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INCH-POUND

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DEPARTMENT OF DEFENSE

HANDBOOK FOR

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 DO NOT CITE THIS DOCUMENT AS A REQUIREMENT.

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DEPARTMENT OF DEFENSE
WASHINGTON, D.C. 20360

ENVIRONMENTAL STRESS SCREENING PROCESS FOR ELECTRONIC EQUIPMENT

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to:

Commander
Naval Electronics Systems Command
Attn: ELEX 8111
Washington, D.C. 20363

by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

The current emphasis on reliability and hardware design integrity has resulted in an increased potential for providing a basically sound and inherently reliable design. As this potential has increased, so has the complexity and density of packaging of contemporary electronic equipment. This complexity and density amplifies the ever present problems of detecting and correcting latent manufacturing defects. The occurrence of a malfunction due to poor workmanship incurs extremely high maintenance costs after the equipment has been deployed. The fact that the unit had been fully qualified and demonstrated a contractual mean time between failures in the laboratory becomes meaningless when such a failure results in loss of life or mission.

Specifications, standards and guidelines currently exist for development, and qualification testing. No similar documentation exists for the Environmental Stress Screening (ESS) Process; consequently, gross inconsistencies in approach, coupled with test ineffectiveness, result in latent defects causing failures in delivered equipment. This standard defines the approach and method to be used for Environmental Stress Screening of electronic equipment so that latent defects may be located and eliminated before the equipment is accepted.

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FIGURES

ENVIRONMENTAL STRESS SCREENING (ESS) TESTING

1. SCOPE

1.1 Purpose. This standard defines the requirements for ESS of electronic equipment, including environmental test conditions, durations of exposure, procedures, equipment operation, actions taken upon detection of defects, and test documentation. The standard provides for a uniform ESS to be utilized for effectively disclosing manufacturing defects in electronic equipment.

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

Category	Service Application
1	Fixed ground equipment
2	Mobile ground vehicle equipment
3	Shipboard equipment
3A	o Sheltered
3B	o Exposed to atmospheric environments
4	Jet aircraft equipment
5	Turbo-propeller and rotary-wing aircraft equipment
6	Air launched weapons and assembled external stores

1.2.1 Large, heavy items. When applying this standard to large, heavy items, the following shall be considered:

- o Potential fatigue
- o Adequate environmental inputs
- o Availability of suitable environmental generation facilities
- o Technical validity of testing at lower assembly levels, i.e., drawers, chassis, etc.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Issues of documents. Unless otherwise specified, the following specifications and standards of the issue listed in that issue of the Defense Index of Specifications and Standards (DODISS) specified in the solicitation, form a part of this standard to the extent specified herein:

SPECIFICATIONS

Military

MIL-E-5400.	Electronic Equipment, Airborne, General Specification for
MIL-E-16400	Electronic, Interior Communication and Navigation Equipment, Naval Ship and Shore: General Specification for

STANDARDS

Military

MIL-STD-109	Quality Assurance Terms and Definitions
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-721	Definitions of Terms for Reliability and Maintainability
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
MIL-STD-1235	Single and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes Functional Curves of the Continuous Sampling Plans
MIL-STD-45662	Calibration System Requirements

2.2 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

(Copies of specifications, standards and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

3. DEFINITIONS

3.1 General. Meanings of terms not defined herein are in accordance with the definitions in MIL-STD-109 and MIL-STD-721.

3.2 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) and line replaceable unit (LRU).

b. System. A group of electronic units, interconnected, which provide a specific function, for example, radar system, navigation system, and so forth.

3.3 Failure. A shortcoming, imperfection or operational nonconformance, including a one-time non-repeatable anomaly, either sudden or gradual in nature, which causes the equipment performance to deviate from specified limits without adjustment of controls other than normal operating controls.

3.3.1 ESS failures. All failures occurring in the defect-free test that cannot be classified as non-ESS (see 3.3.2). ESS failures include those due to:

a. Poor workmanship in the equipment.

b. Defective manufacturing processes.

c. Defective components.

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

3.3.2 Non-ESS failures. The following failures are non-ESS failures:

a. Failures directly attributable to improper installation in the test facility.

3.3.2 (Continued)

b. Failures of test instrumentation or monitoring equipment (other than the BIT function), except where it is part of the delivered item.

c. Failures resulting from test operator error in setting up, or in testing the equipment.

d. Failures attributable to an error in or interpretation of the test procedures.

e. Dependent failures.

f. Failures occurring during repair.

g. Failures clearly attributable to the environmental generation test equipment overstress condition.

3.4 Supplementary definitions.

a. Defect - The causative element that results in a failure.

b. Defect-free - That portion of the ESS sequence which must be completed without the disclosure of a defect (failure).

c. Pre-defect free - That portion of the ESS sequence which is dedicated to the disclosure of defects.

3.5 Procuring activity. Procuring activity, as used in this standard, refers to the Government agency responsible for the procurement.

3.6 Contractor. Contractor includes governmental or industrial activities developing or producing military systems and equipments.

3.7 Seller. The equipment manufacturer.

4. GENERAL REQUIREMENTS

4.1 ESS requirements. ESS tests shall be accomplished in accordance with task 301 of MIL-STD-785 on all deliverable equipment and also those assigned for formal development and environmental qualification testing, to ensure that hardware is free of manufacturing defects. The seller shall furnish all test equipment and shall be responsible for accomplishing the ESS tests. When required by the contract, all inspection and testing shall be under the supervision of the procuring activity/contractor.

4.2 Test conditions. The following conditions shall apply to all ESS tests.

a. All testing shall be accomplished in accordance with the applicable requirements specified herein.

b. There shall be evidence of quality control acceptance of all required inspection or test activity prior to the start of any contractual testing, and at each time maintenance is performed.

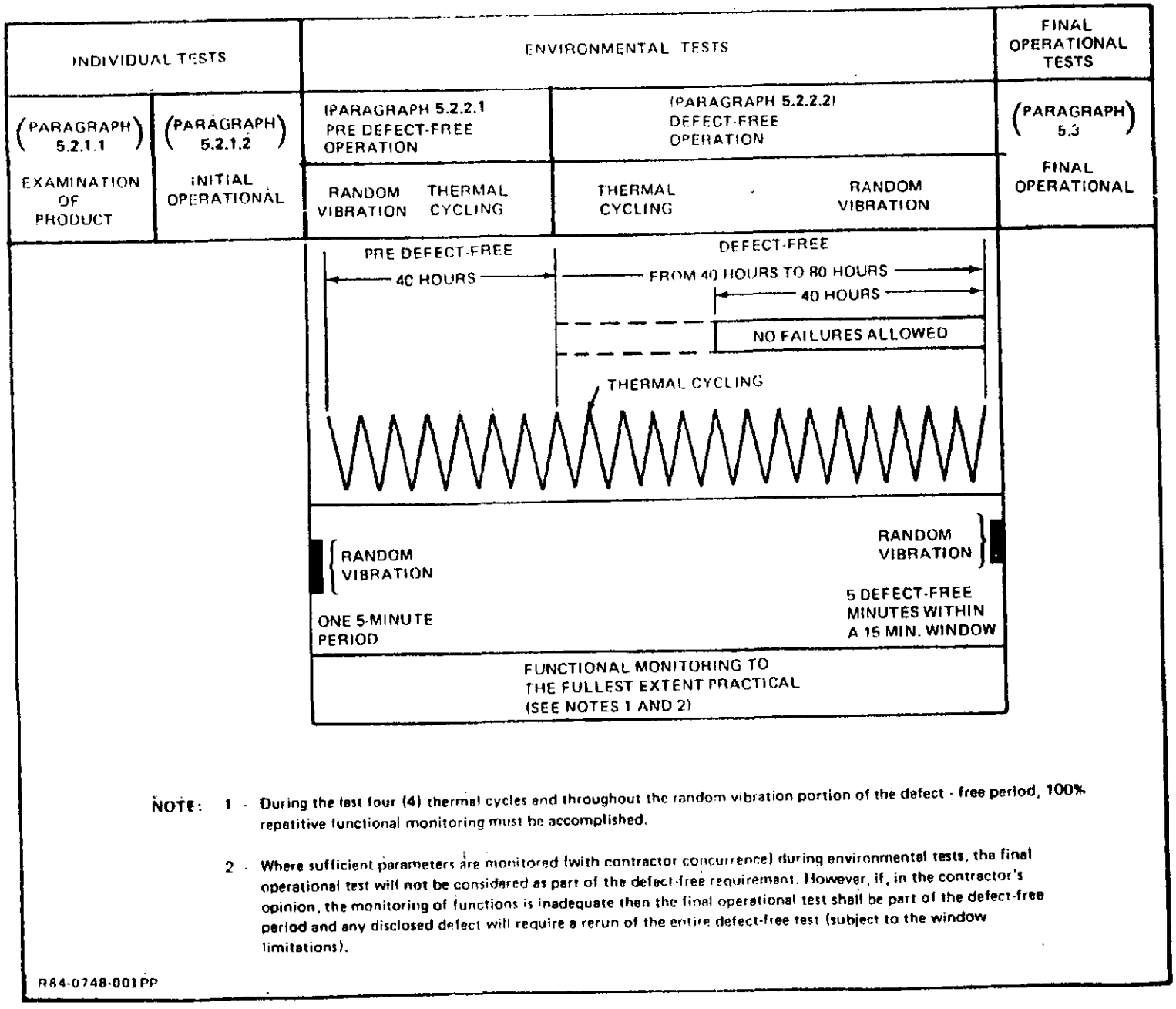
c. All conditions shall be imposed on the equipment in the unpackaged state.

d. The conditions specified shall be applied in the sequence indicated in Figure 1.

e. Equipment shall be installed initially in or on the environmental generation equipment and then operated to assure satisfactory performance of both the equipment under test and the test facility. The time to verify the facility compatibility with the equipment shall not be counted as test time.

f. After a failure has occurred and the defect isolated and corrected, the equipment shall be operated and its performance monitored to ensure proper diagnosis and correction. Replacement of or adjustment to any item during this action shall be reported to the contractor.

g. Unless otherwise stated, the equipment's performance shall be verified before and after each environmental test. Continuous functional monitoring shall be performed in accordance with Notes 1 and 2 of Figure 1.



NOTE: 1 - During the last four (4) thermal cycles and throughout the random vibration portion of the defect - free period, 100% repetitive functional monitoring must be accomplished.

2 - Where sufficient parameters are monitored (with contractor concurrence) during environmental tests, the final operational test will 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 shall be part of the defect-free period and any disclosed defect will require a rerun of the entire defect-free test (subject to the window limitations).

Fig. 1 Environmental Stress Screening Test Constituents

4.2 (Continued)

h. During all equipment operation, functional parameters, such as voltage and current, shall be maintained at nominal values.

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

j. Anticipation of failure shall not be justification for maintenance; for example, if an output is observed, by crew accessible means, to be degrading but is still within specification limits, no replacement or adjustment shall be permitted unless such adjustments are normally made by means of crew-operated controls.

k. Failures detected during the final functional test shall be counted as if they occurred in the defect-free period if the equipment used to monitor the performance characteristics during the test was not capable of detecting that failure. Refer to Figure 1, Notes 1 and 2.

4.2.1 General environmental requirements. Unless otherwise specified herein or in the equipment specification, measurements and tests shall 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-test) are conducted at room ambient conditions as follows:

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

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

Temperature	23°C ± 2°C (73°F ± 3.6°F)
Relative humidity:	50 percent ± 5 percent
Atmospheric Pressure:	$96.45\ ^{+66}_{-10.0}$ kPa
	$(725\ ^{+50}_{-70}$ mmHg)
	$(28.5\ ^{+2.0}_{-3.0}$ inHg)

4.2.1.3 Thermal testing tolerances. The test item shall 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 test item, shall be within ± 2°C (±3.6°F) of the test temperature and shall not exceed 1°C per meter or a maximum of 2.2°C total with equipment nonoperating.

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

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

4.2.1.4 (Continued)

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 shall be made by the use of an analysis system with the following characteristics:

Frequency Range	Maximum Filter Bandwidth
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 shall be measured with an accuracy of ±1 percent.

4.2.2 Accuracy of test instrumentation calibration. The accuracy of instruments and test equipment used to control or monitor the test parameters shall be verified prior to and following each test and then calibrated in predetermined intervals and shall meet the requirements of MIL-STD-45662. All instruments and test equipment used in conducting the tests specified herein shall be calibrated to laboratory standards, whose calibration is traceable to the National Bureau of Standards, and have an accuracy of at least one-third the tolerance for the variable to be measured.

4.3 Test facilities. Test facilities and apparatus used in conducting the tests contained in this standard shall be capable of meeting the conditions specified.

4.3.1 Test chamber. The test chamber shall conform to the following requirements:

a. The test item shall be totally surrounded by an envelope of air (except at necessary support points) as specified in 4.2.1.3.

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

4.3.1 (Continued)

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

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

4.3.2 Vibration apparatus. Any vibration generating machinery capable of satisfying the random vibration requirements specified herein is acceptable. The equipment shall be capable of maintaining the specified 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 represents the space where the equipment is located in the vehicle and, as such, is cycled between -54°C and +71°C for most electronic equipment. As the chamber is programmed to fall below room ambient (approximately +25°C), the probability of reaching the dew point of unconditioned, room ambient air is very high. This condition is entirely unacceptable 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 ground rules. Instrumentation shall be in accordance with:

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

b. Continuous permanent records of all environmental test conditions shall be provided.

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

(1) Location shall be selected to permit accurate measurement of the test article environment.

(2) The transducer characteristics shall not affect the test article.

(3) Control accelerometers shall be mounted using mechanical means.

(4) Response accelerometer attachment method shall be compatible with the maximum levels and frequencies expected during the test.

(5) Unless otherwise specified, thermocouples or equivalent temperature sensors utilized to determine or control the specified chamber temperature shall be centrally located within the test chamber in the supply air stream, or in the return air stream, whichever provides the specified test conditions at the item under test. The thermocouples or temperature sensors shall be baffled or otherwise protected against radiation effects.

d. All instrumentation shall be calibrated, operational and recording prior to supplying power to environmental test equipment.

e. To permit as complete an evaluation as possible of specific test item performance under the various specified test conditions, all relevant critical test signals shall be recorded on magnetic tape or by other suitable means. This will permit post-test analysis to supplement the real-time monitoring and can allow the mechanized accumulation of trend data on critical test parameters. In addition, the operator shall monitor equipment operation.

4.4 (Continued)

f. Test records shall be maintained for the test item. All discrepancies, including those attributed to test equipment, input power, and procedural errors, including their disposition, shall be included in the records.

4.5 Vibration test ground rules. Except where otherwise specified herein, the following rules, test requirements, tolerance and data handling techniques shall apply to all vibration tests.

4.5.1 Test fixture. Test fixtures shall be designed to eliminate or minimize fixture resonances in the frequency range up to 2000 Hz. The fixture characteristics shall 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 shall be such that the vibration input in the axis of applied vibration at any specimen mounting point shall be within plus or minus 3.0 dB of that specified over the entire frequency band from 10 to 2000 Hz. Sinusoidal crosstalk (vibration input in either axis orthogonal to the axis of applied vibration) shall not exceed the input. Resonances whose total accumulative bandwidth do not exceed 300 Hz may be allowed in the band from 500 to 2000 Hz provided they do not deviate more than plus or minus 6 dB from the input level.

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 the test specimen is used, the vibration input shall be limited to low levels.

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

4.6 Performance monitoring requirements. The overall effectiveness of ESS testing is dependent upon the completeness of the performance monitoring before, during and after the environmental exposures. Prior to the environmental exposure, all functional parameters shall be verified and, to the extent possible, quantified. This information shall be utilized throughout the subsequent test 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; therefore, the seller shall monitor all of the operational parameters of the equipment under test.

4.7 Failure reporting, analysis, and corrective action system (FRACAS). The contractor shall utilize a closed loop system that collects data on, analyses, and records timely corrective action for all failures that occur during ESS tests. The contractor's existing data collection, analysis, and corrective action system shall be utilized with the minimum changes necessary to meet the requirements of MIL-STD-785 and this standard. The system shall cover all test items, interfaces between test items, test instrumentation, test facilities, test procedures, test personnel, and the handling and operating instructions.

4.7.1 Failures during pre defect-free test. If an equipment failure occurs during the pre defect-free test, correction may be accomplished immediately or deferred until the end of the period, at the seller's option. However, if the failure should adversely affect the ability to monitor the equipment operation, correction shall be made immediately. As an incentive to reduce the thermal cycling test period, all failures corrected upon their occurrence in order to enable the accumulation of successful operational test time. The advantage to this option is that all consecutive defect-free test time accumulated during the pre defect-free period shall be credited toward the 40 hour defect-free requirement.

4.7.2 Failures during defect-free test. If a failure occurs during the first 40 hours of the defect-free test window, action shall be taken as specified in 4.7. However, if a failure occurs after 40 hours of testing have elapsed, the test shall be terminated and the equipment shall not be submitted for ESS compliance until a positive corrective action plan is proposed and approved by the contractor.

4.7.3 Retest. Retest of rejected equipment shall be initiated only after adequate investigative analyses and correction have been accomplished by the seller and approval of the contractor has been obtained.

4.8 Sampling. Unless otherwise specified, 100% of all units produced shall be ESS tested. If sampling procedures are desired, the seller shall obtain approval of the contractor. Sampling procedures and plans shall be in accordance with MIL-STD-1235 (see Appendix A).

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 2 depicts the random vibration spectrum that shall be applied, as an input, to the equipment under test with the equipment hard mounted to the test 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 shall be obtained from data accumulated during development tests, or by conducting a low level sine sweep.

5.1.1.1 Applied axis determination. Generally random vibration applied in a single axis effectively screens workmanship defects found in electronic equipment. Crosstalk (vibration set up in the two axes not directly being excited) does in fact lso 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 shall be employed in defining which axis or axes 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 shall be perpendicular to the plane of the cards to assure maximum deflection and stimulation.

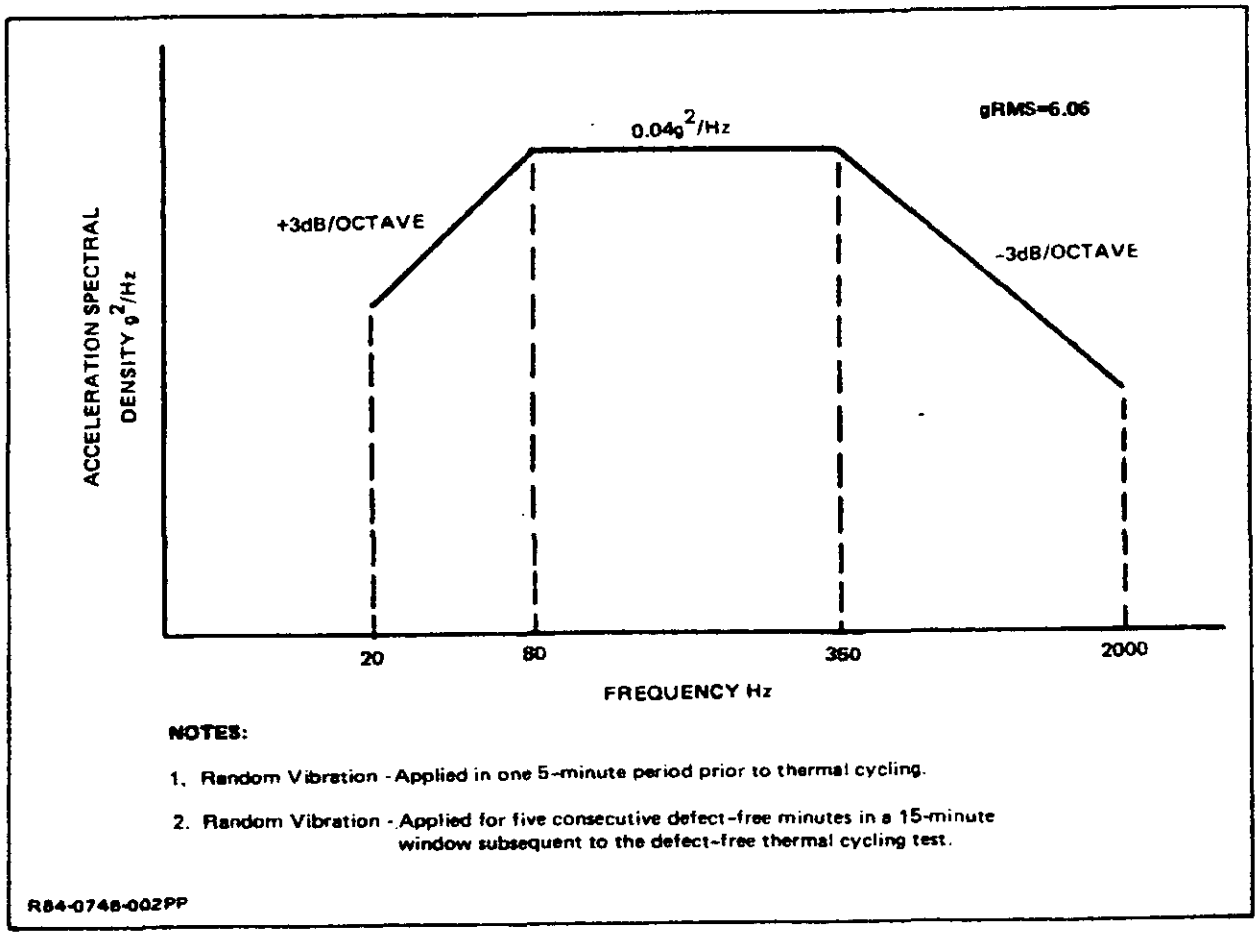


Fig. 2 Random Vibration Spectrum

5.1.1.1 (Continued)

o Vibration tests are conducted during the development program. The acquired data shall be reviewed to determine the axis(s) of major resonances and transmissibilities (Q) values.

5.1.2 Temperature cycling. In order to conduct the ESS test thermal cycling exposure as effectively as possible, it is necessary to obtain a high frequency 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 test profiles illustrated in Figure 3 have been developed to accomplish this and shall be used when performing thermal cycling tests. A minimum of ten thermal cycles should be performed in order to eliminate most latent workmanship defects in complex electronic equipment. The high and low temperature extremes represent chamber air temperature and shall be those dictated by the applicable equipment specifications, both operating and non-operating.

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 shall be followed for thermal surveys of ambient cooled equipment. (Refer to Figure 3A.)

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 test item in the temperature chamber at room ambient temperature. Verify equipment operation and then turn the equipment power off.

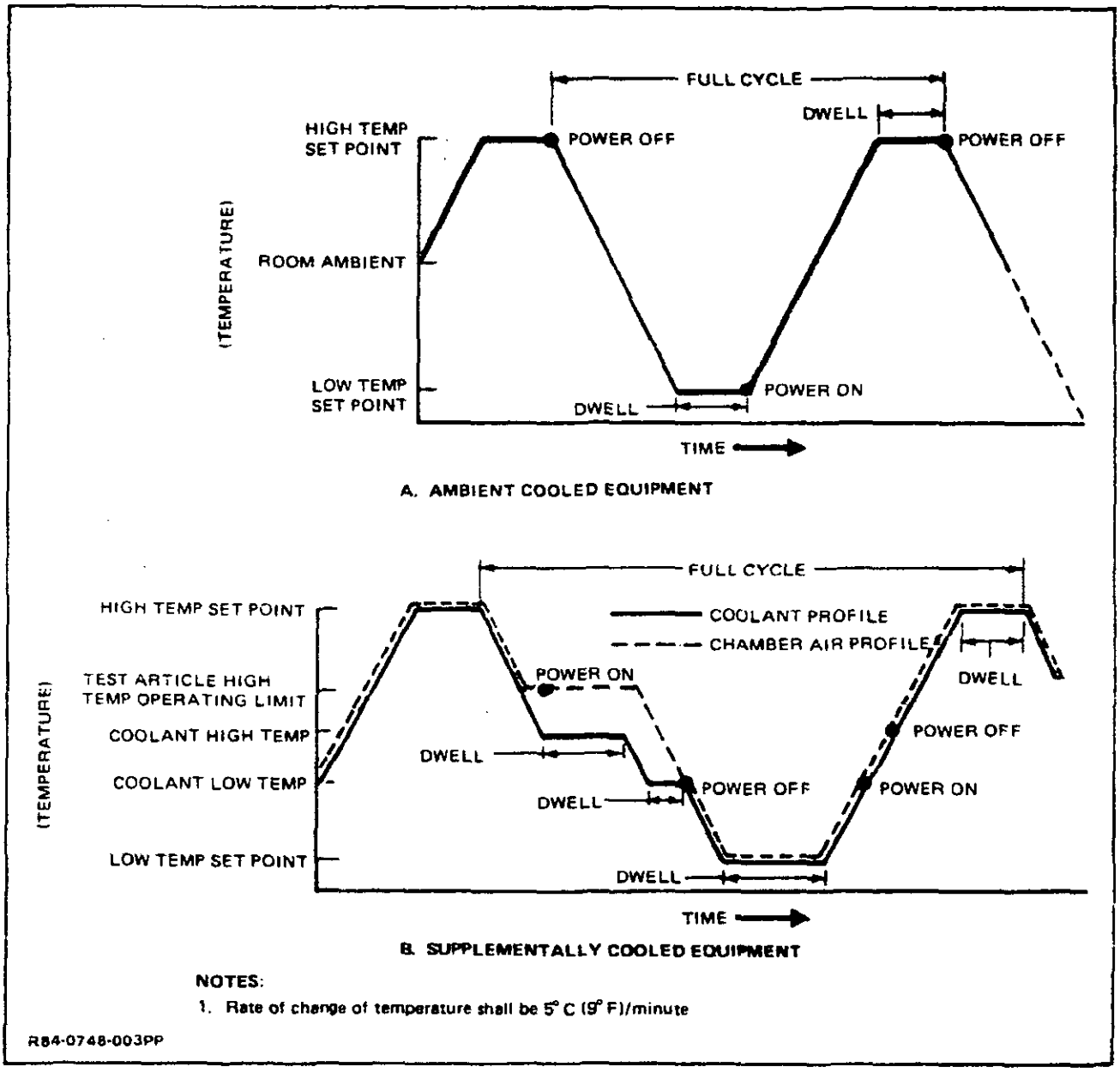


Fig. 3 Temperature Cycling Profile for Ambient Cooled & Supplementally Cooled Equipment

5.1.2.1.1 (Continued)

c. Turn the equipment power 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 5°C per minute. If the chamber cannot provide the rate of temperature change required, auxiliary heating means shall be employed. The average rate shall 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 air temperature at an average rate of 5°C per minute. If the chamber is not capable of an average rate of 5°C per minute, auxiliary cooling means shall be employed. The average rate shall be computed for the total chamber temperature excursion.

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, and again repeat steps c, d and e. These steps will result in 3 high temperature dwells and 2 low temperature dwells. The average of the last two high temperature dwells and the average of the two low temperature dwells are the required dwell periods.

5.1.2.1.1 (Continued)

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 3 hours and 20 minutes. In the event that the cycle duration exceeds 3-1/3 hours, the cycle time shall be increased to four hours and the increase added to the low temperature dwell time.

5.1.2.1.2 Procedure for supplementally cooled equipment. Steps a through k shall be followed for thermal surveys of supplementally cooled equipment (refer to Figure 3B).

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

b. Install the equipment in the temperature chamber at room ambient temperature. Verify proper operation of the test article and the supplementary cooling system. If the coolant specifications permit, the equipment power shall 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 5°C per minute. Simultaneously raise the coolant temperature with the chamber ambient temperature until the high temperature set point is reached. The equipment shall be powered until the coolant temperature reaches the coolant high temperature operating limit, and then the test article power shall 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.

5.1.2.1.2 (Continued)

e. At the end of the high temperature dwell period, reduce both the chamber ambient air and the coolant temperatures at 5°C per minute. Continue to reduce the chamber ambient and equipment coolant temperatures to the specification levels 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 and coolant temperatures 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 equipment specification, and increase both the chamber ambient and equipment coolant temperatures at an average rate of 5°C per minute. 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.

5.1.2.1.2 (Continued)

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 ESS tests. The thermal cycling portion of the ESS tests shall be applied during both the pre defect-free and the defect free segments of the overall test.

5.1.2.2.1 Ambient cooled equipment. The equipment shall be subjected to the temperature cycles developed in paragraph 5.1.2.1.1, as illustrated in Figure 3A.

5.1.2.2.2 Supplementally cooled equipment. Each equipment shall be subjected to the temperature profile cycling illustrated in Figure 3B. Overall duration for one cycle shall be 3 hours and 20 minutes, to provide at least 12 thermal cycles during each pre defect-free and defect-free tests. Using the results obtained from the thermal survey, 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 shall be operated for ten 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 test 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 1 presents the overall test flow which shall be used to verify that an equipment is ready for operational use.

5.2.1 Individual tests. Each equipment under test shall be subjected to:

5.2.1.1 Examination of product. Each equipment shall be examined during appropriate stages of manufacture and assembly to determine compliance with Requirement 9 of MIL-STD-454 and the applicable drawings. Any equipment which does not meet this requirement shall be rejected.

5.2.1.2 Initial operational test. An equipment operational test in accordance with the seller-prepared test procedure shall be performed, and data shall be recorded to verify that the equipment fully complies with detailed performance requirements. The test procedure shall include measurements required for a quantitative assessment of all functional parameters including built-in-test (BIT) functional performance parameters. Verification of BIT operational capability shall be included to the extent possible by external equipment adjustment and without insertion of faults. GO/NO GO evaluation shall not be acceptable except for BIT. The record of pretest data shall be retained for use as a reference during subsequent ESS tests.

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

5.2.2.1 Fixed duration pre defect-free (PDF) test. Each equipment shall be exposed to random vibration and thermal cycling periods as depicted in Figure 1. Since the purpose of this test is to eliminate latent manufacturing defects, all defects detected during this test shall be recorded and repaired, but shall not count against the acceptance of the equipment.

5.2.2.1.1 Vibration. The equipment in an operating mode (power on) shall be exposed to one 5 minute burst of random vibration in the axis deemed most susceptible to vibratory excitation. Failures occurring during this five minute test shall be accrued (if possible) and corrected at the conclusion of the five minute period (See Appendix B). The random vibration spectrum shall be:

20-80 Hz at 3 dB/octave rise

80-350 Hz at $0.04g^2/Hz$

350-2000 Hz at 3 dB/octave rolloff

5.2.2.1.2 Thermal cycling. The equipment in an operating mode (power on) shall be subjected to a thermal cycling test for a period of 40 hours in accordance with the appropriate cycle depicted in Figure 3. The required number of thermal cycles may be interrupted for repair actions.

5.2.2.1.2 (Continued)

The thermal limits (high and low temperature extremes of chamber air) for cycling, shall be those values of temperature defined by the equipment specification:

Example 1 - using MIL-E-5400, Class 1 equipment is required to operate within the temperature range from -54°C to 55°C

Example 2 - using MIL-E-16400, equipment utilized in a sheltered controlled environment (ship or shore) the temperature range 0°C to +50°C

Vibration and thermal cycling tests are not to be applied concurrently, but shall be applied in the sequence defined in Figure 1, that is, vibration, then thermal cycling, and again vibration.

5.2.2.2 Defect-free (DF) test. After completion of the fixed duration pre defect-free test, each equipment shall undergo a defect-free test under the same environmental conditions as in the pre defect-free test. The equipment operating (power on) shall be subjected to 40 consecutive defect-free hours under thermal cycling conditions within an overall test period of 80 hours maximum. After completion of the 40-hour defect-free thermal cycling requirement, the equipment shall withstand 5 continuous minutes of random vibration without failure within a maximum test time of 15 minutes. An equipment which does not successfully complete the defect-free period within either allowable window shall not be submitted for ESS compliance and requires corrective action as described in 4.7.2 and 4.7.3 (see Appendix B).

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

6 NOTES AND CONCLUDING MATERIAL

6.1 Intended use. This standard is used to assure that contracted production electronic products equal or exceed the quality level of the qualified equipment.

6.2 Ordering data. Procurement documents should specify the following:

a. Title, number and date of this standard.
b. Application (see 1.2).
c. Classification (see 1.2).

6.3 Contractual responsibility considerations. The detailed test procedures for demonstrating a contractual requirements are used to show contractual compliance and, therefore, must receive the concurrence of the procuring activity. Otherwise, the requirements of the contract could be compromised without the knowledge of the procuring activity. Great care should be exercised in placing on contract the tasks which will generate the information required by many of the data item descriptions. The procuring activity must avoid telling the contractor how to accomplish the task of attaining the required results. For, if the contractor does all that he states he will do, and still fails the Environmental Stress Screening test, and the procuring activity has given formal approval of the manufacturing methods and the manner in which they were executed, then the procuring activity will have jeopardized its contractual position. Then the only recourse may be to accept the less-than-required results. As long as the procuring activity confines itself to performance requirements, and does not dictate the manufacturing method, the procuring activity is on firm contractual grounds.

Preparing activity:
NAVY EC
(Project RELI-N045)

APPENDIX A

ESS TEST DURATION, REDUCED TESTING AND SAMPLING

10. GENERAL

10.1 Scope. This appendix describes the approach, ground rules and assumptions used to optimize the times for pre defect-free (PDF) and subsequent defect-free (DF) testing under environmental conditions, and define ground rules and techniques for reduced testing and sampling.

10.2 Purpose. The purpose of this appendix is to present the background that led to the test times stipulated in the main body of the standard, and define statistical plans for reduced testing and sampling options.

20. APPLICABLE DOCUMENTS

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

30. ASSUMPTIONS

30.1 Environment 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 under test. 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}) test at a rate which will be constant, independent of the MTBF of the device.

30.2 Defect-free verification. The time on test after an environmental fixed duration exposure, is the defect free portion of the test (T_{DF}). The second test is designed to verify the assumption of 30.1, and any defects thereafter become inconsequential since they become part of the random life process.

40. ANALYSIS

40.1 Setting duration for pre defect-free (PDF) test. The minimum number of hours of cycles are defined by the environmental profile for the test, and shall be a given value independent of the complexity or inherent life of the device.

40.2 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 test, the time dimension will always be in hours of cycling.

40.3 Time on test derivation. Assuming that environmental factors are adequate and we are dealing with production units of known design integrity, the ESS test duration can be described by the classical failure rate ("bathtub") curve shown in Figure 40.3-1, 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.

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

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

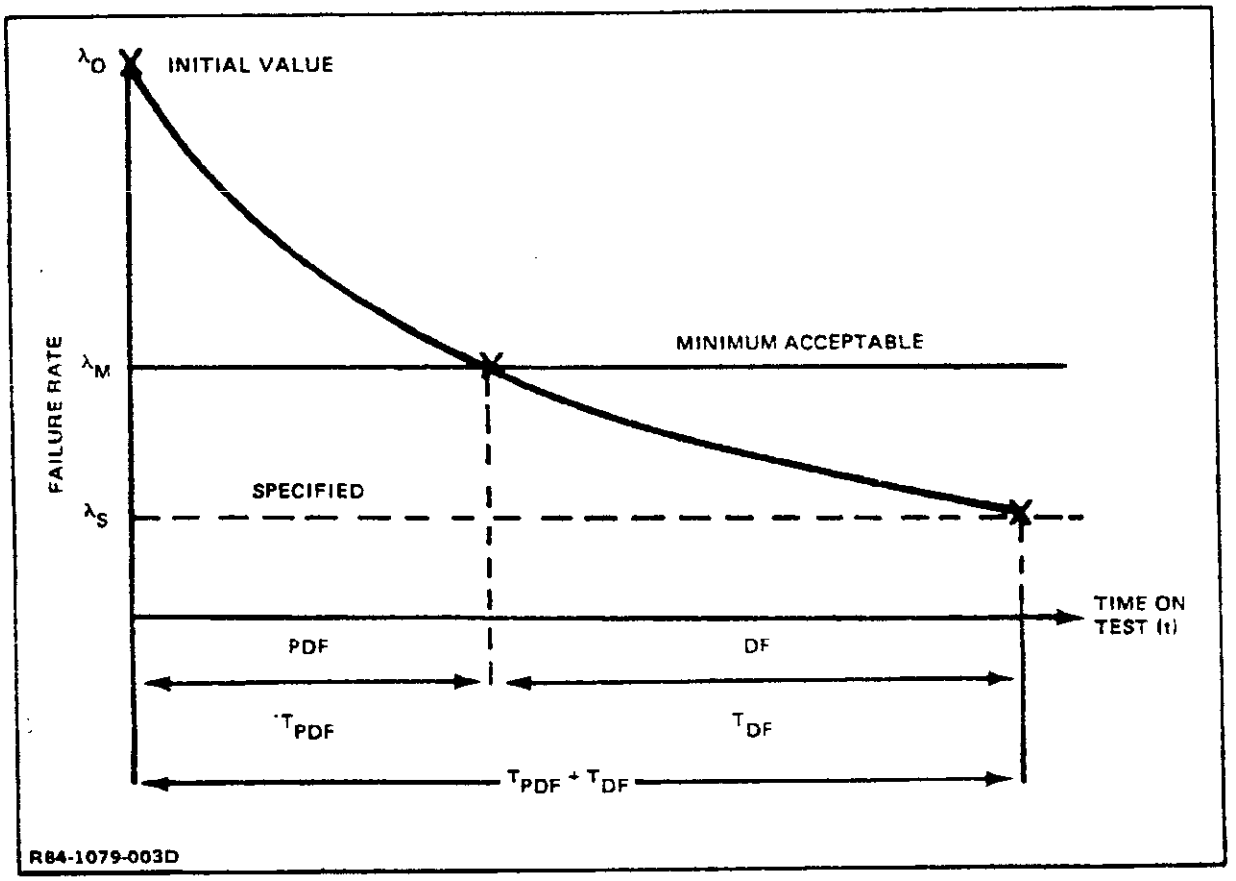


Figure 40.3-1 ESS Characteristic Curve

40.3 (Continued)

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

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

where:

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

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

$$T = T_B + F_F \quad \text{(ESS test duration)} \qquad (1C)$$

t = time on test.

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

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

Where P_A is the probability of a unit passing ESS testing 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 x T_{DF} reduces equation (2) to:

40.3 (Continued)

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

The object is to establish a defect free duration to give the seller a very high probability of passing the DF portion of the test in the order of $\geq$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 test 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

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

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

$$\lambda_0 = \frac{\lambda_M - \lambda_S}{\alpha} + \lambda_S \qquad (5)$$

40.3 (Continued)

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

$$\lambda_0 = \frac{\lambda_S\ (1 + \alpha)}{\alpha} \quad \text{or} \quad \theta_0 = \frac{(1 + \alpha)}{\theta_S\ \alpha} \tag{6}$$

Equation (3) can now be transformed to:

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

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.

40.4 Time on test criteria.

40.4.1 Test duration. The criteria for test 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 30.1 and 30.2, θ_0 for all cases will be relatively small and constant, and is estimated from equation (4) as $\theta_0 = 1$, when $T_{PDF} = T_{DF}$.

40.4.2 Probability of acceptance (P_A). The probability of acceptance for the DF portion of the test is set at $\geq$90% to ensure the seller 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 test objective is not to verify reliability.

40.4.3 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 40.4.1 and 40.4.2, as shown in Table 40.4-1.

Table 40.4-1

Values of P_A for Various α and $T_{PDF} = T_{DF}$

	$T_{PDF} = T_{DF}$ (Hours)		
α	30	40	50
1%	96%	95%	91%
2%	88%	81%	74%
3%	78%	68%	57%
4%	66%	55%	43%
5%	58%	43%	31%

40.5 PDF Time (T_{PDF}). From the environmental profile requirements, paragrah 5.2.1.1, the optimum number of hours of cycling for all devices will be on the order of T_{PDF} = 40 hours.

40.6 DF Time (T_{DF}). The defect free portion of the test, 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 40.6-1 which provides the probabilify of rejection due to random failure (P_F) over the DF period for various levels of MTBF (θ_S).

Table 40.6-1

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

θ_S (Hrs)	P_F
$\leq$ 25	> 50%
50	20%
200	2%
500	0.3%
>1000	0%

40.7 Test duration. The recommended test durations would be as follows for all units tested:

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

50. REDUCED TESTING AND SAMPLING

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

50.2 Test options. The options in a through c apply.

a. 100% testing. Each unit of product shall be submitted for ESS testing.

50.2 (Continued)

b. Sampling plans. Sampling plans, including selections and criteria for the samples, shall be in accordance with MIL-STD-1235. All plans shall have been approved by the procuring activity before being applied. In all cases, both the PDF and DF segments of the ESS test shall be defect free to satisfy the criteria for instituting a sampling plan. A single failure in either PDF or DF portion of the test shall be cause for rejection. Further, Acceptance Quality Levels (AQL's) for sample and test sequencing shall be 1.0% or less. Within this criteria, the Consumer's Risk and Producers Risk will be 10% or less.

c. Reduced DF accountability. In conjunction with options a or b, and with procuring activity approval, should all defects 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 shall be 40 continuous hours of defect-free testing within a maximum of 120 test hours. In order to satisfy option (b), no failure can occur during PDF, and the DF portion would be waived.

APPENDIX B

ESS TROUBLESHOOTING PLAN

10. GENERAL

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

10.2 Purpose. The purpose of this appendix is to assure that adequate planning is accomplished prior to ESS testing to minimize the environmental effects on the equipment under test during the pre defect-free and defect free periods.

20. TROUBLESHOOTING CONSIDERATIONS

20.1 Content. A detailed troubleshooting plan shall be formulated prior to the start of ESS testing. This plan may be a part of or a supplement to the test procedure required in 6.3. The plan shall be coordinated with the performance monitoring procedures, utilize BIT to the fullest extent possible, and take full advantage of all data resulting from performance monitoring, including trend data.

20.2 Considerations. In preparing the plan the following guidelines shall be considered.

20.2.1 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 tests on a module or a

subassembly while exposing it to an environment. The troubleshooting procedures shall address this possibility, not only in terms of powering, operating and monitoring the article, but also in terms of applying the required environment(s).

20.2.2 Monitoring. Equipment performance shall be monitored to the fullest extent practical during the application of environments. When a failure occurs which would mask other functions, the test shall be stopped and troubleshooting procedures shall be initiated to identify and correct the defective item.

20.2.3 Temperature cycling. If the failure is intermittent, the environmental stimuli at the time of the failure shall be noted and troubleshooting procedures relating to the environment shall be 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 shall be initiated while applying that thermal stress. If the specific failure 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 may be applied without affecting the equipment's useful life.

20.2.4 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 shall be exposed to the specified spectrum of random vibration at the lowest GRMS 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 shall be examined and a judgement made by the

20.2.4 (Continued)

contractor 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 test time, during diagnostic testing the vibration shall be reduced to the lowest feasible level. The total equivalent time for all acceptance and diagnostic vibration tests shall not exceed 20 minutes at the full ($0.04G^2Hz$) level. Equivalent test 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 (Grms)	PSD Level (G^2/Hz)	Equivalent Test Time (minutes)
6.0	0.04	20
5.2	0.03	47
4.24	0.02	160
3.0	0.01	1280

EXAMPLE:

Test	G^2/Hz Level	Allowable Exposure	Ratio of Allowable Exposure	Equivalent Test Time
Pre Defect-Free	.04	5 minutes	5/20 or 0.25	5.0 min
Defect-Free	.04	4 minutes	4/20 or 0.20	4.0 min
Diagnostic	.02	20 minutes	20/160 or 0.125	2.5 min
Diagnostic	.01	20 minutes	20/1280 or 0.016	0.31 min
Pre Defect-Free	.04	5 minutes	5/20 or 0.25	5.0 min
			Total = 0.841	16.81 min

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-STD-2164(EC)	

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR
b. ADDRESS *(Street, City, State, ZIP Code)*	☐ USER
	☐ MANUFACTURER
	☐ OTHER *(Specify)*: _____

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

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