations useful in planning and implementing ESS for Navy programs.

C.1.2 Purpose. The purpose of this appendix is to assist Navy program managers in understanding the issues related to, and the implementation of environmental stress screening. In order to affect continuous process improvement, Navy program managers must tailor the information in this appendix for the development of solicitation requirements. Allowance should be made for the implemented processes to change when warranted and justified by the facts.

C.2 APPLICABLE DOCUMENTS

C.2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

C.2.2 Other Government documents, drawings and publications. The following other Government documents form a part of this appendix to the extent specified herein.

TRI-SERVICE TECHNICAL BRIEF 002-93-08 - Environmental Stress
Screening Guidelines

(Application for copies should be addressed to The Office of the Assistant Secretary of the Navy (Research, Development, and Acquisition) Product Integrity, 2211 Jefferson Davis Highway, Arlington, VA 22244.)

TE000-AB-GTP-020A - Naval Sea Systems Command Environmental Stress
Screening Requirements and Application Manual for
Navy Electronic Equipment

(Application for copies should be addressed to the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

C.2.2 Non-Government publications. The following document forms a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation.

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INSTITUTE OF ENVIRONMENTAL SCIENCES (IES)

Environmental Stress Screening Guidelines for Assemblies

(Application for copies should be addressed to the Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056.)

C.3 ESS APPLICABLE AREAS

Best design and manufacturing practice calls for the application of environmental stress screening to:

- All material acquisitions that include electrical, electronic, electro-optical, electromechanical or electrochemical components in program definition & risk reduction, engineering and manufacturing development and production phases.
- Reprocurements where the cost of ESS implementation can be amortized economically
- Depot overhaul programs where opportunities exist for substantial cost savings
- Nondevelopmental items, such as commercial off-the-shelf (NDI-COTS) and domestic or foreign military (NDI-Military) items.
- Systems and equipment that have been specifically designated to receive ESS.

ESS may be applied at any manufacturing level, from piece parts to end items. It is intended to screen defects in a manner that is not harmful to properly manufactured material. Hardware proven to be too fragile may be excluded because screening environments may be harmful. For Navy programs, all ESS requirements may be accomplished at the lowest feasible level of assembly in accordance (see Figure 1-1 of NAVSEA TE000-AB-GTP-020A). All electrical/electronic parts may be purchased as screened parts to the minimum quality levels during Production, Fielding/Deployment, and Operational Support (see Section 2.2.1 of NAVSEA TE000-AB-GTP-020A). All other active parts may be upgrade screened as specified in Table 2-1 (for integrated circuits) and Table 2-2 (for discrete semiconductors) of NAVSEA TE000-AB-GTP-020A. All parts meeting the minimum and upgrade screened quality levels may be subjected to additional part requirements (see Sections 2.2.1 and 2.2.2 of NAVSEA TE000-AB-GTP-020A).

C.4 BENEFITS OF ENVIRONMENTAL STRESS SCREENING

Proper application of environmental stress screening offers several benefits: Reduced overall life cycle cost, on-time deliveries, improved

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performance after delivery, improved user confidence and/or satisfaction, reduced support costs, and improved readiness.

While these benefits far outweigh the costs of implementation, they do not come without a penalty. ESS must be implemented early in the program and closely supervised throughout. The benefits are long term but the requirements for people and funds occur early in the program.

ESS is normally conducted during the manufacturing process to detect latent defects in parts and workmanship, but may also disclose design deficiencies that were not detected during qualification and engineering tests. In addition, there are distinct benefits to conducting ESS during development as well. A considerable percentage of the failures encountered during a reliability growth (test, analyze and fix) test program may be caused by poor workmanship and defective parts. These non-design related failures can mask design-related failures, can cause schedule slippage, and can adversely affect performance. By screening the item prior to this testing, these adverse effects can be minimized. It is virtually impossible to achieve design reliability without reducing to a minimum the reliability degradation due to screenable flaws. Additional benefits are presented in table C-I.

C.5 PLANNING CONSIDERATIONS

It is important that ESS resources be in place when production begins. The cost of rework in manufacturing escalates by orders of magnitude as the assembly process proceeds from piece part level to printed circuit board/module, unit, system, and to the user. Finding defects at the lowest possible level of assembly will tend to minimize rework costs by reducing corrective action time. However, some flaw types manifest themselves only at the higher levels of assembly. Tailoring the screen to the vibration and thermal characteristics of the hardware coupled with defect population at each level of assembly is essential.

C.6 MANAGEMENT ISSUES

The following ESS management issues and guidance should be considered to increase the probability of implementing a viable ESS program:

- How critical are the items proposed for ESS and what level of quality is required? Criticality would be high if a failure of the item results in high probability of loss of life or an inability to complete a mission, high life cycle cost, or high cost of failure.
- The quantity to be procured should be considered. Where small quantities are involved and the item does not qualify as a high criticality item as given above, then it may be cost effective to

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use only the relatively low cost thermal cycling screens or to delete the ESS in favor of field screening.

TABLE C-1. ESS Benefits to Management.

	MANAGEMENT TARGET	BENEFITS/RATIONALE
ENGINEERING & MANUFACTURING DEVELOPMENT	PROGRAM MANAGER AND ENGINEERING MANAGER	<ul style="list-style-type: none"> • ENSURES HARDWARE PERFORMANCE ON DEMAND • CONTRIBUTES TO PARTS LIST DEVELOPMENT • IMPROVES RELIABILITY GROWTH TESTING • ASSURES READINESS OF PRODUCTION SCREENS • ESS WEEDS OUT PROBLEM PARTS, VENDORS • 60% FAILURES DUE TO WORKMANSHIP DEFECTS • 30% FAILURES ARE DUE TO PART FLAWS • ESS DESIGN IS BY NATURE ITERATIVE
PRODUCTION	MANUFACTURING MANAGER	<ul style="list-style-type: none"> • REDUCES REWORK COST • MINIMIZES SCHEDULE DELAYS • FACILITATES ACHIEVEMENT OF DESIGN RELIABILITY IN PRODUCTION HARDWARE • IMPROVES PRODUCTIVITY • REDUCES OR ELIMINATES WORKMANSHIP AND PART DEFECTS • ENTIRE PRODUCTION PROCESS MORE EFFICIENT • DEFECTS SURFACED AT LOWEST LEVELS OF ASSEMBLY AND ROOT CAUSE CORRECTIVE ACTION IMPLEMENTED • ACCEPTANCE TEST PASSED ON FIRST PASS, LESS HIGH ASSEMBLY LEVEL REWORK
GENERAL		<ul style="list-style-type: none"> • LESS PROGRAM COST • LESS SCHEDULE AND QUALITY NEGATIVE VARIANCE • HIGHER FIELD RELIABILITY • FAILURES ARE FORCED TO EMERGE AT CONVENIENT PRODUCTION STEPS • LESS LATENT DEFECTS SHIPPED TO FIELD
USER		<ul style="list-style-type: none"> • INITIALLY DELIVERED HARDWARE MEETS RELIABILITY AND QUALITY REQUIREMENTS • LOWERS SUPPORT COST • LOWERS LIFE CYCLE COST • SPARES MEET RELIABILITY REQUIREMENTS • ON-TIME DELIVERIES • INCREASES CONFIDENCE AND SATISFACTION • REMOVES DEFECTS NORMALLY PRESENT IN DELIVERED HARDWARE • FEWER FIELD FAILURES OR MAINTENANCE ACTIONS • ESS INFLUENCES ACQUISITION CYCLE • SPECIFY ESS IN SPARES CONTRACT • CONTRACTOR SHOULD INCLUDE IN SPARES PROPOSAL

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- Screen levels below those in the example presented in this document are not recommended. The examples presented are starting points only. They should be used to develop a screen based on response surveys and/or tailoring approaches that will optimize these screening profiles.
- Conduct of ESS at the piece part level should be evaluated to ensure cost effective means is utilized to meet critical military requirements.
- The ESS program plan should emphasize the following:
 - Commitment to and understanding of ESS
 - Failure reporting and corrective action system (FRACAS). A FRACAS should be in place and operating.
 - Planned ESS profile optimization technique. The Navy recommends one of four random vibration techniques, and one of two thermal cycling techniques. Each has both advantages and disadvantages.
 - Managerial and technical approaches to ESS. The plan should include proposed methods for determining initial screening environment, applicable assembly levels, data collection, failure analysis and corrective action, and procedures or methods to be used in altering the program.
 - Nondevelopmental items (NDI), such as commercial off-the-shelf and domestic or foreign military items.
- The Navy program manager should also address the following additional issues:
 - ESS profile requirements should not be specified in the RFP. In general, it is better to allow contractors to propose an ESS profile than to specify a particular profile, unless the contract is a reprocurement and the original profile holding fixtures, vibration machine and chamber capabilities are contained on the drawings and are found to be satisfactory. (Note: the original profile may have to be modified due to changes in the production process and component manufacturing variability.)
 - The ESS and quality history of the contractor.
 - The ESS results in recent contracts.

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- When a contractor volunteers to participate in the single process initiative and proposes an ESS process change, the Navy program manager with the highest dollar value contract should designate an individual as the Department of the Navy ESS expert team member to support the Navy team leader.

C.7 PROGRAM MANAGEMENT CHECKLIST

The following checklist should be used in the development of a management plan for implementing ESS in each phase of the acquisition process.

PROGRAM DEFINITION & RISK REDUCTION

- Establish adequate ESS funding. The basis of this verification is the development of an historical data base on costs to implement various screens versus return on investment (cost avoidance).
- Assess the training needs of ESS personnel and develop a plan to correct any identified training and/or qualification deficiencies.
- Determine equipment availability, adequacy, capacity, etc. to perform the intended screens.
- Identify special long lead equipment requirements (e.g., fixtures, racks, etc.)
- Determine appropriate initial profile.
- Establish a FRACAS to report and analyze faults that are precipitated out during screening.

ENGINEERING & MANUFACTURING DEVELOPMENT

- Continue to tailor, refine, and evaluate the adequacy of the ESS profile, striving for an optimum screen. The absence of fault precipitation during initial production or reprourement is an indication of a weak screen that needs further optimization.
- Establish a FRACAS to report and analyze faults that are precipitated out during screening.
- Apply ESS just prior to the start of the TAAF program, while continuing to strive for an optimum screen.

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- Include ESS profiles, identified holding fixtures, vibration machine and chamber capabilities on engineering drawings, and add the following statement: "To the extent that the profile is equipment and/or manufacturer unique, it may have to be modified due to changes in the production process and component manufacturing variability."
- Finalize the ESS profile before the system enters into production. The following guidelines are provided to assist program managers in determining whether or not a reasonable screening profile has been developed. One or more of the following techniques may be required.
 - Verify that the more severe temperature screening profiles are used at the lower assembly levels (e.g., printed circuit board, module, subsystems, etc.). A good ESS program should drive out most faults at the lower levels where faults are more easily corrected and less costly to repair.
 - Verify that the proposed screening profiles meet or exceed an established baseline.
 - Verify that the proposed screening profile is not so severe that it is damaging to the item being stressed. By reviewing failure analyses a determination can be made whether or not a failed component has been overstressed. If the results of this review indicate that the item is being overstressed, the screening profile should be adjusted until failure analyses indicate no failures are due to over stressing.
 - Verification can be made that a screening profile is adequate by seeding known faults into an item and then determining if the proposed screening profile is adequate to precipitate them to hard failure.

The profiles should not change unless the manufacturing processes are changed, the system is redesigned, parts are changed, or a different type of screen is found to be more effective.

PRODUCTION, FIELDING/DEPLOYMENT, AND OPERATIONAL SUPPORT

- Establish a FRACAS to report and analyze faults that are precipitated out during screening.
- Establish procedures to correct/monitor any workmanship/parts problems identified during screening. Screens help to identify processes that are "out of control."

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- Provide parts failure information to parts manufacturers and require continuous improvements to reduce these deficiencies.
- Establish procedures to track fielded systems and evaluate field failure information against the effectiveness of the current screens wherever possible.
- Establish criteria acceptable to the Government on when and under what conditions 100% screening should be reduced to sampling.

REPROCUREMENT AND DEPOT LEVEL OVERHAUL

- Derive the same benefits of ESS in reprocurement items and depot overhauled items as initial production environments. Though the frequency failure may be lower for depot overhaul items (infant mortality/design updates are already in place through field use), poor workmanship and bad replacement parts are still a problem in the depot overhaul environment.

Note: Numerous applications of ESS may be harmful to equipment. Depending on the particular equipment, the ESS program and the frequency of overhaul, some marginal useful life of the equipment may be consumed.

- Require that all originally screened reprocurements be screened. System level equipment should be screened at the originally developed screen or equivalent screen. Where original screens were not developed for replacement modules, a determination based on criticality and cost should be made to determine whether or not to develop an appropriate screen.
- Establish a FRACAS whenever there is a screening effort.

C.8 GUIDANCE SUMMARY

Top management's commitment and attention is the key element in a successful ESS program. Appendix D of "IES Environmental Stress Screening Guidelines for Assemblies" contains a sample Environmental Stress Screening Statement of Work (SOW) that will assist the Navy program manager in preparing contractual acquisition documentation.

Data Item Descriptions (DIDs) DI-RELI-80249 and DI-ENVR-81014 provide additional guidance for the program manager in the preparation of ESS documentation. These two DIDs are often used for ESS acquisition contracts. Contract Data Requirements Lists should be prepared in accordance with local contracting office direction.

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the comment number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of this form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER

2. DOCUMENT DATE (YYMMDD)

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960619

3. DOCUMENT TITLE

ENVIRONMENTAL STRESS SCREENING PROCESS FOR ELECTRONIC EQUIPMENT

4. NATURE OF CHANGE (identity paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

A. NAME (Last, First, Middle Initial)

b. ORGANIZATION

c. ADDRESS (include Zip Code)

d. TELEPHONE (Include Area Code)

7. DATE SUBMITTED (YYMMDD)

(1) Commercial

(2) DSN

(if applicable)

8. PREPARING ACTIVITY

A. NAME Technical Point of Contact (TPOC)

b. TELEPHONE (Include Area Code)

(1) Commercial:

DSN:332-9121, EXT 228

MR. DONALD CROSS, SEA 03K21

ADDRESS ALL CORRESPONDENCE AS FOLLOWS:

TPOC: 703-602-9121, EXT 228

c. ADDRESS (Include Zip Code)

IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:

COMMANDER, NAVAL SEA SYSTEMS COMMAND

Defense Quality and Standardization Office

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