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REVISION B

SPACE SHUTTLE

SPECIFICATION

ENVIRONMENTAL ACCEPTANCE TESTING

REVISION LOG

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FOR

SP-T-0023 - Space Shuttle
Specification
Environmental Acceptance Testing

CHANGE NO. 1

Program Requirements Control Board Directive No. S071024JE/(2-1), dated 2/22/02.(1)

March 15, 2002

Robert H. Heselmeyer
Secretary, Program Requirements
Control Board

CHANGE INSTRUCTIONS

1. Remove the following listed pages and replace with the same numbered attached pages:

Page	PRCBD No.
iii	S071024JE
iv	

   NOTE: A black bar in the margin indicates the information that was changed.

2. A white “index stock” back cover is being provided for your document in this change package. This back cover was omitted from the Baseline previously distributed.
3. Remove the List of Effective Pages, dated May 17, 2001 and replace with List of Effective Pages, dated March 15, 2002.
4. Sign and date this page in the space provided below to show that the changes have been incorporated and file immediately behind the List of Effective Pages.

_____ _____
Signature of person incorporating changes Date

SP-T-0023 - Space Shuttle
Specification
Environmental Acceptance Testing

LIST OF EFFECTIVE PAGES

March 15, 2002

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i - ii	Rev. C	S002130M	April 26, 2001
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iv - x	Rev. C	S002130M	April 26, 2001
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SPACE SHUTTLE

SPECIFICATION

ENVIRONMENTAL ACCEPTANCE TESTING

Approved by:

Ronald D. Dittemore
Manager, Space Shuttle Program

SP-T-0023
Revision C

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PREFACE

Efficient management of the Space Shuttle Program (SSP) dictates that effective control of program activities be established. Requirements, directives, procedures, interface agreements, and system capabilities shall be documented, baselined, and subsequently controlled by SSP management.

Program requirements controlled by the Manager, Space Shuttle Program, are documented in, attached to, or referenced from Volume I through XVIII of NSTS 07700.

This specification has been approved by the Space Shuttle Program Office and is available for use by NASA and associated contractors. The Space Shuttle Program Office, Safety and Mission Assurance is the Office of Primary Responsibility for this document.

All elements of the SSP must adhere to these baselined requirements. When it is considered by the Space Shuttle Program element/project managers to be in the best interest of the SSP to change, waive or deviate from these requirements, an SSP Change Request (CR) shall be submitted to the Program Requirements Control Board (PRCB) Secretary. The CR must include a complete description of the change, waiver or deviation and the rationale to justify its consideration. All such requests will be processed in accordance with NSTS 07700, Volume IV - Book 1 and dispositioned by the Manager, Space Shuttle Program, on a Space Shuttle PRCB Directive (PRCBD).

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1.0 INTRODUCTION

1.1 PURPOSE

This Environmental Acceptance Test Specification establishes the minimum test and documentation requirements to be met by NASA and its contractors in the environmental acceptance testing of hardware, both Government-furnished and contractor-furnished, for use in SSP applications.

1.2 SCOPE

This document specifies the overall requirements applicable to environmental acceptance testing conducted to detect manufacturing flaws and workmanship defects in flight hardware, flight-type test hardware, and selected ground support equipment that cannot be readily detected by normal inspection techniques. Section 2.0 specifies the criteria for the selection of hardware to be tested and the responsibility for hardware selection. Section 3.0 specifies the manner in which environmental acceptance testing is to be conducted. Section 4.0 details the extent to which environmental acceptance testing is applicable to qualification testing; and Section 5.0 specifies the general requirements, test procedures, and tolerances for acceptance vibration, thermal, and thermal/vacuum testing of flight hardware, flight-type test hardware and ground support equipment.

1.3 APPLICABILITY

Environmental acceptance test requirements are applicable to all flight hardware, flight-type test hardware, and ground support equipment for SSP applications selected in accordance with the criteria in Section 2.0 of this specification. The environmental acceptance testing on the selected level of assembly shall be accomplished after manufacturing and inspection is complete, and prior to the next assembly level or subsequent scheduled usage.

1.4 APPLICABLE DOCUMENTS

The following documents form a part of this specification to the extent specified herein:

1.4.1 Johnson Space Center

NHB 5300.4(ID-1)	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program

1.5 REVISIONS

Revisions to this Environmental Acceptance Test Specification will be published by the Space Shuttle Program when deemed appropriate.

1.6 DEFINITIONS

1.6.1 Qualification Testing

Qualification testing consists of those tests conducted to verify that flight hardware and associated ground support equipment meet design specification requirements necessary to assure operational suitability at anticipated environments for their use cycles.

1.6.2 Acceptance Testing

For the purpose of this document, acceptance testing consists of those tests conducted to determine that a component is capable of meeting performance requirements prescribed in the purchase specification or other documents specifying what constitutes adequate performance capability for the item in question.

1.6.3 Environmental Acceptance Testing

Environmental acceptance testing consists of production tests conducted for the purpose of acceptance under environmental rigors other than ambient. This testing compliments the Quality Assurance Program as a means of further verifying that hardware is adequate for flight and/or ground tests and is of a quality equal to the qualification article. For the purpose of this document, environmental acceptance testing will include only the three environments - vibration, thermal cycling, and thermal cycling in a vacuum.

1.6.4 Certification Testing

Certification testing consists of those tests normally considered as qualification tests plus specific additional tests of components, subsystems, and higher levels of assemblies required to certify that the hardware design is adequate for its intended mission. Certification testing does not generally include exploratory, design verification, development, prequalification, piece-part qualification, acceptance, or checkout tests except where such tests are specifically identified as required for certification.

1.6.5 Flight Hardware

This term describes all end items and components procured or provided by NASA which perform a specific function when flown as part of a manned or unmanned spacecraft mission.

1.6.6 Qualification Test Hardware

This term describes that hardware which is used for qualification testing and is identical in configuration and production processing to the flight hardware.

1.6.7 Component

This term describes a combination of parts, devices and structure, usually self-contained, which performs a distinctive function in the operation of the overall equipment. A component may sometimes be referred to as a “black box” (e.g., transmitter, encoder, cryogenic pump, star tracker).

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2.0 HARDWARE SELECTION

2.1 HARDWARE SELECTION CRITERIA

Each component or assembly for which a Certification Requirement is written shall be a candidate for environmental acceptance testing. Items shall be selected from this list of candidates for environmental acceptance testing by application of the following criteria.

a. Items shall be tested that cannot be effectively inspected during manufacture, or whose assembly involves processes and techniques not easily or effectively quality controlled; all electrical, electronic and electro-mechanical components shall be considered for environmental acceptance testing.

b. Items shall be tested which have delicate mechanical mechanisms requiring precise adjustments.

c. Mechanical items with close-tolerance mechanical mating and/or interfacing mechanisms which are not easily or effectively quality controlled using standard inspection procedures shall be tested.

d. Items that have marginal or questionable environmental sensitivity shall be tested. (Table 2-I lists the types of faults expected to be found by acceptance vibration tests. Table 2-II lists the types of faults expected to be exposed by acceptance thermal cycling and thermal cycling in a vacuum.)

e. Items for which additional confidence is desired through the elimination of infant mortality failures shall be tested.

WARNING

To avoid a potentially hazardous condition, items that normally include pyrotechnic devices shall be tested with dummy pyrotechnic devices, or using fuses in place of the pyrotechnic devices.

2.2 HARDWARE SELECTION RESPONSIBILITY

The prime contractor or government furnished equipment hardware supplier shall be responsible for the establishment of the candidate list of components for environmental acceptance testing. The prime contractor or government furnished equipment hardware supplier shall submit to NASA for review and approval a listing of the selected components. This may be accomplished as a part of the certification documentation.

TABLE 2-I

TYPES OF FAULTS EXPECTED TO BE EXPOSED BY ACCEPTANCE VIBRATION TESTING

Fault	Fault Mode	
	Mechanical	Electrical/ Mechanical
Loose electrical connections		X
Loose nuts, bolts, etc.	X	
Low-frequency relay contact chatter		X
Low–frequency switch contact chatter		X
Physical contaminants (loose foreign matter)	X	
Cold solder joints and solder voids		X
Incomplete weld joints		X
Close tolerance mechanisms		X
Improperly crimped connections		X
Wire defects such as strands cut away with insulation removal		X
Insufficient clearance resulting in impact of component parts	X	
Shrinkage of potting resulting in loose assembly within housing	X	
Potting too soft, allowing excessive movement of components and wiring	X	
Wire fatigue failure due to routing	X	
Loose or missing mounting hardware	X	
Excessive valve leakage or abnormal closure	X	
Defective piece parts	X	X

TABLE 2-II

TYPES OF FAULTS EXPOSED BY THERMAL CYCLING AND THERMAL/VACUUM CYCLING

Fault	Test Condition	
	Thermal Cycling	Thermal/Vacuum Cycling
Voids in potting	X	(X)
Short run wires	X	
Welded and soldered connections	X	
Corona leakage		X
Outgassing contaminants		X
Bimetallic effects of leaf spring	X	
Solder splash on printed circuits	X	(X)
Insulation penetration	X	X
Thermal grease application	X	(X)
Close tolerance mechanisms	X	(X)
Hermetically sealed components (environmental seals)		X
Thermal interface integrity		X
Thermal control paint		X
Improperly crimped wires	X	(X)
Poor solder and weld joints	(X)	X
Excessive periods of abnormal continuity	X	
Defective piece parts	X	X

NOTE: A parenthesis indicates the environment in which the characteristic is most sensitive.

2.3 NEW DESIGN OR REDESIGN SELECTION

Any new design or redesign for a program after the establishment of the environmental acceptance test program shall be reviewed for applicability to Paragraph 2.1. If the item is applicable to this selection criteria, it is to be added to the list of those receiving environmental acceptance testing.

2.4 EFFECTIVITY

Once a hardware type has been selected for environmental acceptance testing, 100 percent of the flight items, flight-type ground test items, and selected ground support equipment shall be tested, as well as the qualification unit(s).

3.0 TECHNICAL REQUIREMENTS

3.1 GENERAL

The environmental acceptance testing shall be conducted at the highest practical level of assembly (as defined in Section 3.3) consistent with good practice, and within the requirements of this specification. An acceptance test specification shall be prepared for hardware selected for environmental acceptance testing. It shall define the limits and methods for each test, including any deviations from the specified test methods, limits, sequence, etc., reflected herein, and shall be submitted to the procuring authority for approval. Acceptance test procedures shall be prepared based on the acceptance test specification and submitted to the procuring authority for review and retention.

3.2 TESTING DISCIPLINES

3.2.1 Environmental Exposure

Environmental acceptance testing normally shall include environmental exposures, or combinations of environmental exposures, as required to expose faults expected, as defined in Tables 2-I and 2-II. Both acceptance thermal and acceptance thermal/vacuum testing need not be performed on a particular item; the type selected shall be the one most appropriate for detecting the expected type(s) of flaw(s) in the particular component.

3.2.2 Test Limits

The severity, duration, and number of tests shall not overstress or degrade the hardware, nor reduce its ability to perform its intended mission.

3.2.3 Operational Modes

All normal, alternate, redundant, and emergency operational modes shall be functioned where possible.

3.2.4 Hardware Condition Prior to Test

The hardware shall be calibrated, aligned, and shall have performed properly in functional tests prior to conducting acceptance tests.

3.2.5 Control of Test Conditions

Acceptance tests shall be performed under conditions in which environment and test procedures are strictly controlled. Adjustment or tuning of hardware is not permitted

during acceptance testing unless it is normal to in-service operation. Repair and retest is permitted if the total environmental acceptance test exposure time does not exceed that specified for that part of the qualification test time designed to simulate acceptance test and provide margin demonstration as defined in Section 4.0. A failure is defined as the inability of the test article to perform its required function, within specified limits, under the conditions and for the duration required in the acceptance test specifications. A test procedure deviation sheet shall be utilized to document any procedural changes encountered during performance of the formal test procedure. If, during testing, the hardware is adjusted or tuned in a manner that is not normal to in-service operation, the test article shall be considered to have failed.

3.2.6 Retest Limit

The limit established for retest shall be such that the maximum permitted accumulation of environmental acceptance test exposure time does not exceed that part of the qualification test time designed to simulate acceptance test and provide margin demonstration.

3.2.7 Retest Requirements

If any repairs, modifications, or replacements are made after completion of environmental acceptance testing, the retest requirement shall be established on a case-by-case basis. When only a partial retest is required to assure the acceptability of the change, the proposed degree of retest shall be submitted to the procuring authority for approval.

3.3 HARDWARE ASSEMBLY LEVEL

An assembly level shall be selected in which the construction is such that its dynamic transfer function causes minimum magnification or damping of the input to internal parts. The following shall also be considered in selecting the hardware level of assembly for environmental acceptance testing:

a. Ability of the selected assembly level to be operated and monitored during environmental acceptance testing (black box level).

b. Assembly level of replaceable spares.

3.4 TEST LEVELS AND DURATIONS

3.4.1 Acceptance Vibration Test

3.4.1.1 Levels

Acceptance vibration tests shall be conducted to levels as severe as possible within the boundaries specified in the following paragraphs.

a. Minimum acceptance vibration test levels - The acceptance vibration test levels and test spectrum defined by Figure 1 shall be the minimum test criteria.

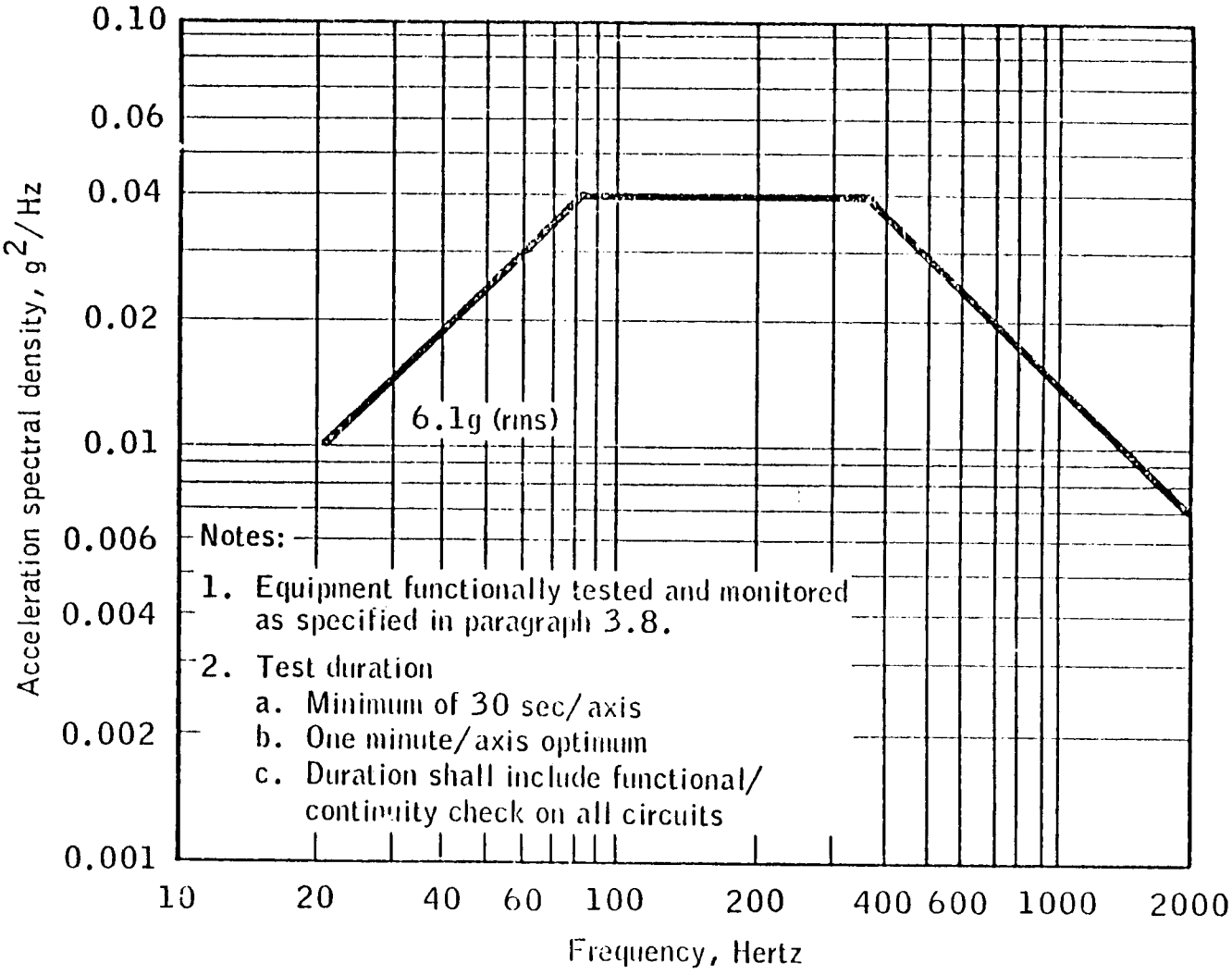
b. Maximum acceptance vibration test levels - Components which have an expected mission level greater than the minimum level, as defined by Figure 1, shall be tested to the greater of the two following levels:

   1. Minimum acceptance acceleration spectral density levels defined by Figure 1,

   2. Acceptance acceleration spectral density levels equal to 1/1.69 times the qualification test levels.

FIGURE 1

MINIMUM ACCEPTANCE VIBRATION TEST SPECTRUM



3.4.1.2 Duration

The acceptance vibration test duration shall be a minimum of 30 seconds per axis. One minute per axis is considered optimum; however, the time shall be sufficient to allow a functional/continuity check on all circuits during the acceptance vibration test, according to Paragraph 3.8.

3.4.1.3 Allowable Level Deviation

The acceptance test spectrum may be adjusted in the hardware resonant frequency zone(s) to the extent necessary to reduce the component resultant level to the desired acceptance test level(s). Such adjustments shall be included in the test specification; or submitted to the procuring authority for approval as a deviation to the specification.

3.4.2 Acceptance Thermal Test

3.4.2.1 Temperature Levels

Acceptance thermal tests shall be conducted to levels as severe as possible within the boundaries specified in the following paragraphs.

a. Minimum acceptance thermal test levels - The acceptance thermal test control temperature range shall be a minimum of a 100° F temperature sweep, and tests shall be performed in accordance with the minimum test criteria defined by Figure 2.

b. Maximum acceptance thermal test levels - Components which have expected mission levels greater than a 100° F temperature sweep shall be tested to the greater of the two following levels:

    1. Minimum acceptance test thermal levels (100° F temperature sweep) as defined by Figure 2, or

    2. Acceptance thermal test levels equal to the temperature sweep resulting from the range limits of 20° F lower than the maximum and 20° F higher than the minimum qualification levels.

    The lower temperature limit should be below freezing (30° F) wherever possible. The initial temperature excursion should be in the direction of the expected flight operating temperature of the equipment (hot or cold) so that the specified temperature extreme is achieved at least twice.

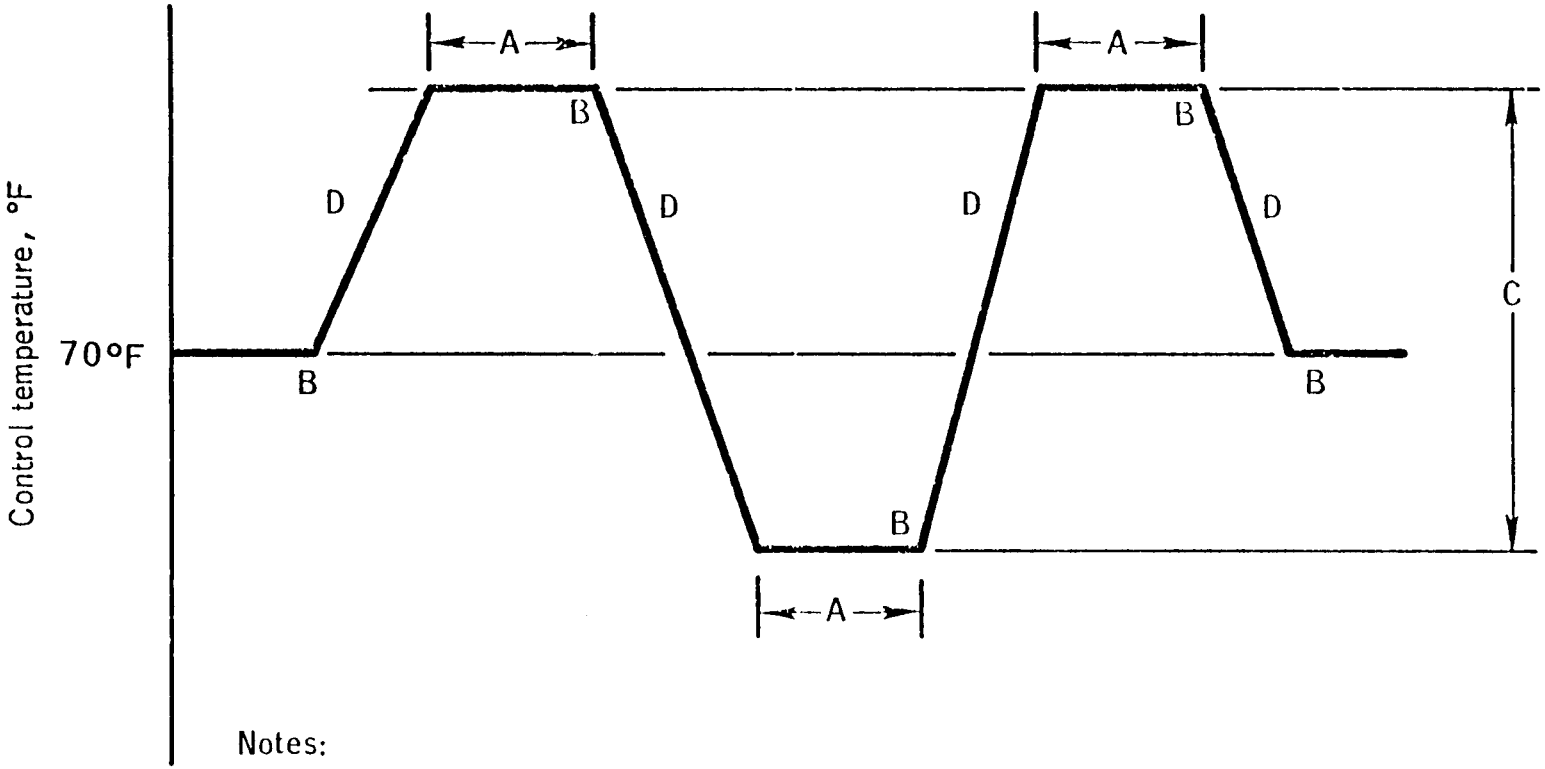
3.4.2.2 Duration

The acceptance thermal test duration shall allow a minimum of one and one-half temperature cycles, stabilized at extremes for one hour and allowing a functional/continuity

check on all circuits at the temperature extremes as well as during the temperature transition. The optimum number of temperature cycles shall be established on a case-by-case basis for each hardware type selected for environmental acceptance testing.

FIGURE 2

MINIMUM ACCEPTANCE THERMAL TEST SPECTRUM



Notes:

1. A = Time to stabilize equipment temperature plus 1-hour minimum.
2. B = Functional tests to be performed as shown and per paragraph 3.8.
3. C = Control temperature range between high and low acceptance test conditions shall be a minimum of $100^{0}F$.
4. D = Functional/continuity check of equipment during temperature transition.

3.4.3 Acceptance Thermal/Vacuum Test

3.4.3.1 Temperature and Vacuum Levels

The acceptance thermal/vacuum test temperature levels shall be the same as those specified in Paragraph 3.4.2.1. The acceptance thermal/vacuum test vacuum level shall be a pressure of 10^{-5} torr or less.

3.4.3.2 Duration

The acceptance thermal/vacuum test duration shall be the same as that specified in Paragraph 3.4.2.2.

3.4.3.3 Allowable Vacuum Level Deviation

Should the atmospheric conditions at the time of test be such that the evacuation equipment cannot evacuate the chamber to 10^{-5} torr, and several additional hours are required to evacuate the chamber from 10^{-4} to 10^{-5} torr, the testing may be initiated at 10^{-4} torr while the chamber evacuation is continued.

NOTE

Equipment should not be operated in a pressure regime that could cause corona discharge unless the equipment would be required to operate in this pressure regime during its mission cycle.

3.5 APPLICABILITY TO QUALIFICATION TESTING

Qualification testing shall verify the acceptance vibration, thermal, and thermal/vacuum test levels in accordance with Sections 4.0 and 5.0 of this specification.

3.6 TEST PROCEDURES

The procedure shall contain as a minimum:

a. Hardware/component identification.

b. Test levels and durations.

c. Monitoring requirements.

   1. Identification of circuits to be functionally checked.

   2. Identification of circuits to be checked for continuity.

d. Data requirements.

   1. Recording methods.

   2. Measurement limits.

3. Sensitivity.

4. Accuracy.

5. Simultaneous measurement requirements.

6. Failure reporting.

7. Data processing procedures.

e. Performance pass/fail criteria.

3.7 ENVIRONMENTAL ACCEPTANCE TEST PERFORMANCE

The environmental acceptance testing shall be conducted in accordance with the applicable test requirements, procedures, and tolerances specified in Section 5.0 of this specification.

3.8 MONITORING

Functional/continuity tests shall be conducted on all components before, during (while equipment is being vibrated and during temperature transition), and after the acceptance vibration test, acceptance thermal test, and/or acceptance thermal/vacuum test. If complete functional verification is impossible during the acceptance test because of limited test time, then those functions that are critical to crew safety and/or mission success shall have priority. (The crew safety functions have a higher priority than mission success functions.) All circuits associated with other functions shall be monitored for continuity during the test.

3.9 WITNESSING

All environmental acceptance tests, the test setup, and instrument calibrations shall be witnessed and verified by Government and/or contractor quality control personnel.

3.10 PROBLEM REPORTING AND CORRECTIVE ACTION

The contractor shall provide a closed-loop system for reporting all problems (failures and unsatisfactory conditions) and establishing corrective action for all problems concerning:

a. Flight hardware

b. Test hardware

c. Simulator hardware

d. Training hardware (where representative of flight hardware)

e. Ground support equipment

f. Applicable Government-furnished equipment

g. Spare hardware

The contractor shall be responsible for ensuring that problem reporting and corrective action systems of suppliers meet the requirements of this section.

3.10.1 Problem Reporting

Reporting of problems shall be in accordance with the applicable reliability plans (Information Requirement List/Information Requirement Description).

3.10.2 Problem Analysis

An analysis of each problem reported to NASA shall be performed to determine the cause of the problem and to implement adequate measures to prevent its recurrence. Primary emphasis shall be placed on hardware teardown analysis; however, where the cause of the problem is understood or where sufficient prior analysis experience has been obtained, additional hardware teardown for analysis may not be required.

3.10.3 Problem Resolution

The contractor shall resolve each problem by one of two methods: closeout or explanation. The contractor shall direct all efforts toward closing a problem in lieu of an explanation, and in no case shall the contractor attempt to “explain” a problem until it becomes impracticable to close the problem.

3.10.4 Problem Status

The contractor shall maintain the status of all open problems. The method(s) employed by the contractor in maintaining the status of problems shall be compatible with the contractor’s needs as well as those of NASA in responding to requests for information. The contractor shall submit to NASA a listing of all open problems in accordance with the applicable Information Requirement List/Information Requirement Description.

3.11 TEST DATA SHEETS

3.11.1 Content

Test data sheets shall provide evidence of the inspection and test performed, and shall be available for review by designated Government representatives. Test data sheets

shall be prepared in suitable format; they shall be accurate and complete, and shall include the following:

a. Identification of equipment or item tested.

b. Test Level and duration imposed.

c. Analysis of malfunction and failures.

d. Identification of inspection and test equipment.

e. Verification of total test configuration and software.

3.11.2 Disposition

A copy of the data sheets for all the acceptance tests shall accompany the particular end item whether the tests were conducted at the contractor's or subcontractor's facility.

3.12 RETEST

In the event that a failure occurs during or as a result of an acceptance test, the failure shall be reported in accordance with Paragraph 3.10. All component failures occurring during or as a result of environmental acceptance testing that are repairable shall be repaired and the unit shall be completely retested. The contractor shall not grant waivers to a subcontractor for the requirements for acceptance tests, nor shall hardware be accepted without the required acceptance tests unless a waiver has been granted by the procuring authority. In no case shall the cumulative acceptance test time, plus the expected mission time, exceed the qualification test time for a given environment.

4.0 APPLICABILITY OF ENVIRONMENTAL ACCEPTANCE TEST REQUIREMENTS TO QUALIFICATION TESTING

4.1 GENERAL

To find manufacturing and workmanship errors, the environmental acceptance test environments must be sufficiently severe to find faults, but not so severe as to weaken or fatigue a component to the point of reducing its useful life. To provide the necessary confidence that flight hardware, flight-type ground test hardware and/or ground support hardware quality has not been degraded by environmental acceptance testing to the point where the useful life of an item is reduced, the qualification unit shall be subjected to tests having adequate safety margins, with vibration test levels greater than the acceptance vibration test levels, and the thermal test levels greater than and less than the acceptance thermal test levels. These qualification tests to simulate the acceptance test durations shall allow for accumulated acceptance test time plus the anticipated flight functional time.

4.2 GENERAL REQUIREMENTS

4.2.1 Verification of Environmental Acceptance Test Limits

The Qualification Program shall include the necessary testing to verify that the environmental acceptance testing (acceptance vibration test, acceptance thermal test, and/or acceptance thermal/vacuum test) performed on a hardware item selected according to the criteria in Section 2.0 will not reduce the useful life of the item.

4.2.2 Test Duration Margins

The qualification test duration margins (refer to Section 4.5) shall be sufficient to allow flight hardware, flight-type ground test hardware, and/or ground support hardware to be retested without reducing the quality requirements of the hardware for flight.

4.3 ACCEPTANCE TESTING OF QUALIFICATION UNIT

The acceptance tests performed on a qualification unit prior to its being subjected to the Qualification Program shall include the environments, levels, and durations established in Section 3.0 of this specification. These acceptance tests shall be identical to the acceptance tests performed on all flight hardware, flight-type ground test hardware, and ground support hardware. The qualification unit is not considered acceptable for the Qualification Program until it has successfully completed all normal acceptance requirements to be imposed on the flight units and ground support hardware.

4.4 REQUIREMENTS FOR VERIFICATION OF ENVIRONMENTAL ACCEPTANCE TESTS

The requirements which apply to the test specimen, simulated environments, passed/failed criteria and requalification testing shall be the same as those for the normal Qualification Program.

4.5 TEST LEVELS AND DURATIONS FOR VERIFICATION OF ENVIRONMENTAL ACCEPTANCE TESTS

4.5.1 Vibration Test

The minimum qualification testing required to verify the ability of the hardware to withstand the acceptance vibration test levels is defined as 1.69 times the acceptance acceleration spectral density (g^2/Hz) test level (which is also 1.3 times the root-mean-square level). The spectrum shape shall be the same as that of the acceptance test. The duration of the qualification testing to verify the ability of the hardware to withstand the acceptance vibration shall include the refurbishment acceptance vibration requirements, if any, and/or up to 5 times the normal acceptance test duration to allow for retest. The testing shall be monitored in accordance with Paragraph 4.6.

4.5.2 Thermal Test

The minimum qualification testing required to verify the ability of the hardware to withstand the acceptance thermal test levels is defined to be 20° F above, and 20° F below, the temperature range of the acceptance test. The duration for the qualification testing to verify the ability of the hardware to withstand the acceptance thermal test shall include the refurbishment acceptance thermal requirements, if any, and/or up to 5 times the normal acceptance test duration to allow for retest. The testing shall be monitored in accordance with Paragraph 4.6.

4.5.3 Thermal/Vacuum Test

The minimum temperature levels and duration of the qualification test to verify the acceptance thermal/vacuum test shall be the same as specified for the thermal test in Paragraph 4.5.2. The qualification test shall be conducted in a minimum vacuum of 10^{-5} torr.

4.6 MONITORING

Functional/continuity tests shall be conducted on all components before, during (while equipment is being vibrated and during temperature transition), and after the testing described in Paragraphs 4.5.1, 4.5.2 and/or 4.5.3. If complete functional verification is impossible during the qualification test because of limited test time, then those functions critical to crew safety and/or mission success shall have priority (the crew safety functions take a higher priority than mission success functions). All circuits associated with other functions shall be monitored for continuity during the test.

4.7 WITNESSING

The qualification for environmental acceptance tests shall be witnessed by Government and contractor quality control personnel. The surveillance of the test shall be in accordance with NHB 5300.4(ID-1).

5.0 TEST REQUIREMENTS, PROCEDURES, TOLERANCES, AND SUCCESS/FAILURE CRITERIA

5.1 GENERAL

This section contains general requirements, test procedures, and tolerances for qualification and acceptance of all spacecraft and experiment hardware which requires acceptance vibration, thermal, and thermal/vacuum testing.

5.2 VIBRATION TEST

The qualification and acceptance test procedures and tolerances contained in this section shall be used when vibration tests are specified for spacecraft and experiment hardware.

5.2.1 Test Requirements

5.2.1.1 Test Fixture

The test fixture shall be designed to minimize fixture resonances in the test frequency range up to 2000 Hz. For complex fixtures, cast or welded methods of construction are preferred over bolted construction. The fixture shall be designed to minimize eccentric loading on the shaker and also to minimize fixture overhang. Multi-axis fixtures are usually not acceptable for large specimens since excessive fixture resonances can be eliminated or minimized by the fabrication of a separate fixture of reduced size for each axis.

5.2.1.2 Dynamic Similarity (Acceptance, and Qualification Verification of Acceptance Vibration)

The test article shall be supported in a test fixture in a manner which allows for a hard-mount installation to assure that the acceptance vibration level is achieved on the test article and not necessarily at the interface between the test fixture and the excitation equipment, or the interface between the test fixture and the test article.

5.2.1.3 Test Axis

Testing shall be conducted in three mutually perpendicular axes. The axes orientation shall be defined in the environmental acceptance test specification for the hardware item.

5.2.1.4 Test Conditions

All measurements and tests shall be conducted at room ambient temperature, atmospheric pressure, and relative humidity.

5.2.1.5 Control Accelerometer System

The vibration input shall be measured and controlled at one or more points in each axis by accelerometers located on the test fixture as near as possible to the specimen/ fixture interface. The use of two control accelerometers, one with a wider range setting, is required to provide test data in cases of testing anomalies.

a. The accelerometer shall be attached to the test fixture by bolts, studs, or non-elastic cement, with the sensing axis parallel to the direction of excitation. Orthogonal sensing accelerometers shall be provided in addition to the prime axis sensing accelerometer to detect cross-coupled acceleration and prevent confusion in failure assessment.

b. The dynamic transfer function between the control accelerometer and the specimen/fixture interface at frequencies in the test frequency range shall be as close to 1.0 as possible. If the test specimen/fixture interface has multiple attachment points and, if the fixture has resonances in the test frequency range, then a fixture survey shall be conducted. This fixture survey shall determine the best control locations for accelerometers and whether multiple-input control is necessary.

c. The output of all accelerometers shall be continuously recorded throughout all vibration tests in a form capable of being reproduced and analyzed in order to verify that the correct vibration levels were induced.

d. Photographs or sketches showing the accelerometer locations and recordings of the vibration input acceleration spectral density versus frequency shall be included in the test report.

e. The control accelerometer system shall be calibrated against a standard accelerometer which is no more than two steps removed from the reference standard located at the National Bureau of Standards in Washington, D. C. The control accelerometer system shall have been calibrated against the standard in accordance with standard recall cycle.

f. The control accelerometer shall have no adverse operating characteristics when operating in other environmental extremes such as temperature, pressure, and humidity. The accelerometer manufacturer’s recommended environmental operating ranges shall not be exceeded.

g. Prior to each test or each time the control accelerometer system electronics are altered (other than for the normal sinusoidal-to-random calibration verification using optical techniques), the verification may be accomplished using optical magnification measuring instruments or an optical wedge of the type commonly

found in vibration laboratories. If the optical verification sensitivity differs from the normal shaker readout sensitivity by more than ±10 percent, the control accelerometer system shall be analyzed to determine the cause of the difference and corrective action shall be taken. The optical verification shall be repeated after corrections are made. The optical technique should be performed with the test specimen detached from the shake table. If this is not feasible, the displacement during the wedge check shall not exceed one-half the displacement specified for a sinusoidal qualification at the selected frequency. If a sinusoidal qualification is not specified, then the specimen must be removed during the wedge check.

h. In using the optical wedge method, it is essential that the frequency be measured to the nearest 0.1 Hz on a frequency counting device. Also, the optical wedge must be precise in its measurement. Greater accuracy will be possible at larger displacements (0.2- to 0.4-inch double amplitude). In no case shall the verification frequency be less than 20 Hz, and the displacement shall not be less than 0.1-inch double amplitude.

5.2.2 Test Procedures

5.2.2.1 Equalization Procedures

The vibration system (vibrator, test fixture, and test specimen) shall be equalized in each test axis to obtain the specified vibration spectrum shape. The equalization technique (manual, automatic, closed-loop, specimen removed, etc.) shall be at the discretion of the vibration test engineer, except that the following constraints shall apply for acceptance testing:

a. The vibration control accelerometer signal and any response accelerometer signals shall be recorded (and identified by voice annotation) on magnetic tape whenever the hardware to be acceptance or qualification tested is mounted to the shaker and power is applied to the shaker system. System calibration information sufficient to allow analysis of the vibration signals subsequent to the test shall also be recorded on the magnetic tape and any other applicable documentation. The magnetic tapes shall be maintained as part of the vibration test records until final test report approval by the buyer. The vibration control accelerometer shall be located immediately adjacent to the test specimen mounting point to ensure that the specified vibration is being applied to the test specimen.

b. For random vibration testing, a dynamically similar dummy may be used in place of the test specimen, when possible, for pretest equalizations. The final

equalization prior to the test shall be accomplished using the test specimen and shall be conducted at the full specified random vibration level. The time expended during the final equalization shall be counted as part of the required test time for the random vibration test. The final equalization shall be verified by a narrow-band analysis in accordance with Paragraph 5.2.2.2 prior to initiation of the test.

c. Equalization during qualification testing shall be held to the minimum required to perform a rigorous test. Full-level equalization runs which are proven to be within tolerance, or out of tolerance on the positive side, shall be considered part of the specified test time for that axis. Equalization runs which are out of tolerance on the negative side shall not be considered part of the specified test time.

5.2.2.2 Verification of the Test Spectra

The test spectra shall be verified by narrow-band spectral analyses by an analysis system that is independent from the analyzer/equalizer used to control the test. (The tolerances specified in Paragraph 5.2.3.1 and 5.2.3.2 apply, as appropriate, to these spectra verifications.) In addition, the overall root-mean-square acceleration shall be monitored continuously throughout the test. The output of the control accelerometer system used to establish the test spectra and to determine the overall root-mean-square acceleration shall be recorded. The spectral analyses and the overall root-mean-square acceleration shall be included as part of final test report.

5.2.3 Test Tolerances

5.2.3.1 Acceptance Test

The following test tolerances shall apply for parameters associated with acceptance vibration tests.

a. The tolerances on acceleration spectral density shall vary with analyzer filter bandwidth. The desired analysis system should provide more than 100 statistical degrees of freedom; however, in no case shall the analysis system provide less 50 degrees of freedom. Tolerances on acceleration spectral density are as follows:

Spectrum frequency band, Hz	Normal filter bandwidth, Hz	Tolerances, dB
20-100	10 or less	1.0 -3.0
100-350	25 or less	1.0 -3.0
350-2000	50 or less	1.0 -3.0
20-100	5 or less	1.0 -4.5
100-350	10 or less	1.0 -4.5
350-2000	25 or less	1.0 -4.5

NOTE: Normal filter bandwidths are the difference in frequency as determined at the half-power points.

b. Exceptions to the preceding acceleration spectral density tolerances in the frequency range of 200 Hz to 2000 Hz are permitted according to the following criteria which shall be used for approval of random vibration acceptance tests.

1. The total number of allowable peaks and valleys is not to exceed four in any combination which complies with the criteria below.

2. Peaks which exceed the upper tolerance limit are acceptable if there are not more than three, the tolerance limit is not exceeded by more than +1.5 dB, and the peak width at the 1/2-power point is less than 5 percent of the center frequency of the peak.

3. Valleys which extend below the lower tolerance limit are acceptable if there are no more than three, the tolerance limit is not exceeded by more than -3 dB, and the valley width at 50 percent of the valley depth is less than 5 percent of the center frequency of the valley.

c. The tolerance on overall root-mean-square acceleration shall be ± 10 percent as measured by a true rms voltmeter with a 200-Hz cutoff filter of at least 12 dB per octave.

d. The tolerance on frequency shall be ± 10 percent.

e. The tolerance on test duration shall be +10 percent, -0.

5.2.3.2 Qualification Test

The following test tolerances shall apply for parameters associated with qualification tests.

a. The tolerances on acceleration spectral density shall vary with analyzer filter bandwidth. It is desirable that the analysis system provide more than 100 statistical degrees of freedom; however, the analysis system should never provide less than 50 degrees of freedom. Tolerances on acceleration spectral density are as follows:

Spectrum frequency band, Hz	Normal filter bandwidth, Hz	Tolerances, dB
10-100	10 or less	3.0 -1.0
100-350	25 or less	3.0 -1.0
350-2000	50 or less	3.0 -1.0
10-100	5 or less	4.5 -1.0
100-350	10 or less	4.5 -1.0
350-2000	25 or less	4.5 -1.0

NOTE: Normal filter bandwidths are the difference in frequency as determined at the half-power points.

b. Exceptions to the above acceleration spectral density tolerances in the frequency range of 200 Hz to 2000 Hz are permitted according to the following criteria which shall be used for approval of random vibration certification tests:

1. The total number of allowable peaks and valleys is not to exceed four in any combination which complies with the criteria below.

2. Peaks which exceed the upper tolerance limit are acceptable if there are no more than three, the tolerance limit is not exceeded by more than +3 dB, and the peak width at the 1/2-power point is less than 5 percent of the center frequency of the peak.

3. Valleys which extend below the lower tolerance limit are acceptable if there are no more than three, the tolerance limit is not exceeded by more than

-3 dB, and the valley width at 50 percent of the valley depth is less than 5 percent of the center frequency of the valley.

c. The tolerance on overall root-mean-square acceleration shall be +15 percent and -5 percent measured by a true rms voltmeter with a 2000-Hz cutoff filter of at least 12 dB per octave.

d. The tolerance on frequency shall be ±10 percent.

e. The tolerance on test duration shall be +10 percent, -0.

5.2.4 Success/Failure Criteria

The test article shall operate satisfactorily as defined in the design or procurement specification throughout the entire test and in the post-vibration functional test. Where the test vibration levels exceed the design flight environments, the test articles with out-of-tolerance performance at the peak vibration level may be subsequently checked at the design flight vibration levels. If satisfactory performance at the design flight levels is achieved, the article may be considered acceptable. However, the anomaly shall be reported, the cause of the anomaly determined, and substantiation provided that the anomaly was not caused by a defect in the test article.

5.3 THERMAL AND THERMAL/VACUUM TEST

The qualification and acceptance test procedures and tolerances contained in this section shall be used when acceptance thermal and/or thermal/vacuum tests are specified for spacecraft and experiment hardware. The vacuum portion of the thermal/vacuum tests shall meet the requirements of Paragraph 3.4.3, and the thermal portion shall meet the requirements of this section.

5.3.1 Definitions and Test Requirements

5.3.1.1 Control Temperature

The control temperature is defined as that temperature which is monitored during the test and used to control the heat exchange with the test article. The control temperature sensor location depends on the method of heat exchange used in the test.

a. For radiation-cooled equipment to be tested in a vacuum, the control temperature sensor shall be centrally located on the test article surface but not between the test article and the heat exchanger or between the test article and the mounting fixture. For ambient pressure tests with forced convective heat exchange, the control temperature sensor shall be mounted within 3 inches of

the test article or directly on the test article, but not between the test article and the heat exchanger.

b. For coldplate-cooled equipment, the coldplate-controlled temperatures shall be measured at the coolant inlet to the coldplate. Where the equipment mounting and coldplate configuration cannot thermally simulate the flight vehicle configuration, the temperature at the mounting flange root may be used as the control temperature. When using flange root temperature, the temperature limits shall be adjusted to account for the difference in temperature between the coolant and flange.

5.3.1.2 Stabilizing Temperature

The stabilizing temperature, which may be different than the control temperature, is defined as the temperature of the largest centrally located thermal mass of the test article. Stabilization is achieved when the temperature at this point does not change more than 3° F per hour. When instrumentation to ascertain temperature stabilization is not practical, the soak time for stabilization shall be specified in the test procedure.

5.3.2 Test Procedures

The test article shall be placed in the test chamber in such a manner that the heat is transferred in the correct mode. Equipment which is not coldplate-mounted shall be supported in the test chamber so that heat flow in the holding fixture is negligible compared to the required heat-transfer mode. Coldplate-cooled equipment shall be mounted in a configuration identical to that of the flight hardware, and the coldplate shall thermally simulate the flight coldplate.

5.3.2.1 Functional Tests

Complete functional/continuity tests at ambient conditions shall be performed both before and after the thermal test. Functional testing during thermal cycling shall be in accordance with Paragraph 5.3.2.2f.

5.3.2.2 Thermal Cycling

The thermal cycling shall be performed as defined in the following paragraphs.

a. The temperature cycle during the acceptance thermal test shall approximate the curve shown in Figure 2 where the temperature is the “control temperature” defined in Paragraph 5.3.1.1. Where the surrounding environment deviates significantly from the coolant temperature for coldplate-mounted equipment, both the surrounding temperature (not on the equipment) and the coolant temperatures shall be used for temperature control. For coldplate-mounted

equipment, the coolant temperature shall cycle, in phase with the surrounding temperature, to the coolant allowable temperature limits.

b. The initial temperature excursion may be in the direction of the equipment's nominal operating temperature (hot or cold) so that the specified temperature extreme is achieved at least twice as shown in Figure 2.

c. The rate of temperature change during transient phases shall be the predicted maximum rate during flight or it shall be within a range which does not exceed 4° F per minute, nor be less than 1° F per minute. An acceptable deviation is permissible if the qualification test has substantiated the capability of the equipment to operate at a higher rate.

d. Equipment shall be operated continuously during the entire test cycle, except where this would result in excessive operation of life-limited equipment or when temperature limits would be exceeded. Life-limited circuits or equipment may remain nonoperative during transient and stabilization phases, and operated only during the functional tests.

e. Equipment shall be monitored continuously during the entire test cycle for circuit continuity.

f. A complete functional test shall be performed at least once at each temperature extreme after the temperature has stabilized. If only one complete functional test is to be performed at the temperature extreme occurring twice, the functional test shall be performed during the last cycle of that temperature extreme. In the event that the article has two or more modes of operation, all combinations of temperature and modes of operation shall be selected during the test. The changing of operating modes during the test shall be programmed so that the total test duration is not increased because of operation in more than one mode. If the complete functional test for complex test articles would result in excessive test time, abbreviated functional test of critical circuits may be performed with the following constraints.

    1. The abbreviated functional test shall include all operations affecting crew safety.

    2. Selection of other operations to be included in the abbreviated functional test shall be based on descending order of mission criticality.

5.3.3 Test Tolerances

The actual control temperatures at the extreme temperature levels shall be within 5° F of the specified levels. In no case shall the control temperature exceed the maximum

nor be less than the minimum equivalent qualification test temperature. The average temperature during the soak periods shall be 20° F below the maximum and 20° F above the minimum qualification temperatures. The average rate of temperature change between successive temperature levels shall be within ±20 percent (but not more than ±10° F) of the specified rate per hour. The instantaneous rate of change shall not exceed the specified rate by more than 40 percent. The actual average and instantaneous rates shall not exceed the temperature change rates in the qualification test.

5.3.4 Success/Failure Criteria

The test article shall operate satisfactorily as defined in the design or procurement specification throughout the entire test and in the post-thermal functional test. Where the test temperature limits exceed the design flight environment, test articles with out-of-tolerance performance at the temperature extremes may be subsequently checked at the design flight temperature limits. If satisfactory performance at the design flight temperature limits is achieved, the article may be considered acceptable. However, the anomaly shall be reported, the cause of the anomaly determined, and substantiation provided that the anomaly is not caused by a defect in the test article.