National Aeronautics and
Space Administration

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CONSTELLATION PROGRAM ENVIRONMENTAL QUALIFICATION AND ACCEPTANCE TESTING REQUIREMENTS (CEQATR)

REVISION AND HISTORY PAGE

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-		Baseline (Reference CxCBD C000095/1-1, dated 12/14/06)	12/19/06
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1.0 INTRODUCTION

1.1 PURPOSE

This document, also known as the CEQATR, defines the baseline environmental test requirements that apply to the qualification and acceptance of Constellation (Cx) flight hardware. It also presents alternative strategies and associated test requirements that can apply when appropriate approval to deviate from the baseline qualification/acceptance program has been granted.

1.2 SCOPE

This document provides the general baseline requirements for environmental qualification and acceptance testing for the Constellation Program (CxP) referenced in CxP 70000, Constellation Architecture Requirements Document (CARD). These test requirements do not necessarily comprise the total test program required. They exist in concert with other test requirements as established by applicable hardware development specifications, verification plans, and test requirement documents, which may include additional tests that are not identified in this document (as well as various analyses, demonstrations, and inspections). The requirements of this document apply at the unit, Multi-Unit Module (MUM), and through the major assembly level. For the purpose of this document, a MUM is treated as a unit. For definitions of levels of assembly, reference Appendix A.

When some major assemblies are integrated, another level of major assembly is created. This integrated major assembly may or may not be appropriate for testing in accordance with the requirements in this document.

When testing at the major assembly level is not appropriate due to the size or weight of the Test Article (TA), facility dimensions, or test equipment limitations, testing shall be accomplished at logical sublevels of the major assembly. The identification of these sublevels is the responsibility of the Projects, and the overall major assembly test strategy shall be clearly defined in the applicable Master Verification Plan (MVP).

Table 1.2-1 provides a list of where various qualification and acceptance requirements are defined for the CxP. Table 1.2-1 does not invoke any requirements but is provided as a convenient reference.

TABLE 1.2-1 QUALIFICATION AND ACCEPTANCE REFERENCES

Constellation Requirements	Verification Requirements
Acoustic Noise	CxP 70024
Acoustic Vibration	CxP 70036
Atomic Oxygen	NASA-STD-6016
Corona/Arcing (1)	CxP 70080
Depressurization/Repressurization	CxP 70036
Electromagnetic Compatibility (EMC)	CxP 70080/CxP 70141/MIL-STD-461
Explosive Compartment	CxP 70036
Functional/Performance	CxP 70036
Fungus	NASA-STD-6016
Gravity-Earth, Lunar, Martian	Analysis
Humidity	CxP 70036
Ice/Snow/Hail	Analysis
Ionizing Radiation	CxP 70144
Leak	CxP 70036
Low Earth Orbit (LEO) Spacecraft	CxP 70036/NASA-STD-4005
Life	CxP 70036/CxP 70135
Micro Meteoroid Orbital Debris (MMOD)	Analysis
Modal Survey	CxP 70135
Multipaction (1)	CxP 70080
Offgas	NASA-STD-6016/CxP 70024
Outgas (1)	NASA-STD-6016
Oxygen Compatibility	NASA-STD-6016
Ozone	Not applicable
Plasma	CxP 70036
Pressure	CxP 70135
Rain	CxP 70036 (Test)/NASA-STD-6016 (Analysis)
Random Vibration	CxP 70036
Run-In	NASA-STD-5017
Salt Fog	CxP 70036 (Test)/NASA-STD-6016 (Analysis)

TABLE 1.2-1 QUALIFICATION AND ACCEPTANCE REFERENCES (CONCLUDED)

Constellation Requirements	Verification Requirements
Sand/Dust	CxP 70036
Shock	CxP 70036
Sinusoidal Vibration	CxP 70036
Solar Radiation	CxP 70036
Static Load	CxP 70135
Thermal Cycle	CxP 70036
Thermal Vacuum and Balance	CxP 70036

NOTE: (1) Should be performed during thermal vacuum testing defined by this document, when possible.

1.2.1 Applicable Hardware

This document addresses the following unit classifications:

a. Electrical/electronic equipment

b. Antennas

c. Mechanisms

d. Solar panels

e. Batteries

f. Fluid equipment

g. Thermal equipment

h. Pressure vessels

i. Optical equipment

NOTE: Where a unit falls under more than one classification (e.g., mechanism and electrical/electronic), the requirements of all applicable classifications shall apply. If limits are different for any applicable classes, testing shall be to the most severe limit.

1.2.2 Flight Termination Equipment

Flight Termination Systems (FTS) and associated units shall be tested to the more severe requirements of this document and requirements defined in AFSPCMAN91-710V4, Range Safety User Requirements Manual Volume 4 – Airborne Flight Safety System Design, Test, and Documentation Requirements.

1.2.3 Hardware Covered by Other Specifications

1.2.3.1 Unit Level

This document does not address the following unit classifications, which are covered by other specifications:

a. Liquid rocket engines and thruster assemblies (see note below)

b. Solid and hybrid propellant rocket motors (see note below)

c. Pyrotechnics and pyrotechnic-actuated devices (see Section1.2.4, letter e)

d. Parachutes or parafoils and associated harnesses

e. Ground facilities and equipment

NOTE: Units comprising these assemblies, such as valves, electronic boxes, and mechanical assemblies, are required to meet the unit-level requirements of this document. The integrated propulsion subsystems feeding liquid rocket engines or thrusters are required to undergo systems-level testing in accordance with this document. This document does not address unit- or system-level propulsion hot firings; these tests are mainly functional and not environmental in nature.

1.2.3.2 Subunit/Part Level

Tests required by this document do not apply to levels-of-assembly below the unit level, for example:

a. Circuit card assemblies

b. Electrical, Electronic, and Electromechanical (EEE) parts

c. Roller bearings

d. Solar cells

1.2.4 Qualification and Acceptance Tests Specified by Other Program Documentation

a. Static structural tests, pressure tests, and modal survey tests as defined in CxP 70135, Constellation Program Structural Design and Verification Requirements.

b. Space environments such as atomic oxygen, neutral atmosphere, ionizing radiation, etc. as defined in CxP 70144, Constellation Program Ionizing Radiation Control Plan, and CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE).

c. Electromagnetic Interference (EMI)/Electromagnetic Compatibility (EMC) and Lightning tests as defined in CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.

d. Test requirements for pyrotechnics and pyrotechnic devices are not defined in this document but are specified in CxP 70199, Constellation Program Pyrotechnic Specification.

1.2.5 Stowable Equipment

Units or items that are packaged and stowed in lockers or other locations within Constellation elements and that provide functionality to Constellation flight systems are subject to the requirements of this document. Equipment-unique requirements shall be developed by determining the applicable category or combinations of categories of equipment defined in tables 4.1-2 and 4.1-4. Engineering judgment and tailoring shall be applied to avoid undue degradation or damage to stowable equipment.

In cases where functionality is not provided to Constellation flight systems, the units or items are only assessed for "safety of flight" by the CxP in accordance with applicable Interface Requirement Documents (IRDs) and Materials and Processes (M&P) standards.

Some examples of stowable equipment not covered by this document are: International Space Station (ISS) equipment being transported to/from the ISS, crew personal items, food, and medical experiments.

1.2.6 Heritage Equipment

The requirements of this document apply to "new design" flight hardware for the CxP. Hardware previously qualified and certified for other applications in other programs shall be evaluated for acceptability on the CxP in accordance with Section 10.1 of CxP 70008, Constellation Program Master Integration and Verification Plan (MIVP).

1.3 CHANGE AUTHORITY/RESPONSIBILITY

Proposed changes to this document shall be submitted by a CxP Change Request (CR) to the CxP Systems Engineering Control Board (SECB) for consideration and disposition.

The CR must include a complete description of the change and rationale to justify its consideration. All such requests will be processed in accordance with CxP 70073-01, Constellation Program Management Systems Requirements, Volume 1: Configuration Management Requirements.

The National Aeronautics and Space Administration (NASA) Office of Primary Responsibility (OPR) for this document is the CxP Systems Engineering and Integration (SE&I) Office.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

CxP 70008	Constellation Program Master Integration and Verification Plan (MIVP)
CxP 70023	Constellation Program Design Specification for Natural Environments (DSNE)
CxP 70056	Constellation Program Risk Management Plan
CxP 70068-01	Constellation Program Problem Reporting, Analysis and Corrective Action (PRACA) Requirements, Volume 1: Problem Processing Requirements
CxP 70068-02	Constellation Program Problem Reporting, Analysis and Corrective Action (PRACA) Requirements, Volume 2: Information Management System Requirements
CxP 70068-03	Constellation Program Problem Reporting, Analysis and Corrective Action (PRACA) Requirements, Volume 3: Appendices
CxP 70073-01	Constellation Program Management Systems Requirements, Volume 1: Configuration Management Requirements

CxP 70135	Constellation Program Structural Design and Verification Requirements
CxP 70144	Constellation Program Ionizing Radiation Control Plan
CxP 70199	Constellation Program Pyrotechnic Specification
MIL-STD-810F, Change Notice 3	Department of Defense Test Method Standard: Environmental Engineering Considerations And Laboratory Tests
NASA-STD-4005	Low Earth Orbit Spacecraft Charging Design Standard
NASA-STD-(I)-6001A	Flammability, Offgassing, and Compatibility Requirements and Test Procedures
NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document.

CxP 70000	Constellation Architecture Requirements Document (CARD)
CxP 70013	Constellation Program System Engineering Management Plan
CxP 70024	Constellation Program Human-Systems Integration Requirements
CxP 70043	Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology
CxP 70074	Constellation Program Modeling and Simulation Integrated Management Implementation Plan
CxP 70080	Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document
CxP 70141	Constellation Program Electromagnetic Environmental Effects (E3) Control Plan

AFSPCMAN91-710V4	Range Safety User Requirements Manual Volume 4 – Airborne Flight Safety System Design, Test, And Documentation Requirements
MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MSFC-PROC-404 Revision A	Marshall Space Flight Center: Procedure, Gases, Drying and Preservation Cleanliness Level and Inspection Methods
NASA-HDBK-7004B	Force Limited Vibration Testing
NASA-STD-5017	Design and Development Requirements for Mechanisms

3.0 GENERAL REQUIREMENTS AND GUIDELINES FOR TEST

CxP hardware and systems shall be subjected to environmental qualification and acceptance tests specified in this document or by other program documentation applied by this document. In case of conflicting testing requirements (levels and durations), the requirements of this document shall be interpreted to represent the minimum test levels and durations acceptable to the CxP; requirements specified elsewhere may fulfill and surpass the requirements of this document, as applicable. These tests verify that hardware and systems meet program performance and functional requirements throughout the full range of environmental conditions and operational modes anticipated throughout the product's service life.

Product developers and test agencies must identify, document, and adhere to all appropriate or applicable safety policies, guidelines, and requirements during testing, including pretest preparations, test operations, and posttest operations.

Section 3.0 provides general requirements and guidance to aid in the development, implementation, and reporting of effective environmental qualification and acceptance test programs.

3.1 TEST BASELINE DEFINITION AND TAILORING

Environmental test requirements are defined in Section 4.0 for units and MUMs and Section 5.0 for major assemblies. Hardware developers shall assess the reasonableness and prudence of fully complying with these requirements. Hardware developers must then document their application of these test requirements to the TA as a Test Verification Requirement (TVR).

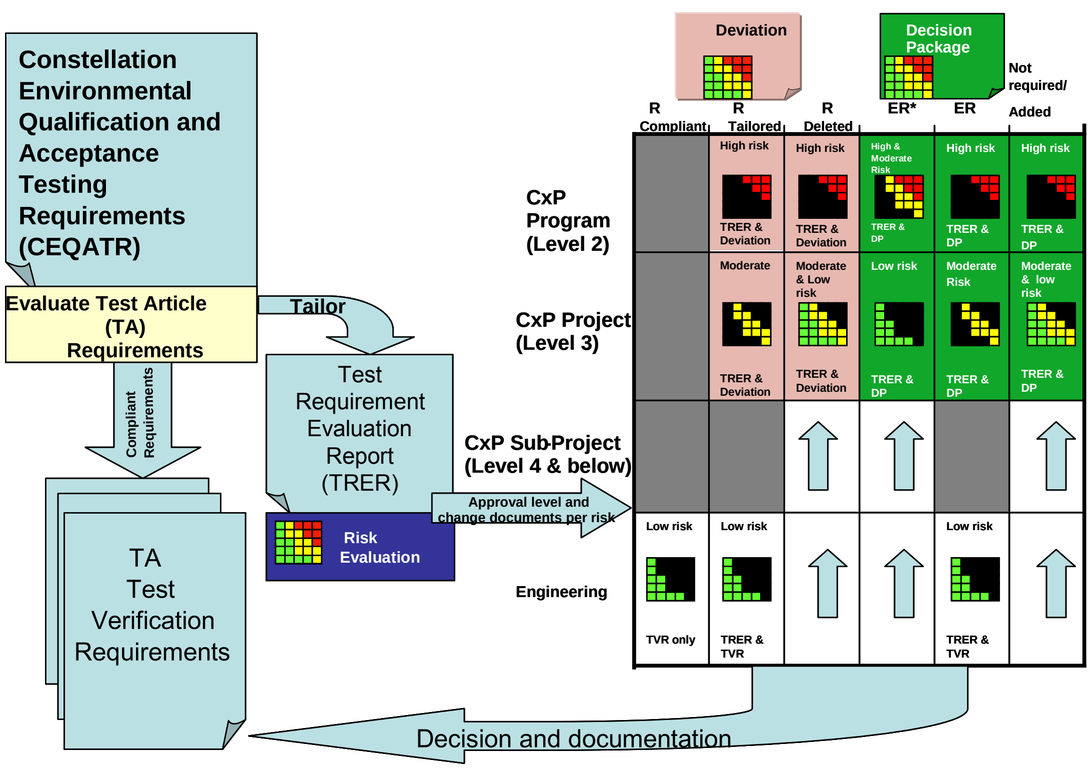
Applying the requirements without adjustment is considered "risk neutral" in that it is consistent with the risk foundation on which the program is formulated. However, hardware developers may need to optimize or adjust the application of these tests, a process referred to in this document as “tailoring.” This document treats any adjustment or tailoring as potential risk. Tailoring should first seek to improve the ability of the tests to find problems, then to avoid inappropriate testing. Inappropriate testing may create more risk than is mitigated. Tailoring involves the following three factors:

a. Risk-based assessment (see Section 3.1.1)

b. Documentation (see Section 3.1.2)

c. Approval levels (see Section 3.1.3)

In addition, unique aspects of equipment design, operation, or usage conditions may dictate that additional environmental tests be performed that are not required by this document. The test baseline set of requirements for implementation, with tailoring, must be documented and approved as defined in figure 3.1-1.



R Required Test
ER* Evaluation required for costly or complex major assembly tests involving significant technical risk
ER Evaluation required
“-“ (dash) Test not normally required

FIGURE 3.1-1 TEST REQUIREMENT BASELINE AND TAILORING

3.1.1 Risk-Based Assessment

When tailoring, a risk-based assessment is required (in accordance with CxP 70056, Constellation Program Risk Management Plan). The risk is categorized on a five by five (5 x 5) matrix with technical rationale provided. The axes denote the evaluator's assessment of risk likelihood and consequences. A risk-based assessment shall be performed independently by the following parties:

a. The Hardware Developer

b. The responsible NASA Project Engineering Office

c. The responsible Center Engineering Technical Authority Subsystem Manager

d. An expert practitioner of the environmental test discipline(s) (CEQATR Technical Expert)

e. A Safety, Reliability, and Quality Assurance (SR&QA) representative

Failure to reach consensus requires elevation of the proposed modification of the test baseline to the approval level required by the highest individual assessed risk, as defined in figure 3.1-1.

3.1.2 Documentation

The developer provides TVR data for each level of hardware to be verified by test. TVR content is defined by the CxP 70008.

The hardware developer documents the results of the risk assessment and other engineering considerations in a Test Requirement Evaluation Report (TRER) when tailoring is required. At a minimum, the TRER should address the following kinds of information:

a. The physical response or lack of response of the equipment to the environment in question. (The response may be categorized as changes to material properties or performance variability due to the environmental exposure.)

b. The severity of environmental exposure of the equipment to the environment in question. (The severity of the environment and the duration of exposure throughout the total equipment service life with potential impacts on hardware performance and life expectancy must be considered.)

c. The fidelity of the predictive modeling associated with the environment and hardware history.

d. The criticality of the equipment (i.e., the consequence of failure of the equipment to perform in the manner required) during or after exposure to the environment, especially as it affects safety of flight.

e. The ability to identify and respond in a timely manner to any environmentally-induced failures.

f. The ability to mitigate all hazards of equipment failure including levels of redundancy, hardware redundancy, and operational backups.

g. Assessment of whether any redundant equipment is like the failed unit or of unlike design.

h. Review of in-flight maintenance or replacement capability and associated risks.

i. The effectiveness of the environment to precipitate latent manufacturing defects in the equipment to failure that cannot otherwise be precipitated through application of other environmental acceptance tests.

j. The cost and schedule impacts associated with conducting the test versus cost of failure manifesting at later points in the mission preparation and operational flow.

For tailoring of requirements categorized as “R” (required test), a CxP Program Deviation is prepared for approval by the hardware developer. Deviation content is defined in the CxP 70073-01. The deviation disposition and data are maintained in the hardware TVR document.

For tailoring of requirements other than those classified as “R” (required test), a Decision Package (DP) addressing all aspects of the tailoring decision is prepared. The DP content is defined in CxP 70013, Constellation Program System Engineering Management Plan. The DP disposition and data is maintained in the hardware TVR document.

3.1.3 Approval Levels

a. Risk assessments judged high risk (red) and assessments of large-scale tests judged moderate risk (yellow) require approval by the CxP SECB.

b. Risk assessments judged moderate risk (yellow) and assessments of large-scale tests judged low risk (green) require approval by the Level III Project Manager or delegated authority.

c. Risk assessments judged low risk (green) require approval by the Center engineering technical authority for the hardware category.

3.2 ACCEPTANCE TESTING

Acceptance testing is required to verify acceptable functionality and performance, verify adequate workmanship and material quality, and provide evidence of overall product acceptability for delivery to the customer. Acceptance testing includes integrity tests that verify hardware functions during and after exposure to the specified environments (e.g., functional/performance and leakage).

Acceptance testing is a risk mitigation strategy that verifies that the manufacturing and assembly process has been accomplished in an acceptable manner and that the product performs within specified parameters.

The required acceptance test baseline for unit–level testing is defined in table 4.1-3, and the recommended sequence is defined in table 4.1-4. The required acceptance test baseline for major assemblies is defined in table 5-3, and the recommended sequence is defined in table 5-4.

The reason these are only recommended sequences is that there is no single correct order to ensure maximum effectiveness applicable to all TAs. Additionally, resource availability will sometimes drive the order of testing. The order of qualification and acceptance testing is typically more valid if it is in agreement with the order in which the environments will be encountered by the flight hardware during its mission life.

3.2.1 Test Facilities

Environmental acceptance tests should be conducted in the same facilities using the same (or identical in make/manufacture) equipment and overall test setups as the corresponding qualification test program, including resident firmware and software. If environmental tests are not conducted in the same facilities using the same test equipment, any differences in configuration must be carefully analyzed for possible configuration influences that would invalidate design certification and require requalification of the hardware and software. Any differences shall be documented and approved in accordance with figure 3.1-1.

3.2.2 Environmental Stress Screening (ESS)

Minimum ESS levels and durations are provided for random vibration, acoustic vibration, thermal cycle, and thermal vacuum testing. These minimum levels and durations are independent of any mission or other service environments. They rely on the application of generalized minimum environmental stress levels to stress hardware to precipitate some percentage of latent manufacturing, material, or workmanship defects into detectable conditions during test or posttest.

For random vibration, ESS criteria are specified at a minimum test spectrum and test duration in Section 4.6.2.1 for units and Section 5.3.2.1 for major assemblies.

For electrical/electronic units, thermal cycle and thermal vacuum criteria are specified as minimum and maximum temperatures; the number of cycles are specified in Sections 4.10.2 and 4.11.2, respectively.

For thermal cycle testing, a minimum rate of temperature change between the test temperature extremes is also specified in Section 4.10.2.2.

For unit-level screening via acoustic vibration, the minimum requirements are specified in Section 4.7.2. Major assembly acoustic vibration minimum screening requirements are defined in Section 5.4.2.

Applying these minimum ESS environments to certain types of equipment requires engineering judgment and caution. Excessively stressing items such as optical devices, computer displays, and other delicate hardware may result in catastrophic failures or damage. In these cases, the ESS levels and/or durations should be reduced, adjusted, or eliminated altogether. Tailoring these screening requirements is a risk-based engineering assessment defined in figure 3.1-1. Other means of workmanship screening (e.g., enhanced inspection, nondestructive evaluation, or testing at lower levels of assembly) must be employed in these cases.

3.3 QUALIFICATION TESTING

Qualification testing is conducted to verify that hardware and systems design, materials, and manufacturing processes have produced equipment that conforms to development specification requirements. Qualification testing includes integrity tests that verify hardware functions during and after exposure to the specified environments (e.g., functional/performance and leakage).

Qualification testing is a risk mitigation strategy for potential design deficiencies. The testing typically stresses the hardware and systems beyond the design operating and nonoperating conditions to ensure that positive margins exist for design requirements and material and process variability.

Qualification tests shall duplicate acceptance tests in TA configuration (including any resident firmware and software), test control, test fixturing, test facilities, and test support equipment, with the exception of appropriate adjustments (e.g., test level and/or duration and response instrumentation and provisions for its installation) as specified in this document.

The required qualification test baseline for unit–level testing is defined in table 4.1-1, and the recommended sequence is defined in table 4.1-2. The required qualification test baseline for major assemblies is defined in table 5-1, and the recommended sequence is defined in table 5-2.

3.3.1 Qualification Test Conditions

The qualification test requirements address the design requirements levied in the appropriate specification. It is expected that the specification will envelop all appropriate worst-case service environments and operational cycles for the applicable item's service life (reference Section 3.0). The service life includes acceptance tests (including acceptance retesting), higher level of assembly tests, mission operations, and ground operations.

3.3.2 Qualification Article Acceptance Testing

In order to reduce the risk of workmanship-related failures during the qualification test program, it is recommended that an acceptance test be performed on the qualification TA prior to beginning the qualification test program. At a minimum for units, the following acceptance tests should be performed on all qualification articles prior to qualification testing:

a. Proof pressure (for pressurized units and systems) as referenced in CxP 70135

b. Functional/performance (including leakage as required)

c. Random or acoustic vibration

d. Thermal cycle (and thermal vacuum) for electrical/electronic units

3.3.3 Qualification Article Fabrication

A single qualification TA (unit, MUM, or major assembly) shall undergo a complete environmental qualification test program. Higher level-of-assembly qualification articles shall be fabricated by one of the following options:

a. Fabricated with new hardware of the same part numbers as qualified units. This option is normally used but requires that qualification testing for lower–level units and/or MUMs completely encompasses the total environmental life profile of the higher–level assembly. This includes environments to which the flight units would be exposed during all higher–level assembly environmental acceptance testing. The major assembly test hardware qualification testing shall not include any hardware item that has been previously subjected to qualification testing.

b. Fabricated from qualification articles of the constituent lower levels of assembly. These lower–level qualification units shall not be refurbished after completion of their lower–level qualification program. The purpose of this approach is to verify acceptable performance of the unit after exposure to the cumulative effects of the environment at all levels of assembly to which the flight hardware will be subjected during acceptance testing. If this option is chosen, the test agency must prevent over-testing by careful planning of the testing increments to ensure that sufficient life remains for higher–level testing.

3.3.4 Qualification Test Margins

Qualification test margins are intended to demonstrate overall robustness of design and to satisfy all of the following objectives on a single qualification article:

a. Demonstrate a degree of tolerance of the differences between the qualification item and the production items due to normal variances in parts, material properties, dimensions, processes, and manufacturing workmanship.

b. Demonstrate a degree of immunity to excessive degradation such as fatigue, wear, loss of material properties, or loss of functionality after enduring a specified maximum number of acceptance tests prior to operational use of the item.

c. Meet specified requirements during or after exposure, as applicable, to the extreme predicted conditions in operational use.

3.4 DEVELOPMENT TESTING

Development tests are exploratory in nature and are usually conducted to establish design approaches and solutions, determine interface compatibility, establish validity of analytical approaches and assumptions, detect unexpected response characteristics, and demonstrate test approaches for qualification and acceptance.

Due to this broad nature of objectives, a requisite degree of latitude is required in development testing; thus, no requirements are established in this document. Constellation product developers are expected to establish reasonable and prudent development test programs as needed for their products.

3.5 TESTING IN SUPPORT OF TROUBLESHOOTING

Unexpected problems or concerns may occur during testing that dictate additional testing on the qualification article or flight hardware to identify causes of problems or to aid in problem resolution. These tests are not considered part of the formal qualification or acceptance program and may be conducted in a manner deemed most appropriate for the objective. However, if environmental stress is applied (e.g., vibration, thermal), the levels applied shall not exceed qualification levels (when troubleshooting qualification hardware) or acceptance levels (when troubleshooting flight hardware). When flight hardware is undergoing environmental testing as part of troubleshooting, the level and duration of exposure to the environment shall be closely monitored, controlled, and documented so as not to exceed qualified life capability.

Retesting after any rework/repair process shall be in accordance with Section 6.0 of this document.

3.6 INSTRUMENTATION AND DATA ACQUISITION AND PROCESSING

Product developers and test agencies must evaluate the testing to be conducted and the data to be acquired. They must then select appropriate instrumentation (including range and accuracy), locations for instrumentation, instrumentation installation methods, and data acquisition and processing techniques necessary to achieve overall test objectives. They are responsible for ensuring proper data acquisition strategies (e.g., sampling rates), validation of data quality, data processing and analysis, and protection against acquisition of erroneous data such as proper use of anti-aliasing filters when necessary. For all environmental qualification tests, the qualification TAs shall have instrumentation (thermocouples, strain gauges, accelerometers, etc.) to acquire TA data under the given environmental conditions.

Calibration of all test instrumentation shall be verified prior to all qualification and acceptance tests. Specific metrology data (Identification [ID]/serial number, calibration performed, or due dates, etc.) for each unique instrumentation device shall be recorded in as-run procedures and reports.

3.7 INSPECTION OF HARDWARE PRE AND POSTTEST

Inspection of test hardware shall be conducted prior to and following each environmental test. These inspections shall not involve any disassembly of the TA. Inspections shall include verification of cleanliness, absence of physical damage, surface finish, clearances, identification markings, integrity of torque striping, and other characteristics, as appropriate. If a test discrepancy occurs, hardware disassembly and inspection shall be in accordance with instructions defined by the nonconformance disposition process.

Inspection of unit/hardware following completion of qualification testing shall entail disassembly only to the extent that wear and/or mechanical integrity can be confirmed (fractures in circuit boards are not present, heavy component staking is in place, there are no broken brackets, wedge locks and internal connectors are secure, etc.). Moving mechanical assemblies required to undergo a life test may be subjected to a limited inspection sufficient to confirm viability prior to the life test. A complete disassembly inspection shall be performed at the conclusion of life testing. Periodic inspection during life testing may be appropriate for some cases.

3.8 TEST PROBLEM REPORTING

Pass/fail criteria shall be established prior to beginning any qualification or acceptance test. Wherever possible, the pass/fail criteria shall be defined by measurable parameters, normally a numerical value or range demonstrating compliance with performance requirements. The performance requirements are defined in the hardware development specification. The actual measured value shall be recorded in the as-run test procedure or test logbook (i.e., no recording of simply “pass” or “fail”). However, in some cases, problems are characterized by loose hardware, deformation, intermittent performance, or other observable conditions. These problems are also considered failures.

Pass/fail criteria shall reflect the expected hardware performance either by design assessment or historical performance experience, but in no case may the pass/fail criteria be less stringent than the applicable development specification requirements. Any unexpected problem or performance outside the nominal, previously observed range of like units, shall be documented as a problem.

Problems observed during qualification or acceptance testing shall be documented in accordance with the following documents:

a. CxP 70068-01, Constellation Program Problem Reporting, Analysis and Corrective Action (PRACA) Requirements, Volume 1: Problem Processing Requirements;

b. CxP 70068-02, Constellation Program Problem Reporting, Analysis and Corrective Action (PRACA) Requirements, Volume 2: Information Management System Requirements; and

c. CxP 70068-03, Constellation Program Problem Reporting, Analysis and Corrective Action (PRACA) Requirements, Volume 3: Appendices.

The record of the problem shall include, at a minimum, the following data:

a. Type of test

b. Coordinated Universal Time (UTC) and date of occurrence

c. Test cycle number or elapsed duration time

d. Pertinent test data such as TA pressure and temperature, ambient conditions, voltage, power consumption, and test chamber environments

e. Observing personnel

f. Previous problems on the TA

g. Problems on similar or like hardware

h. The specific pass/fail criteria defining the problem

i. Test procedure number and revision

j. Step number at which the problem was detected

3.9 TEST DOCUMENTS

Test plans, test procedures, test reports, and Test Readiness Reviews (TRRs) are to be prepared in accordance with the requirements specified in CxP 70008.

3.10 TEST TOLERANCES

Test condition tolerances shall be applied to input test parameters during testing and shall be clearly defined in the test procedures. These tolerance bands shall define the boundaries of acceptable test execution and shall be the basis for nonconformance reporting if test conditions deviate from the allowed tolerance bands. The maximum allowable tolerances on test conditions shown in table 3.10-1 shall apply.

TABLE 3.10-1 TEST CONDITION TOLERANCES

Condition	Tolerance Bands
Temperature	Hot: +3 °C/-0 °C Cold: +0 °C/-3 °C
Pressure More than 1 atmosphere (atm) (760 torr/14.7 psia) 133 pascal (Pa) (1 torr) to 1 atmosphere (760 torr) 0.133 to 133 Pa (0.001 to 1 torr) Less than 0.133 Pa (<0.001 torr)	 +5/-0% +0/-10% ± 25% +0/- 80%
Relative Humidity	± 5%
Acceleration (Gs)	+10/-0%
Vibration Frequency 25 Hz and above Below 25 Hz	 ± 2% ± 1 Hz
Sinusoidal vibration Amplitude (Gs)	± 10%
Time	+10/-0%
Random Vibration Control Frequency Bandwidth Acceleration Spectral Density (20 to 2,000 Hz) Overall grms	 10 Hz or less See Sections 4.6.3 & 5.3.3 ± 10%

TABLE 3.10-1 TEST CONDITION TOLERANCES (CONCLUDED)

Condition	Tolerance Bands
Sound Pressure Levels (1)	
1/3 octave Mid-band Frequencies	
20 to 40 Hz	± 5.0 dB
40 to 2,000 Hz	± 3.0 dB
2,000 to 10,000 Hz	± 5.0 dB
OASPL	± 1.5 dB
Shock Response Spectrum (Peak Acceleration, Q=10)	
Natural Frequencies spaced at 1/6-Octave Intervals	-3.0 dB/ +6.0 dB
Overall	At least 50% of the test SRS values shall be at or above the nominal test criteria.

NOTE: Tighter tolerances are allowable.

3.11 ALTERNATIVE STRATEGIES TO THE STANDARD QUALIFICATION AND ACCEPTANCE TEST PROGRAM

The general requirement for the CxP shall be an environmental test program consisting of full qualification and acceptance testing. However, two alternative strategies may be used with approval of the CxP SECB:

a. Protoflight

b. Highly Accelerated Life Testing (HALT)/Highly Accelerated Stress Screening (HASS)

3.11.1 Protoflight

Protoflight refers to a strategy where no test-dedicated qualification article exists and all production (flight) hardware is intended for flight. In general, protoflight testing exposes all flight hardware to testing at qualification magnitudes for acceptance durations. In cases where a qualification test would generally be required without a corresponding acceptance test (e.g., salt fog), the protoflight test would be the same as the qualification test with any appropriate adjustment made to the test duration to preclude unnecessary wear or life consumption.

All items are tested to identical levels and duration in a protoflight program, except for certain tests that are used for design verification only and are not required to be performed on all items. In general, these are identified with an “R” (or possibly “ER”) in the qualification test baseline tables (tables 4.1-2 and 5-2) and as an “ER” or a “-” for the same test in the acceptance test baseline tables (tables 4.1-4 and 5-4).

A protoflight approach carries a higher technical risk than a full qualification test program since it lacks a demonstrated life capability over the anticipated service life of the hardware. The protoflight approach shall be used only for low-risk applications since no design margin for fatigue, wear, or yield is demonstrated.

NOTE: Testing that is intended to demonstrate service life or ultimate strength capability in a baseline qualification program (such as life testing, burst pressure, and pressure cycling) shall not be performed on protoflight hardware.

When using the protoflight approach, the risk should be mitigated by actions such as increased development testing and use of higher factors of safety. The protoflight option shall not be used under any of the following conditions:

a. The hardware performs a Criticality 1, 1R, 2, or 2R function as defined in CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology.

b. There are more than five production articles to build.

c. The hardware and systems are required to perform more than one space mission.

3.11.2 Highly Accelerated Life Testing (HALT)/Highly Accelerated Stress Screening (HASS)

HALT should be evaluated for application on EEE components, units, and assemblies. HASS can then be performed at screening levels verified not to impact hardware life, significantly increasing confidence in system performance. The HALT/HASS process typically improves screening capability for latent defects and workmanship errors.

Projects should identify key assemblies that are potential candidates for HALT based on criteria such as flight safety, critical functions, reliability requirements, quality goals, etc. Individual test plans shall be written and submitted to the CxP SECB for approval.

The decision to apply the HALT/HASS approach should consider the availability of the following resource capabilities:

a. In-house HALT-compatible equipment or provision for testing at outside test labs.

b. Six degrees-of-freedom (three linear and three rotational) vibration testing for TA with capability of >35 grms.

c. Thermal chamber with a minimum test range of -80 to 170 °C (-112 to 338 °F) with temperature ramp rate capability of at least 45 °C (81 °F) per minute.

d. Lab test equipment to collect and store the test data for vibration, thermal, vacuum, power cycling, and product functional performance from the sensors/accelerometers mounted on the TA and its actual performance data.

e. Capability to monitor functional test data during environmental stimulation (thermal step stress, rapid thermal transition testing, power cycling, vibration step stress, and combined ESS).

f. Ability to provide power to and monitoring of the TA during the test.

g. Rapid root cause analysis and design resolution team to fix the identified failure conditions and document results through the corrective action system.

4.0 UNIT TEST BASELINE

4.1 TEST REQUIREMENTS AND SEQUENCING

The hardware developer is required to develop a unit test program in accordance with the requirements specified in tables 4.1-1 and 4.1-3. When a unit falls under more than one classification (e.g., mechanism and electrical/electronic), the requirements of all applicable classifications shall apply.

The recommended order of testing is defined in tables 4.1-2 and 4.1-4. There are tests identified in the tables that are not governed by this document, but they should be performed in the correct order to ensure maximum effectiveness.

TABLE 4.1-1 UNIT QUALIFICATION TEST BASELINE

Test	Ref. Section	Electrical or Electronic Equipment	Antenna	Mechanism	Solar Panel	Battery	Fluid Equipment	Pressure Vessel (9)	Thermal Equipment	Optical Equipment
Functional/Performance (1)	4.2	R	R	R	R	R	R	R	R	R
Leak (2, 7)	4.4	R	-	ER	-	R	R	R	R	R
Shock (8)	4.5	R	ER	ER	ER	ER	ER	ER	ER	ER
Random Vibration	4.6	R	R (3)	R	R (3)	R	R	R (3)	R (3)	R
Acoustic Vibration	4.7	ER (12)	R (3)	ER (12)	R (3)	-	-	R (3)	R (3)	ER (12)
Sinusoidal Vibration (10)	4.8	ER	ER	ER	ER	ER	ER	ER	ER	ER
Acceleration	4.9	ER	-	-	-	ER	ER	-	ER	ER
Thermal Cycle	4.10	R	ER	ER	ER	ER	R	ER	ER	ER
Thermal Vacuum	4.11	R (11)	R	R (4)	R	R	R	R	R	R (11)
Thermal Gradient	4.12	-	-	ER	ER	-	-	-	ER	ER
Depressurization/ Repressurization	4.15	R	-	R	-	R	R (5)	ER	R (5)	ER
Climatic	4.16	ER	ER	ER	ER	ER	ER	ER	ER	ER
Life (6)	4.18	-	-	R	-	R	ER	R (9)	ER	-

LEGEND: Reference figure 3.1-1 for explanation of R, ER, ER* designations. The dashes mean test is generally not required unless specific aspects of the unit design, sensitivity to environment or environmental severity warrant conducting the test. When a unit falls under more than one hardware category, the required tests of each category shall apply.

NOTES:

(1) A performance test shall be the first and last test conducted for the baseline qualification test program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall qualification test sequence.
(2) Required for sealed units or pressurized units.
(3) Either random, acoustic, or both are required, whichever is most appropriate based on unit design sensitivity to excitation method.
(4) Required for units external to pressurized volumes and units internal to normally pressurized volumes but which are required to operate under vacuum conditions.
(5) Not required if burst pressure testing in accordance with CxP 70135 provides an equivalent or more severe pressure differential across the unit.
(6) For full qualification only. Not to be performed for protoflight approaches.
(7) Specific attention shall be given to COPVs to ensure that excessive pressure cycles and time at MDP are minimized. Any need to proof pressure adjacent systems should consider isolation of the COPV.
(8) Required for all units that contain shock-sensitive components such as crystals, ceramics chips, or other parts sensitive to high-frequency environments. Also required for all units whose shock response spectrum peak acceleration in Gs exceeds 0.8 times the frequency in Hz.
(9) Required for pressure vessels using bellows or other flexible fluid-delivery devices or lines.
(10) For equipment subjected to sinusoidal vibration during flight.
(11) Hermetically-sealed units shall be oriented in thermal vacuum testing to minimize the effect of natural convection (i.e., the effect of gravity).
(12) Units typically requiring both random vibration and acoustic vibration testing are acoustically-sensitive units that are mounted with mechanical isolators and units consisting of piece parts that are resonant above 2,000 Hz.

TABLE 4.1-2 UNIT QUALIFICATION RECOMMENDED TEST SEQUENCE

Test	Suggested Sequence	Requirement Document	Document Section
Functional/Performance (1)	1, 14	CxP 70036	4.2
Proof Pressure	2	CxP 70135	
Leak (2)	3	CxP 70036	4.4
Shock	4	CxP 70036	4.5
Random Vibration	5	CxP 70036	4.6
Acoustic Vibration	5	CxP 70036	4.7
Sinusoidal Vibration	6	CxP 70036	4.8
Acceleration	7	CxP 70036	4.9
Thermal Cycle	8	CxP 70036	4.10
Thermal Vacuum (3)	9	CxP 70036	4.11
Thermal Gradient (3)	9	CxP 70036	4.12
Corona/Arcing (3)	9	CxP 70080	
Plasma/Arcing	9	CxP 70080	
Depress/Repress (3)	10	CxP 70036	4.15
Climatic	11	CxP 70036	4.16
- Rain	11.1	CxP 70036	4.16.1
- Salt Fog	11.2	CxP 70036	4.16.2
- Sound, Dust, Regolith	11.3	CxP 70036	4.16.3
- Humidity	11.4	CxP 70036	4.16.4
Oxygen Compatibility	12	CxP 70036	4.17
Electromagnetic Compatibility (EMC) (4)	13	CxP 70080	4.16.5
Explosive Atmosphere	11.5	CxP 70036	
Life	15	CxP 70036	4.18
Static Load	16	CxP 70135	
Design Burst	17	CxP 70135	

NOTES:

(1) A performance test shall be the first and last test conducted for the baseline qualification test program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall qualification test sequence.

(2) A leak test shall be performed anytime a functional or performance test is required.

(3) Thermal Gradient and Corona/Arcing should be performed as part of thermal vacuum testing whenever possible. Depressurization/repressurization can be performed during thermal vacuum testing as well, if required pressure rate of change can be achieved.

(4) It is highly recommended that EMC qualification testing be accomplished prior to and following dynamic and thermal testing to identify mechanical design and manufacturing deficiencies. However, if only one EMC test is feasible, then it should be performed after the dynamic and thermal tests to ensure that these environments did not induce failures. Since perceptive monitoring is performed during these environmental tests, problems with electrical system installations should be discernible. This provides substantial assurance that recycling of these environmental tests will not be required due to EMC-related problems.

TABLE 4.1-3 UNIT ACCEPTANCE TEST BASELINE

Test	Ref. Section	Electrical or Electronic Equipment	Antenna	Mechanism	Solar Panel	Battery	Fluid Equipment	Pressure Vessel (7)	Thermal Equipment	Optical Equipment
Functional/Performance (1)	4.2	R	R	R	R	R	R	R	R	R
Leak (2)	4.4	R	-	ER	-	R	R	R	R	R
Shock	4.5	-	-	-	-	-	-	-	-	-
Random Vibration	4.6	R	ER (3)	R	ER (3)	R	R	R (3)	R (3)	R
Acoustic Vibration	4.7	ER (6)	ER (3)	ER (6)	ER (3)	-	-	R (3)	R (3)	ER (6)
Thermal Cycle	4.10	R	ER	ER	ER	ER	ER	ER	ER	ER
Thermal Vacuum	4.11	R (4)	R	R (5)	R	R	-	R	R	R (4)
Thermal Gradient	4.12	-	-	ER	ER	-	-	-	ER	ER
Depressurization/ Repressurization	4.15	R	-	R	-	ER	-	-	-	ER
Explosive Atmosphere	4.16.5	ER	-	-	-	ER	-	-	-	-
Oxygen Compatibility	4.17	-	-	-	-	-	R (7)	-	-	-

LEGEND: Reference figure 3.1-1 for explanation of R, ER, ER* designations. The dashes mean test is generally not required unless specific aspects of the unit design, sensitivity to environment or environmental severity warrant conducting the test. When a unit falls under more than one category, the required tests of each category shall apply.

NOTES:

(1) A performance test shall be the first and last test conducted for the baseline acceptance test program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall acceptance test sequence.

(2) Required for sealed units or pressurized units.

(3) Either random, acoustic, or both are required, whichever is most appropriate based on unit design sensitivity to excitation method.

(4) Hermetically-sealed units shall be oriented in thermal vacuum testing to minimize the effect of natural convection (i.e., the effect of gravity).

(5) Required for units external to pressurized volumes and units internal to normally pressurized volumes but which are required to operate under vacuum conditions.

(6) Units typically requiring both random vibration and acoustic vibration testing are acoustically-sensitive units that are mounted with mechanical isolators and units consisting of piece parts that are resonant above 2,000 Hz.

(7) Only applicable to units that contain liquid or gaseous oxygen. See Section 4.17.3 for specific criteria.

TABLE 4.1-4 UNIT ACCEPTANCE RECOMMENDED TEST SEQUENCE

Test	Suggested Sequence	Requirement Document	Document Section
Run-In (4)	1	NASA-STD-5017	
Functional/Performance (1)	2, 10	CxP 70036	4.2
Proof Pressure	3	CxP 70135	
Leak (2)	4	CxP 70036	4.4
Random Vibration	5	CxP 70036	4.6
Acoustic Vibration	5	CxP 70036	4.7
Thermal Cycle	6	CxP 70036	4.10
Thermal Vacuum (3)	7	CxP 70036	4.11
Thermal Gradient (3)	7	CxP 70036	4.12
Corona/Arcing (3)	7	CxP 70080	
Depress/Repress (3)	7	CxP 70036	4.15
EMC (5)	8	CxP 70080	
Explosive Atmosphere	9	CxP 70036	4.16.5
Oxygen Compatibility	10	CxP 70036	4.17

NOTES:

(1) A performance test shall be the first (except when run-in is required) and last test conducted for the baseline acceptance test program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall acceptance test sequence.

(2) A leak test shall be performed anytime a functional or performance test is required.

(3) Thermal gradient and corona/arcing should be performed as part of thermal vacuum testing whenever possible. Depressurization/repressurization can be performed during thermal vacuum testing as well, if required pressure rate of change can be achieved.

(4) Run-in is a preacceptance test process that breaks in mechanical hardware to provide smooth and consistent performance.

(5) It is highly recommended that EMC qualification testing be accomplished prior to and following dynamic and thermal testing to identify mechanical design and manufacturing deficiencies. However, if only one EMC test is feasible, then it should be performed after the dynamic and thermal tests to ensure that these environments did not induce failures. Since perceptive monitoring is performed during these environmental tests, problems with electrical system installations should be discernible. This provides substantial assurance that recycling of these environmental tests will not be required due to EMC-related problems.

Tailoring of requirements is accomplished in accordance with the process specified in Section 3.1.

4.2 UNIT FUNCTIONAL AND PERFORMANCE TESTS

The functional and performance tests verify the capability of the unit to meet the operational requirements of the applicable development specification.

4.2.1 Test Description

Unit tests shall be conducted such that unit functionality and performance, including all redundant modes of operation, are adequately verified in accordance with the requirements in the unit development specification. Input, internal performance, and output shall be determined in accordance with the specification requirements. Unit output and response shall be measured to verify that the unit performs to specification requirements and to identify performance degradation or “out-of-family” behavior.

For performance tests, units shall be varied throughout their specification ranges and the sequences expected over the entire service life. Performance tests shall include measurements of all performance parameters defined in the unit specification.

Functional tests shall apply nominal or expected input to the unit and verify basic functionality and output.

4.2.2 Supplementary Requirements

The specific modes and sequences of operation that are expected to occur in the mission shall be duplicated to the greatest extent practical. The performance test should be a “test like you fly” test that captures the entire service life of the hardware, including acceptance testing, preflight checkout, servicing, maintenance, and repair. Typical functional/performance testing examples follow:

a. Electrical/electronic units: The tests shall include application of voltages, load impedances, frequencies, pulses, and waveforms (commands, data, clocking, polarity, etc.) at the electrical interfaces of the unit, including all redundant circuits. The functional and performance tests shall also measure electrical continuity, response time, or other capabilities/features that relate to a particular unit design.

b. Mechanisms: The tests shall include application of torque, load, and motion, as appropriate. Redundant modes of operation shall be demonstrated during the test in a manner equivalent to operation in service.

4.3 UNIT PRESSURE TEST

Refer to CxP 70135 for unit pressure testing requirements.

4.4 UNIT LEAK TEST

The unit leak test verifies the capability of pressurized or sealed units to meet the leakage rate requirements specified in the development specification and verifies adequate fabrication and quality.

4.4.1 Test Description and Alternatives

Leak testing shall be performed on sealed and pressurized units for qualification and acceptance. Leak testing shall be conducted immediately following any proof pressure test. Leak tests shall be performed prior to the initiation of and following the completion of the qualification and acceptance tests listed below:

a. Thermal vacuum and/or thermal cycle

b. Random, sinusoidal, or acoustic vibration

c. Pyrotechnic or mechanical shock

d. Humidity

The pass/fail criteria for leak testing shall be based on the unit design or the expected leakage rate from historical data, but in no case shall it be greater than the maximum leakage rate in the corresponding unit development specification. For tracer gas leak tests, prior to each leak test, the end-to-end test setup shall be demonstrated to have a sensitivity to detect leakage of at least half the specified pass/fail criteria (e.g., if the pass/fail criteria is less than 1.0×10^{-6} sccs, then a sensitivity to detect at least 5.0×10^{-7} sccs shall be demonstrated). This sensitivity verification shall be by use of a calibrated standard leak.

NOTE: Special precaution shall be taken in establishing pass/fail criteria for leak testing of lubricated elastomer seals. Experience has shown that excessive application of lubricant can result in masking of leaks and an excessively low leak detector output. The potential for lubricant masking of leaks shall be taken into account, and suitable pass/fail criteria shall be established, as appropriate, to detect this occurrence.

An evaluation of the unit design and operational characteristics shall be performed when temperature potentially affects the sealing materials or surfaces. If technically warranted, the leak test shall be conducted at the minimum and maximum temperature limits per Sections 4.10 and 4.11. If it is determined from the evaluation that a leak test at temperature limits is warranted on equipment of a given level of assembly due solely to one or more lower tier units comprising the assembly and it can be shown that all of those lower tier unit(s) receive an appropriate leak test at temperature limits as part of a lower-level leak test, then the higher level of assembly does not require leak testing at temperature limits.

All fluids used for leak testing shall be compatible with the unit's operational fluid and materials of construction. When fluids other than the operational fluid are used for leak testing, the molecular size of the leak test fluid shall be equal to or less than the molecular size of the operational fluid unless doing so presents unacceptable safety concerns or unacceptably impairs the ability to perform a satisfactory leak test. Leak detection and measurement procedures may require the use of vacuum chambers, bagging of the entire unit, or other special techniques to achieve the required sensitivity.

One of six Suitable Leak Test (SLT) methods described in Sections 4.4.1.1 through 4.4.1.6 shall be used. Methods I, II, IV, V, or VI, as appropriate, shall be used for pressurized units. Method III shall be used for units operating at a negative pressure differential (i.e., external pressure greater than internal pressure). Other methods may be used as alternatives to the above, provided they can be shown to satisfy the criteria for an SLT method. For a detailed definition of SLT, reference Appendix A .

NOTE: Local leak detection methods (e.g., detector probe) shall not be used to verify requirements for total leakage rate.

4.4.1.1 Method I (Vacuum Chamber)

Method I (vacuum chamber) may be used for total internal-to-external leak testing of pressurized units and systems.

a. The unit shall be placed in a vacuum chamber (bell jar) and tested for leakage with a leak detector appropriate for the tracer gas used.

b. The vacuum chamber system leak test sensitivity shall be demonstrated by installing a calibrated standard leak (not to exceed one-half of the maximum allowable leakage rate for the test) at a point farthest from the leak detector.

   NOTE: This leak test system sensitivity check shall be made immediately prior to each leak test.

c. The unit shall be charged with a known concentration of a tracer gas to the required pressure.

d. Pressure shall be maintained until stabilization of the leak detector output is achieved (stabilization shall be defined as four consecutive readings no less than 5 min apart with no more than a 10 percent variation in the leak detector output from one measurement to the next, including the first and last measurements).

e. Sensitivity check data and leak detector initial and final readings shall be recorded.

f. The final unit leakage rate shall be recorded along with the minimum four data points within a 15 minute duration to demonstrate stabilization in accordance with the definition above.

4.4.1.2 Method II (Pressure Change)

Method II (the pressure decay technique) may be used for total internal-to-external leak testing of pressurized units and subsystems. To improve the accuracy of this technique, a reference vessel connected to the pressurized unit or system may be used. If the ambient temperature changes, the unit and reference vessel volumetric change shall be taken into account.

The pressure rise technique may be used for total external-to-internal leak testing of sealed units and systems. The unit internal pressure, barometric pressure, and ambient temperature (or temperature of the unit) shall be monitored for the required time to determine the actual pressure drop or rise and the corresponding leakage rate. The pressure gauge/transducer shall have accuracy and sensitivity adequate to measure the minimum required pressure change. The tolerance/error associated with the total internal volume of the unit and test fixture under pressure used for the leakage rate calculation shall be taken into account as a maximum positive value.

4.4.1.3 Method III (Hood)

Method III (hood) may be used for total external-to-internal leak testing of sealed units and systems.

a. The unit internal volume shall be evacuated to a vacuum compatible with a tracer gas leak detector.

b. The system sensitivity shall be demonstrated by installing a standard leak (not to exceed one-half of the maximum allowable leakage rate for the test) at the farthest point from the leak detector. If the system has only one port, a standard leak shall be installed at this port location.

c. The external surfaces of the unit shall be exposed to a verified concentration of a tracer gas.

d. Pressure shall be maintained until stabilization of the leak detector output is achieved (stabilization shall be defined as four consecutive readings no less than 5 minutes apart with no more than a 10 percent variation in the leak detector output from one measurement to the next, including the first and last measurements).

e. Sensitivity check data and leak detector initial and final readings shall be recorded.

f. The final unit leakage rate shall be recorded along with the minimum four data points within a 15 minute duration to demonstrate stabilization in accordance with the definition above.

4.4.1.4 Method IV (Accumulation)

Method IV (accumulation) may be used for total internal-to-external leak testing of pressurized units and systems.

a. The unit shall be enclosed in a suitable enclosure.

b. The enclosure shall be calibrated by placing a standard leak in the enclosure for a predetermined period of time, which shall be determined by the size of the enclosure and anticipated leakage rates.

c. At the end of the time period, a detector probe shall be placed in the enclosure (at the top of the enclosure for lighter-than-air trace gas and the bottom of the enclosure for heavier-than-air trace gas).

d. The maximum leak detector response and exposure time shall be recorded as the enclosure calibration.

e. The enclosure shall then be purged with N_2 or air until residual trace gas is removed to the background level of the leak detector.

f. The unit shall be charged with a known concentration of a tracer gas to the required pressure.

g. Prior to examination, the test pressure shall be held for a minimum duration of 30 minutes to allow the unit leakage rate to stabilize.

h. The enclosure shall then be purged again with N_2 or air and sealed in a manner that would preclude hazardous pressure buildup in the enclosure.

i. After the time period used for enclosure calibration, the detector probe shall be placed in the enclosure.

j. Calibration data and leak detector initial and final readings shall be recorded.

4.4.1.5 Method V (Volumetric Displacement)

Method V (volumetric displacement) may be used for total internal-to-internal leak testing of pressurized units such as valves, pressure regulators, or heat exchangers. One side of the unit shall be pressurized to the required pressure, while the other side (across the internal barrier) shall be sealed from the atmosphere and attached to a suitable device for the purpose of demonstrating volumetric displacement. This will be accomplished by either using a displacement of liquid or by moving a fluid meniscus along the graduations of the measuring device.

4.4.1.6 Method VI (Leak Detector Direct Connection)

Method VI (leak detector direct connection) may be used for total internal-to-internal leak testing of pressurized units such as valves, pressure regulators, or heat exchangers.

a. The system sensitivity shall be demonstrated by installing a standard leak (not to exceed one-half of the maximum allowable leakage rate for the test) at the farthest point from the leak detector.

b. For the test, one side of the unit shall be charged with a known concentration of a tracer gas to the required pressure, while the other side (across the internal barrier) shall be sealed from the atmosphere and attached to the leak detector.

c. Pressure shall be maintained until stabilization of the leak detector output is achieved (stabilization shall be defined as four consecutive readings no less than 5 minutes apart with no more than a 10 percent variation in the leak detector output from one measurement to the next, including the first and last measurements).

d. Sensitivity check data and leak detector initial and final readings shall be recorded.

e. The final unit leakage rate shall be recorded along with the minimum four data points within a 15 minute duration to demonstrate stabilization in accordance with the definition above.

4.4.2 Test Levels and Durations

4.4.2.1 Test Levels

The leak tests shall be performed with the unit pressurized at the Maximum Design Pressure (MDP) and then at the minimum operating pressure if the seals are dependent upon pressure for proper sealing.

4.4.2.2 Durations

Regardless of the method used, the test duration shall be sufficient to detect any unacceptable leakage. All leak tests shall be conducted with the differential pressure across the sealing mechanism during the test the same as potential worst case mission operating conditions, including overpressure and differential pressure to vacuum.

4.4.3 Supplementary Requirements

If the unit has redundant seals, each seal shall be verified independently when the following conditions are met:

a. Leakage would constitute a Criticality 1 or 2 failure mode.

b. Leak test verification of independent seal redundancy is possible due to the presence of leak test ports or independent sealing can be verified by characterization of leakage rise rate on a tracer gas leak detector.

Where use of a total leak test method as specified in Sections 4.4.1.1 through 4.4.1.6 is impossible or impractical or where leakage of individual penetrations (such as feedthroughs) or other potential leakage sites (such as welds) is specified, local leak test methods (such as bell jars or hoods) may be used to verify leakage integrity. In all cases, sensitivity of the leak test approach chosen and its implementation shall be demonstrated and documented consistent with the requirements for total leakage testing using the methods above.

4.5 UNIT SHOCK TEST

The unit shock test verifies the capability of the unit to operate or survive, as required, the design level shock environment as specified in the unit development specification. The testing in this section is for high-frequency shocks typically induced by pyrotechnic events or high velocity metal-to-metal impacts with dominant energy above 2 kHz. Examples of high-frequency shock include, but are not limited to, stage and fairing separations and pyrotechnic device deployment of payloads, solar arrays, and antennas.

4.5.1 Test Description

a. The unit shall be mounted to a fixture through the normal mounting points of the unit.

b. If shock isolators are to be used in service, they shall be installed for the shock tests.

c. The selected test method shall be capable of meeting the required shock spectrum with an oscillatory transient waveform that has duration comparable to the duration of the expected shock environment during the mission.

d. The unit shall be tested along each of three mutually perpendicular axes.

e. Testing for low frequency shock environments induced during packaging, handling, and transportation shall be performed when analysis indicates that levels are greater than the specification's levels for flight and other operational events. Test methodology for Packaging, Handling, Storage and Transportation (PHS&T) shall be in accordance with MIL-STD-810F, Department of Defense Test Method Standard: Environmental Engineering Considerations and Laboratory Tests, Method 516.5.

4.5.2 Test Levels and Durations

4.5.2.1 Test Levels

For qualification testing, the test level shall be the level defined in the applicable unit development specification plus 3 dB. When the development specification defines more than one shock environment, the qualification test may be conducted using a single test level that envelops all of the specification environments or by applying each specification environment individually.

4.5.2.2 Durations

Testing shall be performed two times in each axis for a total of six shock applications at a minimum.

4.5.3 Supplementary Requirements

A visual inspection of the unit shall be performed prior to and following each shock test. The visual inspection shall not entail any disassembly. During shock testing, interface cables and harnesses shall be flight equivalent up to the first attachment point. Electrical and electronic units, including redundant circuits, shall be energized and monitored for failure or intermittence during the shock test, regardless of whether they are powered and operating during exposure to the shock environment during the mission. Relays shall be checked for indications of chattering during shock application.

4.6 UNIT RANDOM VIBRATION TEST

The unit random vibration test verifies the unit's capability to meet applicable functional/performance requirements during or after exposure to the service life random vibration environments. This includes acceptance testing to screen production units for latent manufacturing, material, and workmanship defects.

An option to perform force limited vibration testing on units is described in Appendix C. Force limiting alleviates the severe overtest inherent in conventional shaker vibration tests. Force limiting requires measuring and controlling the force between the test item and shaker. Piezoelectric force gauges are typically employed to measure the force, and the force is typically controlled real time using the external control feature available in most vibration controllers.

4.6.1 Test Description

The baseline unit random vibration test program is comprised of Acceptance Vibration Test (AVT), Qualification for Acceptance Vibration Test (QAVT), and Qualification Vibration Test (QVT).

The QVT TA shall be the same model/serial number as used for QAVT and shall not be refurbished between the two tests. The QVT and QAVT may be performed in any sequence, and both tests may be accomplished in a given axis before repositioning to another axis.

If the unit is required to operate during exposure to flight mission random vibration environments, the associated performance requirements shall be demonstrated during AVT, QAVT, and QVT. The units shall be tested in each of three orthogonal axes.

AVTs and QAVTs shall be conducted with the unit hard mounted to the shaker through a rigid test fixture through the normal mounting points of the unit. One or more control accelerometers shall be placed on the test fixture near the unit mounting points. When more than one control accelerometer is used, test control shall be by the mean average of the output of all control accelerometers.

For AVTs and QAVTs of all units of a given part number, the overall test setup and control shall be duplicated to the greatest extent practical. This includes overall mounting to the shaker, placement of control accelerometers, and signal acquisition and processing for control of the test.

For QVT (except Method 4 described in Section 4.6.2.3, letter d), units shall be mounted in a manner representing the flight installation, including shock or vibration isolators. For the shock or vibration isolator configuration, test control shall be at the location consistent with the specification environment definition. If the environment in the specification represents the input to the isolators, the test control shall be at the test fixture-to-isolator interface. If the specification environment represents the input to the unit, the test control shall be at the isolator-to-unit interface.

Qualification vibration of isolators themselves shall be performed in accordance with the requirements of this section and shall employ dummy mass(es) representing the article being isolated and shall be conducted at minimum and maximum temperature extremes for isolators whose dynamic performance is affected by temperature.

4.6.2 Test Levels and Durations

4.6.2.1 Acceptance Vibration Test (AVT)

The AVT shall be accomplished by one of the two following methods:

a. Method 1: The test level and spectrum shall envelop all of the design service life random vibration environments as defined in the applicable unit development specification. It shall also envelop the minimum workmanship screening level and spectrum defined by table 4.6.2.1-1 and figure 4.6.2.1-1. The test duration shall be 1 minute per axis.

TABLE 4.6.2.1-1 MINIMUM UNIT AVT WORKMANSHIP SCREENING LEVEL

Frequency Range (Hz)	Level/Slope
20	0.01 g^2/Hz
20-80	+3dB/Octave
80-800	0.04 g^2/Hz
800-2,000	-4.55 dB/Octave
2,000	0.01 g^2/Hz
Composite (grms)	7.33

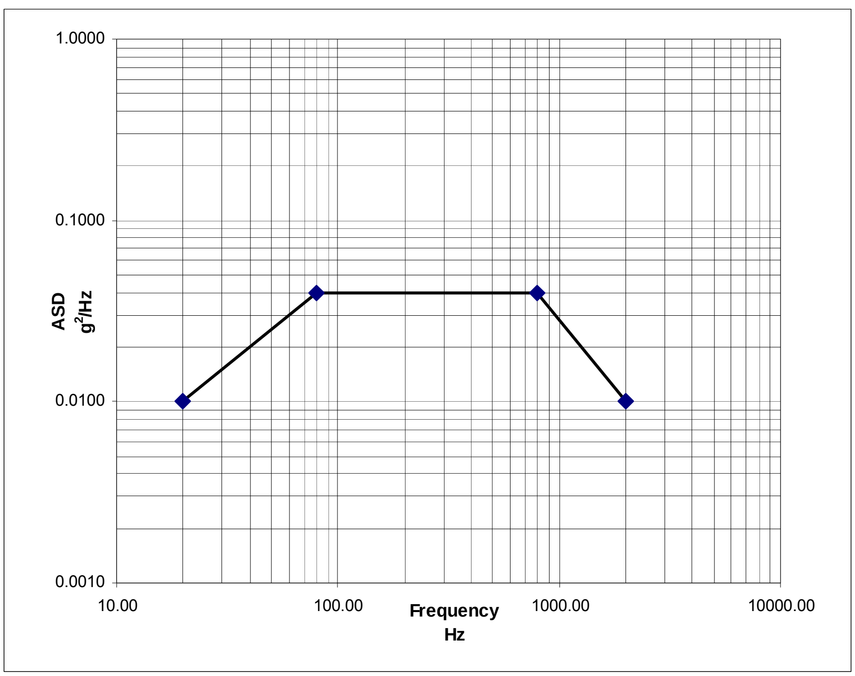


FIGURE 4.6.2.1-1 UNIT MINIMUM WORKMANSHIP VIBRATION TEST SPECTRUM

b. Method 2: In this method, multiple AVTs are conducted for each mission phase where significant random vibration occurs. For each AVT, the corresponding specification level for that mission phase shall be enveloped with the minimum workmanship screening level and spectrum defined by table 4.6.2.1-1 and figure 4.6.2.1-1. The test duration for each AVT shall be 1 minute per axis. When the minimum workmanship screening level has been achieved at all frequencies for at least 1 minute per axis, it no longer needs to be enveloped for AVTs covering the remaining mission phases. The complete AVT program in any axis may be completed prior to repositioning the TA for another axis.

4.6.2.2 QAVT Levels and Durations

The test input Acceleration Spectral Density (ASD) shall be the AVT ASD increased by 3 dB. The duration per axis shall be 1 minute times the number of AVTs to be qualified (e.g., if qualifying an electrical/electronic unit for five AVTs, the total duration per axis shall be 5 minutes). The number of AVTs to be qualified shall be as specified in the applicable unit development specification or as defined by a Logistics Supportability Analysis, but shall not be less than five.

NOTE: When Method 2 of AVT is employed, an individual QAVT shall be conducted for each AVT conducted.

4.6.2.3 QVT Levels and Durations

One of the four methods below shall be used for performing QVT.

Service life random vibration environment input ASDs, as defined in the applicable unit development specification, shall be increased by 3 dB for Methods 1, 2, and 3. When Method 4 is chosen, the test input ASD shall be 6 dB higher than the envelope of all of the service life environments.

a. Method 1

1. Each applicable service life random vibration environment, except for acceptance testing, as identified in the applicable unit development specification shall be applied individually.

2. The overall test level and spectrum shall be the greater of the level and spectrum as defined in the development specification.

3. The test duration for each environment shall be four times the exposure duration for that environment as defined in the unit development specification. The sum total test duration for each axis for all environments shall be no less than 3 minutes. If the sum total of the four times exposure durations for each environment is less than 3 minutes in any axis, then the time required to reach 3 minutes shall be proportionally divided across the environments being tested, and that amount of time shall be added to the required test duration for each environment such that the sum total duration for each axis is 3 minutes.

4. The configuration of the unit (e.g., pressurized/unpressurized, operating/nonoperating) shall be in accordance with development specification requirements for the applicable environment.

b. Method 2

1. A test level and spectrum enveloping all service life random vibration environments, except for acceptance testing, shall be applied to each of the three orthogonal axes.

2. The test duration in each axis shall be the greater of four times the total equivalent duration of exposure to all of the environments defined in the development specification or 3 minutes.

c. Method 3

Method 3 is a combination of the first two methods where the unit is not required to operate during exposure to some mission random vibration environments. Generally, this method is appropriate when one or more of the nonoperating environments is more severe than the operating environments, and the unit may not meet functional/performance requirements while exposed to the higher nonoperating environment(s). This method shall consist of a nonoperating test followed by an operating test. The nonoperating test is described below:

1. A single nonoperating random vibration environment that envelops all nonoperating mission environments shall be applied to each of the three axes as defined in the development specification.

2. The test duration in each axis shall be the greater of four times the total lifetime exposure time to the nonoperating environments defined in the development specification or 3 minutes.

3. After testing all three axes, the unit shall then undergo a functional test in accordance with Section 4.2.

4. In addition to the nonoperating random vibration test, an operating random vibration test shall be conducted. A single operating random vibration environment that envelops all of the operating random vibration mission environments shall be applied to each of the three axes as defined in the development specification.

5. The test duration in each axis shall be the greater of four times the total lifetime exposure time to the operating environments defined in the development specification or 3 minutes.

d. Method 4

1. A test level and spectrum enveloping all service life random vibration environments (including acceptance testing) shall be applied to each of the three orthogonal axes.

2. The test duration in each axis shall be the greater of four times the total equivalent duration of exposure to all of the service life environments including a minimum of five acceptance tests or 3 minutes.

3. Units shall be hard mounted to the shaker through a rigid test fixture when using this method.

NOTE: When using Method 4, a QAVT is not required.

4.6.3 Supplementary Requirements

A functional test shall be conducted in accordance with Section 4.2 prior to and following any random vibration test (AVT, QAVT, or QVT). At a minimum, all electrical/electronic units shall be powered and monitored for failures or intermittence during all random vibration testing (except for nonoperating tests during QVT) when Method 3 is being used.

For AVT, where the minimum workmanship spectrum governs the required input test level, the input may be limited or notched to prevent the following problems:

a. Unrealistic input forces

b. Damaging unit responses for units whose masses exceed 23 kg (50 lbs) where analysis has shown the potential for response levels in excess of design limits

NOTE: For units that exceed 23 kg (50 lbs), screening of the internal electronic boards and components should be considered prior to unit-level assembly.

In no case shall the input be less than the maximum design service level in that frequency range.

Wiring harnesses and hydraulic and pneumatic lines up to the first attachment point, instrumentation, and other connecting items shall be included in the test configuration. These items shall be connected using flight-like connectors.

The fixture shall be designed to preclude fixture-induced resonances throughout the test frequency range. Bare fixture surveys shall be conducted prior to each unit vibration test. As a goal, input ASD in the off-axes should be maintained at least 10 dB below the input ASD in the primary excitation axis.

During exposure to qualification test vibration environments, the unit shall undergo performance testing as required to demonstrate the required capability.

The configuration of the unit (e.g., pressurized/unpressurized, operating/nonoperating) shall be in accordance with development specification requirements for the applicable environment. Units that are pressurized during exposure to random vibration during the mission shall be pressurized to their maximum or minimum operating pressure, as appropriate, and monitored for internal pressure decay.

The test plan shall clearly and fully explain the derivation of the required test parameters to demonstrate compliance with these requirements.

Maximum allowable tolerances for random vibration testing shall be as follows:

a. AVT: +1.5/-3.0 dB

b. QAVT: +3.0/-1.5 dB

c. QVT (methods 1 through 3): ± 3.0 dB

d. QVT (method 4): +3.0/-1.5 dB

Excursions from the specified tolerance bands are permissible provided all of the criteria below are met:

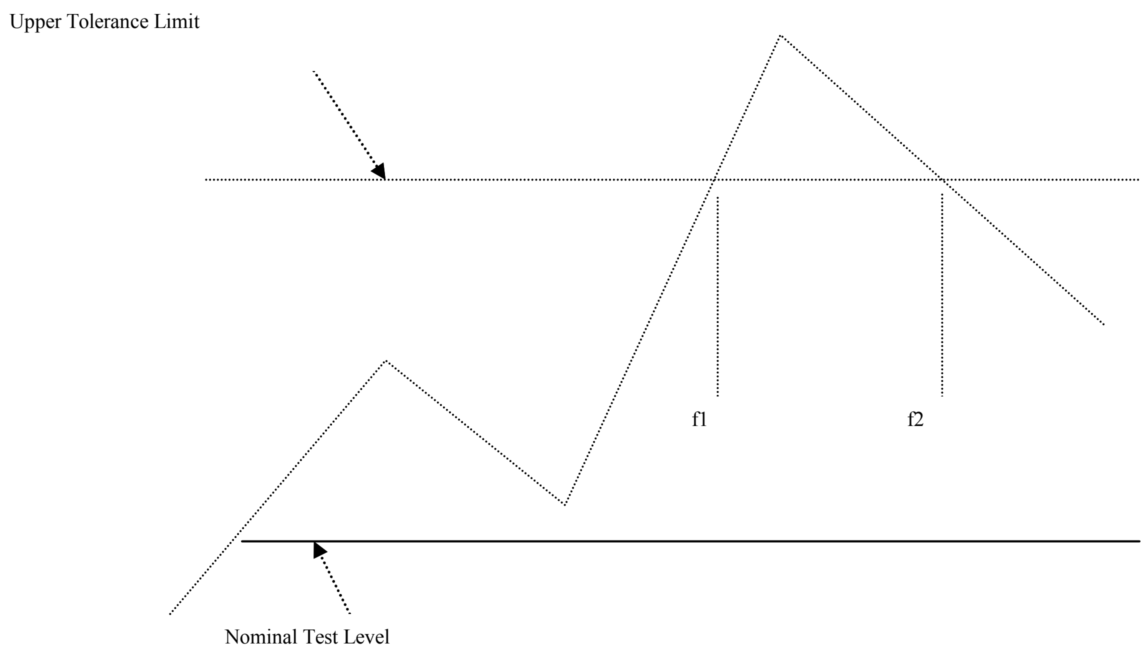
a. The total number of excursions in any test shall not be greater than four.

b. The total number of excursions in any test on either the low side or high side shall not exceed three.

c. No excursion peak shall exceed the tolerance limit by more than 1.5 dB.

d. No excursion shall have a bandwidth greater than 10 Hz or 10 percent of the geometric mean frequency of the excursion, whichever is greater.

The geometric mean frequency shall be defined as the square root of the product of the lower and upper crossing frequencies at the tolerance limit (see figure 4.6.3-1 for an example).



Geometric mean frequency = $\sqrt{(f1)(f2)}$

FIGURE 4.6.3-1 GEOMETRIC MEAN FREQUENCY EXAMPLE

4.6.4 Equivalent Times for Different Random Vibration Environments

The following method shall be used to equate time at one random vibration environment to equivalent time at another random vibration environment. A value of no greater than 4 shall be used for the fatigue exponent *b* without explicit approval of the CxP. If data exists justifying a lower value, then that lower value shall be used.

When it can be clearly shown that all resonant response frequencies within the test frequency range are known, the equation below shall be evaluated at each resonant frequency *i*.

$$t_1 = t_2\left(\frac{w_{2i}(f_i)}{w_{1i}(f_i)}\right)^{\frac{b}{2}}$$

where

t_1 = the equivalent duration for environment 1
t_2 = the time of exposure for environment 2
W_{1i} = the input ASD of environment 1 at resonant frequency i
W_{2i} = the input ASD of environment 2 at resonant frequency i
b = fatigue exponent

If any of the resonant response frequencies within the test frequency range are unknown, the equivalent duration shall be established by evaluating the above expression at the frequency where the input ASD ratio between the two environments is at a minimum.

4.7 UNIT ACOUSTIC VIBRATION TEST

The unit acoustic vibration test is applicable to units with large surface areas that are sensitive to direct acoustic excitation. This test verifies the capability of the unit to withstand the design acoustic environments as defined in the unit development specifications and to serve as a screen for latent manufacturing and workmanship defects during acceptance testing. Acoustic tests shall be conducted when it is judged that this environment, rather than a random vibration environment, will be the worst-case condition (for example, for units characterized by large surface-to-area ratios such as antennas or solar arrays), or if random vibration testing is impractical because of the unit's size and mass.

4.7.1 Test Description

a. The unit shall be installed in an acoustic test setup capable of generating the desired Sound Pressure Levels (SPLs).

b. The configuration of the unit during testing shall be as it is during subjection to the specified mission acoustic environment.

c. The unit shall be mounted on a flight-type support structure or simulation thereof with ground-handling equipment removed.

d. Significant fluid and pressure conditions affecting structural damping shall be replicated.

e. Appropriate dynamic instrumentation shall be installed to measure vibration and strain responses.

f. Control microphones shall be placed at a minimum of four well-separated locations around the TA. They shall be no closer than 0.5 m (20 in) from any acoustically reflective surface such as chamber walls or the TA. For free-field acoustic testing, the control microphones shall be no farther than 1 m (39 in) from the TA surfaces.

g. The unit shall then be subjected to the specified acoustic input levels for the required duration as specified in Section 4.7.2.2.

4.7.2 Test Levels and Durations

4.7.2.1 Test Levels

Qualification: The SPL at ⅓ octave band center frequencies shall be 3 dB above the acceptance test level (when acceptance acoustic testing is required) or 3 dB above the envelope of the ⅓ octave band center frequency levels defined in the applicable unit development specification (when acceptance acoustic testing is not required).

Acceptance: The SPL at ⅓ octave band center frequencies shall be the envelope of the ⅓ octave band center frequencies as specified in the applicable unit development specification, but not less than a level of 138 dB Overall Sound Pressure Level (OASPL) whose spectrum shape is identical to the envelope of the specification acoustic environments.

4.7.2.2 Durations

Qualification: The test duration shall be the greater of four times the service life exposure to all acoustic environments (including acoustic acceptance testing when required) as specified in the development specification or 3 minutes.

Acceptance: The test duration shall be 1 minute.

4.7.3 Supplementary Requirements

A functional test in accordance with Section 4.2 shall be conducted prior to and following the acoustic test. Electrical and electronic units shall be electrically energized and monitored for failures and intermittences during the test regardless of whether they are powered or operating during acoustic exposure in flight.

If the unit is required to operate during exposure to the specified acoustic environment, a performance test shall also be conducted during the unit qualification and acceptance acoustic test. The performance test only needs to cover those functions that are required to be performed by the unit during exposure to flight acoustic environments.

Only those functions that are required to be performed while the unit is exposed to acoustic excitation during the mission need to be verified during the test. The test plan shall clearly and fully explain the derivation of the required test parameters to demonstrate compliance with these requirements.

4.8 UNIT SINUSOIDAL VIBRATION TEST

The unit sinusoidal vibration test verifies the capability of the unit to withstand and, if appropriate, to operate at the specified levels of the sinusoidal vibration environment. This test is a qualification test only and is not required for unit acceptance testing.

4.8.1 Test Description

a. The unit shall be mounted to a fixture through the normal mounting points of the unit.

b. The unit shall be tested in each of three mutually perpendicular axes consistent with sinusoidal vibrations input directions as defined in the unit development specification.

c. Significant resonant frequencies shall be recorded.

4.8.2 Test Levels and Durations

4.8.2.1 Test Levels

The test level shall envelop the maximum sinusoidal environment experienced during the unit's service life plus a 25 percent margin.

4.8.2.2 Durations

The test duration shall be sufficient to demonstrate a fatigue life of the unit of four times the total service life exposure. Sweep rates shall not be less than 2 octaves per minute.

4.8.3 Supplementary Requirements

A functional test shall be conducted prior to and following the sinusoidal vibration test. Electronic units shall be powered during the test (regardless of whether they are powered during exposure to the sinusoidal vibration environment) and relevant parameters shall be monitored for failures or intermittences.

If the unit is required to operate during exposure to the specified sinusoidal vibration environment, a performance test shall also be conducted during the exposure to qualify for the sinusoidal vibration environment. Only those functions required to be performed by the unit during exposure to flight sinusoidal vibration input are required to be demonstrated during this sinusoidal vibration test. If the unit is to be mounted on dynamic isolators in the space vehicles, the unit shall be mounted on these isolators during the qualification test, and the vibration test level control shall be at the locations consistent with the development specification environment.

4.9 UNIT ACCELERATION TEST

The unit acceleration test verifies the capability of the unit to withstand, or if appropriate, to operate in the design-level acceleration environment. This test is a design qualification test only.

4.9.1 Test Description

a. The unit shall be mounted to a test fixture through the normal mounting points of the unit.

b. The unit shall be tested in each axis through which an acceleration constitutes a design-to mission environment in accordance with the applicable unit development specification.

c. If accelerations are specified in both directions in a given axis, the unit shall be tested in both directions. The specified accelerations apply to the center of gravity of the test item.

4.9.2 Test Levels and Durations

4.9.2.1 Test Levels

Acceleration levels shall be 1.4 times the design level specified in the applicable development specification.

4.9.2.2 Durations

The test duration shall be 5 minutes in each direction of each axis for which the test is required.

4.9.3 Supplementary Requirements

A performance test in accordance with Section 4.2 shall be conducted during the test for units that are required to operate during exposure to the acceleration environment during the mission. Only those functions that are required to be performed by the unit during mission acceleration exposure need to be verified during the test. If the unit is to be mounted on dynamic isolators in the flight installation, the unit shall be mounted on these isolators during this acceleration test.

4.10 UNIT THERMAL CYCLE TEST

The unit thermal cycle test verifies the capability of units to operate at temperature extremes while in an ambient pressure environment and to serve as a workmanship screen for electrical and electronic units during acceptance.

4.10.1 Test Description

The unit shall be mounted in a thermal chamber on a thermally-controlled heat sink or in another manner representative of the flight installation. The unit shall be instrumented with one or more (one backup recommended) temperature sensors mounted in locations corresponding to representative locations on the unit thermal model. For electrical/electronic units, the sensor shall be located on the baseplate for conduction cooled configurations or on the chassis for radiation or convection cooled configurations. This sensor shall serve as the basis for compliance with the temperature requirements of this test (i.e., temperature, transition rate, and dwell periods).

a. The test begins with the chamber and unit at ambient temperature.

b. Electrical/electronic units shall be powered up and operating through various modes (including all redundant circuits and paths).

c. Electrical/electronic units shall be monitored for failure or intermittent behavior throughout the test, except for power off and functional/performance test periods as specified in this thermal cycle section.

d. The unit shall be brought to the cold test temperature condition. Electrical/electronic units shall be powered off once the cold test temperature condition is reached.

   NOTE: For equipment subject to damage by exposure to temperatures colder than the low test temperature extreme, cooling should be reduced during the last 10 degrees of the cycle to prevent potentially damaging overshoot.

e. The unit shall undergo a dwell period sufficient to achieve internal thermal equilibrium, but not less than 1 hr. Electrical/electronic units shall be powered back on after the dwell.

f. The temperature of the unit shall then be raised to the hot test temperature condition and undergo a dwell period sufficient to achieve internal thermal equilibrium, but not less than 1 hr.

g. Electrical/electronic units shall then be powered off for a time period sufficient to allow electrical circuits to discharge, and then the unit(s) shall be powered back on and brought back to internal thermal equilibrium.

h. The unit shall then undergo a functional or performance test in accordance with Section 4.2.

i. Performance tests shall be conducted on the first and last temperature cycles, and functional tests shall be conducted on all intermediate cycles. After the last hot cycle, the unit shall be brought back to ambient temperature.

NOTE: Alternatively, the test may begin with the hot cycle first followed by cold, but in all cases appropriate measures shall be taken to preclude condensation of moisture on and around the TA during chamber repressurization.

4.10.2 Test Levels and Durations

4.10.2.1 Pressure Levels

The test shall be conducted at ambient pressure.

4.10.2.2 Temperature Levels

At each temperature extreme on each cycle, the unit shall undergo a dwell period sufficient to achieve internal thermal equilibrium in accordance with figures 4.10.2.2-1 (qualification) and 4.10.2.2-2 (acceptance); however, in no case shall it be less than 1 hr. The rate of change between hot and cold shall be at an average rate of 3 °C to 5 °C per minute (5 °F to 9°F per minute) and not slower than 1 °C (1.8 °F) in any 1 minute.

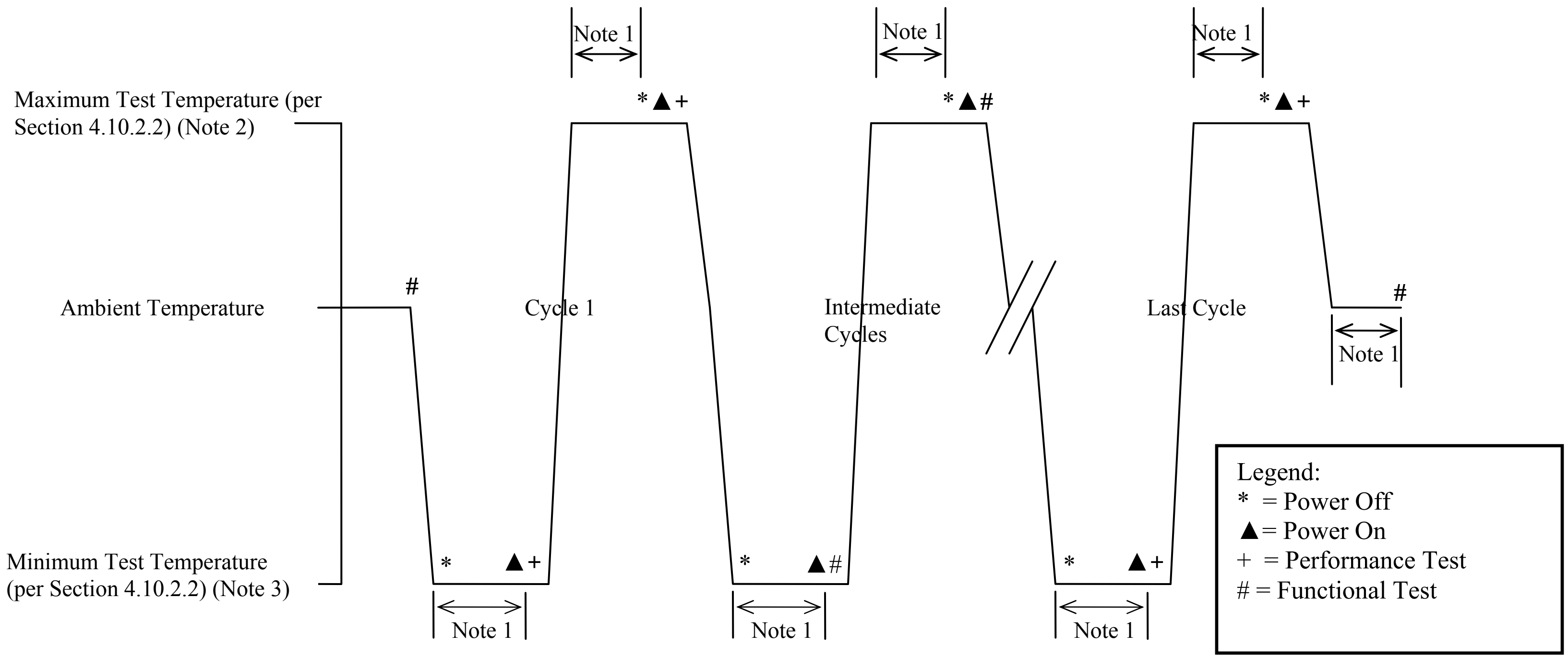
Qualification: For units that require an acceptance thermal cycle test, the minimum and maximum thermal cycle qualification test temperatures shall be 11 °C (20 °F) beyond the minimum and maximum acceptance thermal cycle test temperatures.

For units not requiring an acceptance thermal cycle test, the minimum and maximum qualification test temperatures shall be one of the following:

a. 11 °C (20 °F) beyond the minimum and maximum temperatures specified in the applicable unit development specification.

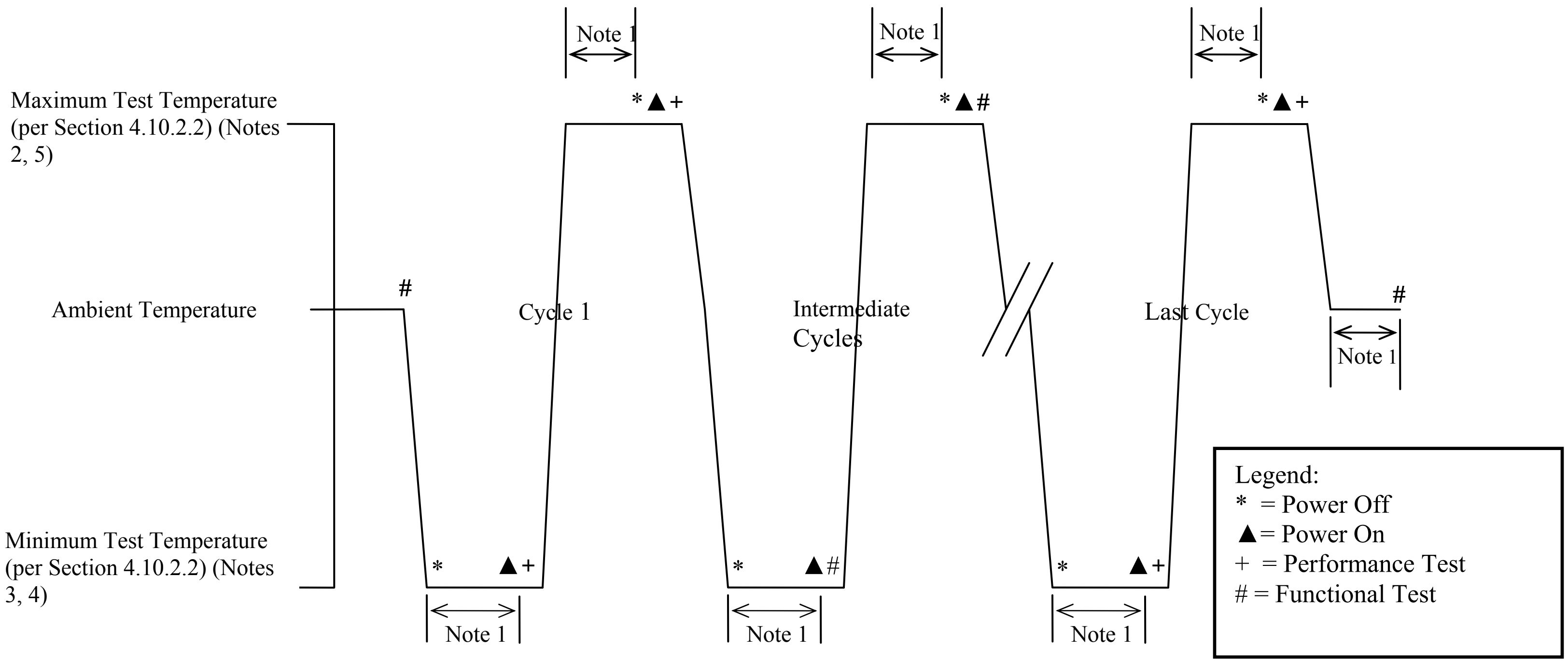
b. 22 °C (40 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has been properly accredited in accordance with CxP 70074, Constellation Program Modeling and Simulation Integrated Management Implementation Plan.

NOTE: This 22 °C level provides for 11 °C of uncertainty associated with the analytically-derived temperatures from an accredited model and an additional 11 °C of qualification margin.



Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of this test, but in no case shall it be less than 1 hr.
Note 2: Equal to or hotter than +71 °C (+160 °F) for electrical/electronic units.
Note 3: Equal to or colder than -54 °C (-65 °F) for electrical/electronic units.

FIGURE 4.10.2.2-1 QUALIFICATION THERMAL CYCLE TEST



Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of the thermal vacuum qualification test, but in no case shall it be less than 1 hr.

Note 2: Equal to or hotter than +60 °C (+140 °F) for electrical/electronic units.

Note 3: Equal to or colder than -43 °C (-45 °F) for electrical/electronic units.

Note 4: For nonelectrical/electronic units, the minimum temperature should be below -1.0 °C (30 °F) whenever possible.

Note 5: The total operational time at the maximum temperature condition for electrical/electronic units shall not be less than 200 hr. Operating time at maximum operating temperature during acceptance thermal vacuum testing may be included in the 200-hr requirement.

FIGURE 4.10.2.2-2 ACCEPTANCE THERMAL CYCLE TEST

c. 28 °C (50 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has not been properly accredited in accordance with CxP 70074.

NOTE: This 28 °C level provides for 17 °C of uncertainty associated with the analytically-derived temperatures from an unaccredited model and an additional 11 °C of qualification margin.

Acceptance: The minimum and maximum acceptance temperature limits shall be one of the following:

a. The minimum and maximum temperature levels specified in the applicable unit development specification.

b. 11 °C (20 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has been properly accredited in accordance with CxP 70074.

   NOTE: This 11 °C level provides for the uncertainty associated with the analytically-derived temperatures from an accredited model.

c. 17 °C (31 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has not been properly accredited in accordance with CxP 70074.

   NOTE: This 17 °C level provides for the uncertainty associated with the analytically-derived temperatures when using an unaccredited thermal model.

The above 11 °C and 17 °C uncertainties may be eliminated for units that have active thermal control (e.g., via heaters or fluid loops), provided that a heat-load margin of 25 percent is used to size the system.

For the purpose of workmanship screening, electrical/electronic units shall be subjected to acceptance test temperatures equal to or colder than -43 °C for the minimum test condition and no less than 60 °C for the maximum test condition. These values shall supersede the values of a, b, or c above when they are more severe.

4.10.2.3 Durations

Qualification: For nonelectrical/nonelectronic units: 8 temperature cycles minimum

For electrical/electronic units: 20 temperature cycles minimum

Acceptance: For nonelectrical/nonelectronic units: 4 temperature cycles minimum

For electrical/electronic units: 10 temperature cycles minimum

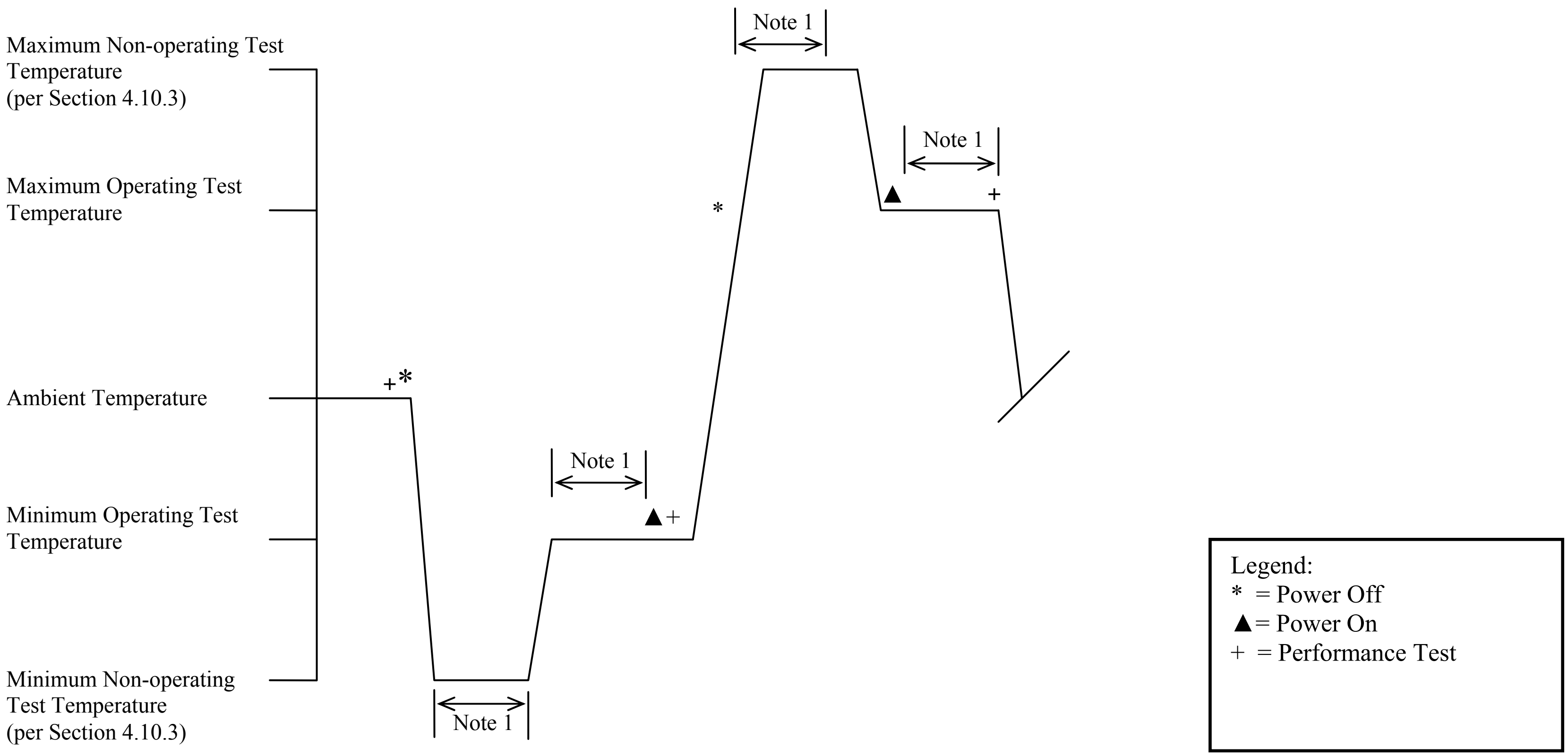
4.10.3 Supplementary Requirements

For acceptance testing, electrical/electronic units shall have power on and demonstrate failure-free operation at the hot temperature condition for 200-hr minimum. This 200-hr requirement may be achieved by extending the power on dwell periods across all hot cycles or by extending the dwell period on the next to last hot cycle. The 200 hr shall be equally split between primary and redundant circuits. Power-on time during exposure to the hot operational temperature during thermal vacuum testing may be included in the 200 hr.

A functional test in accordance with Section 4.2 shall be conducted at ambient temperature prior to and following the test. Units shall be cycled through various operational modes and monitored for failure or intermittent performance throughout the test with the following exceptions:

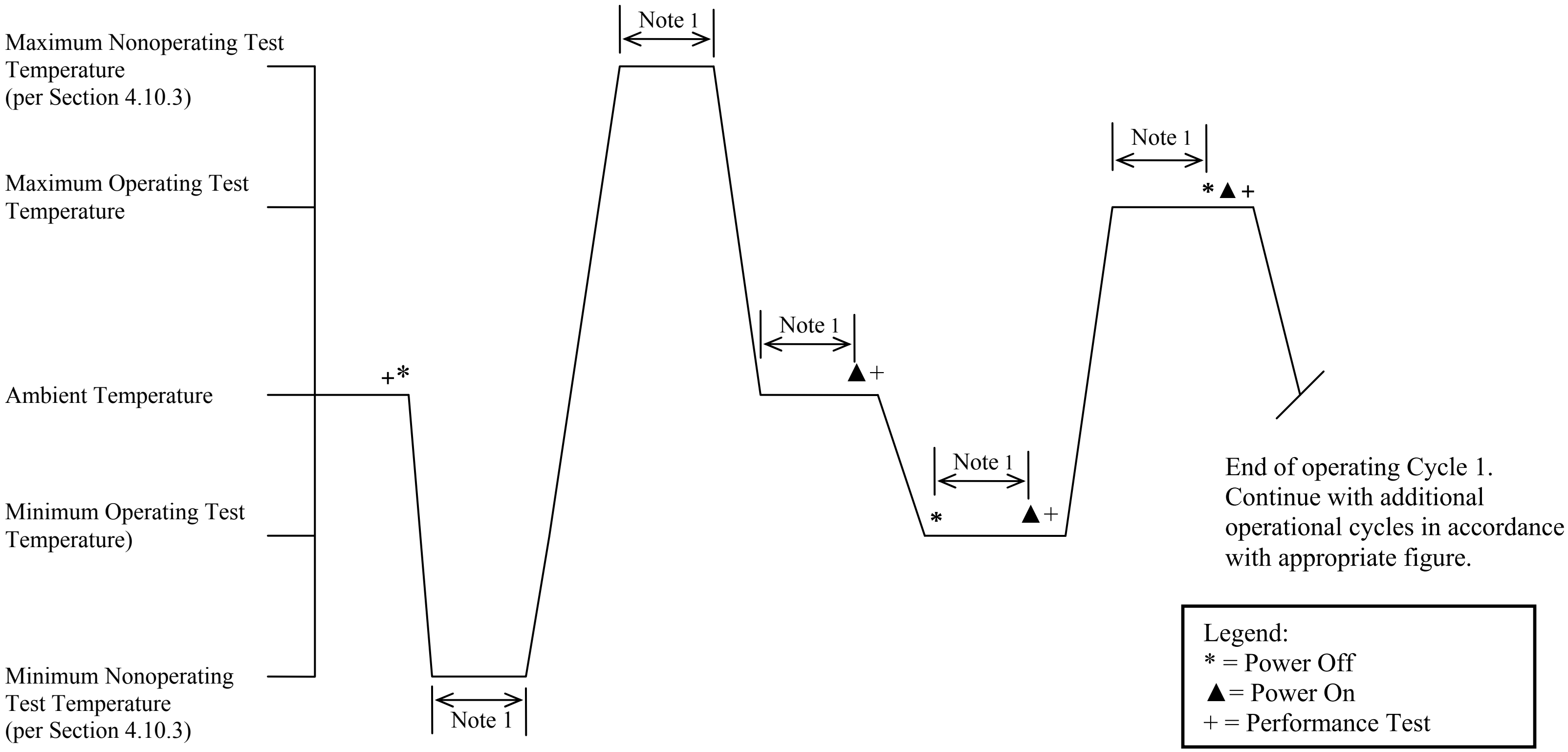
a. Electrical power shall be turned off at the times indicated in figures 4.10.2.2-1 and 4.10.2.2-2.

During qualification and acceptance testing, units shall undergo performance tests in accordance with Section 4.2 at the maximum and minimum test temperatures on the first and last cycles after internal thermal equilibrium has been achieved. The performance test at the high temperature shall occur after the power-off/power-on cycle that occurs after thermal equilibrium is achieved (reference figures 4.10.2.2-1, 4.10.2.2-2, 4.10.3-1, and 4.10.3-2). A functional test in accordance with Section 4.2 shall be conducted on intermediate cycles at each temperature extreme after thermal equilibrium is achieved. These functional and performance tests shall include the operation of any manual modes regardless of whether they are primary or backup modes of operation, and they shall be operated in a manner consistent with the operation in service. Perceptive monitoring shall be performed during thermal transition to identify intermittent or anomalous conditions.



Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of this test, but in no case shall it be less than 1 hr.

FIGURE 4.10.3-1 COMBINING FIRST NONOPERATIONAL CYCLE WITH FIRST OPERATIONAL CYCLE



Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of this test, but in no case shall it be less than 1 hr.

FIGURE 4.10.3-2 SEPARATE NONOPERATIONAL CYCLES PRECEDING FIRST OPERATIONAL CYCLE

b. When the unit development specification specifies nonoperating temperatures in excess of the operational temperatures, the thermal cycle tests shall include exposure to the nonoperational temperature(s). For acceptance testing, one nonoperational temperature cycle shall be performed. For qualification, two nonoperational temperature cycles shall be performed. Nonoperational temperature cycles shall either precede the operational temperature cycles or be combined with the first operational temperature cycles (reference figures 4.10.3-1 and 4.10.3-2).

c. The test temperature conditions for qualification and acceptance testing for nonoperational temperatures shall be as specified in Section 4.10.2.2. If the unit is also required to undergo a thermal vacuum test in accordance with Section 4.11, this nonoperational cycle may be conducted during the thermal vacuum test, but is not required to be performed during both tests.

d. Units that have fluids flowing through them and are required to operate over a fluid inlet temperature range of 11 °C (20 °F) or greater shall be tested using a fluid flow inlet temperature that varies between the minimum and maximum inlet temperatures during performance tests on the first and last cycle. During the remainder of the test, the inlet fluid temperature may be the nominal inlet temperature level.

e. Appropriate measures shall be taken to ensure against condensation on and inside the unit during the test at low temperature. This test may be conducted at reduced pressure conditions (including vacuum) and combined with the thermal vacuum test specified in this document, provided that the temperature requirements (including rate of temperature change and dwell periods for electrical/electronic units) comply with test requirements.

4.11 UNIT THERMAL VACUUM TEST

The unit thermal vacuum qualification test verifies the ability of the unit to perform as required in a thermal vacuum environment. The unit acceptance thermal vacuum test applies thermal and vacuum stresses to facilitate propagation of latent defects to failure.

Corona/arcing tests, including multipaction (as defined in CxP 70080), should be combined with this thermal vacuum test (or the depressurization/repressurization test described in Section 4.15) whenever possible.

4.11.1 Test Description

The unit shall be mounted in a vacuum chamber on a thermally-controlled heat sink or in another manner representative of the flight installation. Hermetically-sealed units shall be oriented in thermal vacuum testing to minimize the effect of natural convection (i.e., the effect of gravity).

The unit shall be instrumented with one or more (one backup recommended) temperature sensors mounted in locations corresponding to representative locations on the unit thermal model. One or more of these sensors shall be selected to serve as control sensors for the test and used to confirm compliance with the temperature requirements defined in Section 4.11.2.2.

a. With the unit and chamber at ambient conditions, the chamber pressure shall be reduced to the specified vacuum level per Section 4.11.2.1.

b. The unit shall then be brought to the specified low test temperature per Section 4.11.2.2. For hardware safety, margin should be included between the low test temperature and the lowest acceptable exposure temperature for the hardware.

c. The power should be turned off before reaching the test temperature to prevent low-temperature spikes.

d. The unit shall then be maintained at the low-temperature condition until internal thermal equilibrium is achieved.

e. Electrical power shall then be reapplied, and the unit temperature shall then be raised to the high test temperature level per Section 4.11.2.2.

f. The unit shall then be maintained at the high-temperature condition until internal thermal equilibrium is achieved.

g. Electrical and electronic units shall then be powered off for a time period sufficient to allow electrical circuits to discharge, and then the unit(s) shall be powered back on. Temperature cycles are specified in Section 4.11.2.3.

NOTE: Alternatively, the test may begin with the hot cycle first followed by cold, but in all cases appropriate measures shall be taken to preclude condensation of moisture on and around the TA during chamber repressurization.

4.11.2 Test Levels and Durations

4.11.2.1 Pressure Levels

For equipment required to operate under space vacuum conditions, the pressure shall be at or below 0.01333 Pa (1 x 10^{-4} torr). If hardware is covered by multi-layered insulation, the pressure shall be at or below 0.001333 Pa (1 x 10^{-5} torr). Otherwise, the pressure shall be at or below the minimum operational pressure specified in the applicable unit development specification.

If the depressurization/repressurization requirements are to be satisfied during thermal vacuum testing, the time rate of pressure change shall be equal to or greater than the development specification requirements.

4.11.2.2 Temperature Levels

The unit temperature change rate during acceptance and qualification thermal vacuum testing shall be no less than the maximum rate of change specified in the applicable unit development specification or as predicted by an accredited thermal math model. The average temperature change rate shall be a minimum of 1 °C per minute (1.8 °F per minute). At each temperature extreme on each cycle, the unit shall undergo a dwell period sufficient to achieve internal thermal equilibrium; however, in no case shall the dwell period be less than 1 hr.

Qualification: For units required to undergo an acceptance thermal vacuum test, the minimum and maximum thermal vacuum qualification test temperatures shall be 11 °C (20 °F) beyond the minimum and maximum acceptance thermal vacuum test temperatures.

For units not requiring an acceptance thermal vacuum test, the minimum and maximum qualification test temperatures shall be one of the following:

a. 11 °C (20 °F) beyond the minimum and maximum temperatures specified in the applicable unit development specification.

b. 22 °C (40 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has been properly accredited in accordance with CxP 70074.

   NOTE: This 22 °C level provides for 11 °C of uncertainty associated with the analytically-derived temperatures from an accredited model and an additional 11 °C of qualification margin.

c. 28 °C (50 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has not been properly accredited in accordance with CxP 70074.

   NOTE: This 28 °C level provides for 17 °C of uncertainty associated with the analytically-derived temperatures from an unaccredited model and an additional 11 °C of qualification margin.

Acceptance: The minimum and maximum acceptance temperature limits shall be one of the following:

a. The minimum and maximum temperature levels specified in the applicable unit development specification.

b. 11 °C (20 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification.

   NOTE: This 11 °C level provides for 11 °C of uncertainty associated with the analytically-derived temperatures from an accredited model.

c. 17 °C (31 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has not been properly accredited in accordance with CxP 70074.

   NOTE: This 17 °C covers the uncertainty associated with the analytically-derived temperatures when using an unaccredited thermal model.

The above 11 °C and 17 °C uncertainties may be eliminated for units that have active thermal control (e.g., via heaters or fluid loops), provided that a heat-load margin of 25 percent is used to size the system.

For the purpose of workmanship screening, electrical/electronic units shall be subjected to acceptance test temperatures equal to or colder than -43 °C for the minimum test condition and no less than 60 °C for the maximum test condition. These values shall supersede the values of a, b, or c above when they are more severe.

4.11.2.3 Durations

Qualification: 8 temperature cycles minimum

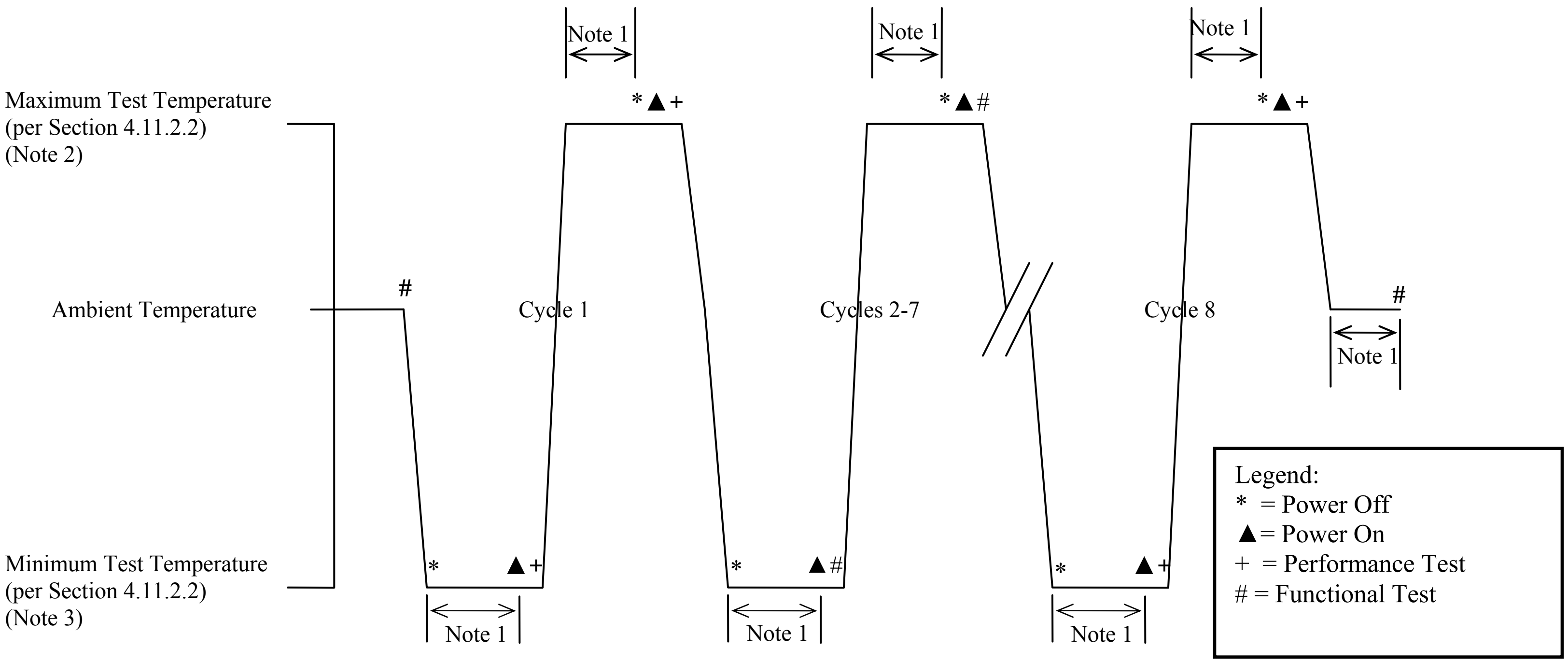
Acceptance: 4 temperature cycles minimum

4.11.3 Supplementary Requirements

A functional test in accordance with Section 4.2 shall be conducted at ambient temperature prior to and following the test. Units shall be cycled through various operational modes and monitored for failure or intermittent performance throughout the test with the following exceptions:

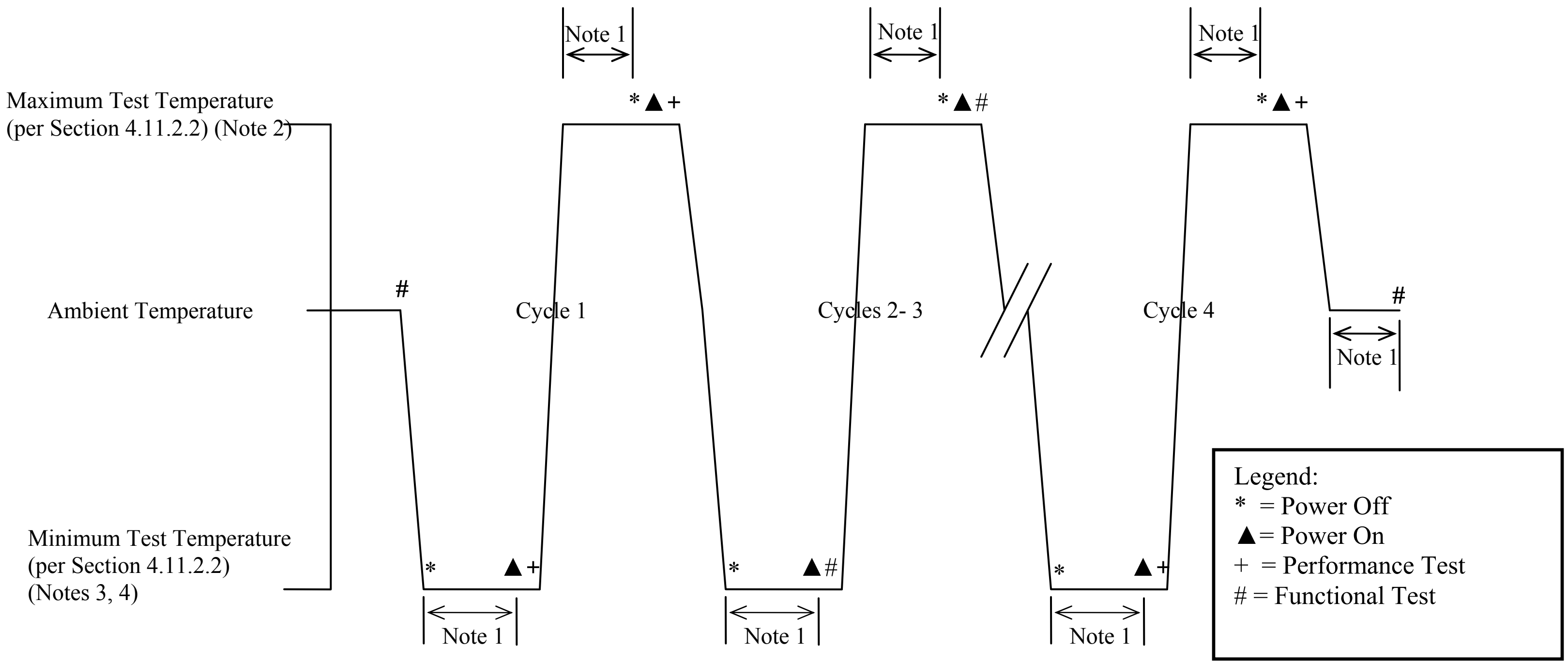
a. Electrical power shall be turned off at the times as indicated in figures 4.11.3-1 through 4.11.3-4.

b. Units required to be powered during a pressure change from ambient to reduced pressure or vice versa shall be required to be powered during this test during chamber evacuation and/or repressurization.



Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of this test, but in no case shall it be less than 1 hr.
Note 2: Equal to or hotter than +71 °C (+160 °F) for electrical/electronic units.
Note 3: Equal to or colder than -54 °C (-65 °F) for electrical/electronic units.

FIGURE 4.11.3-1 QUALIFICATION THERMAL VACUUM TEST



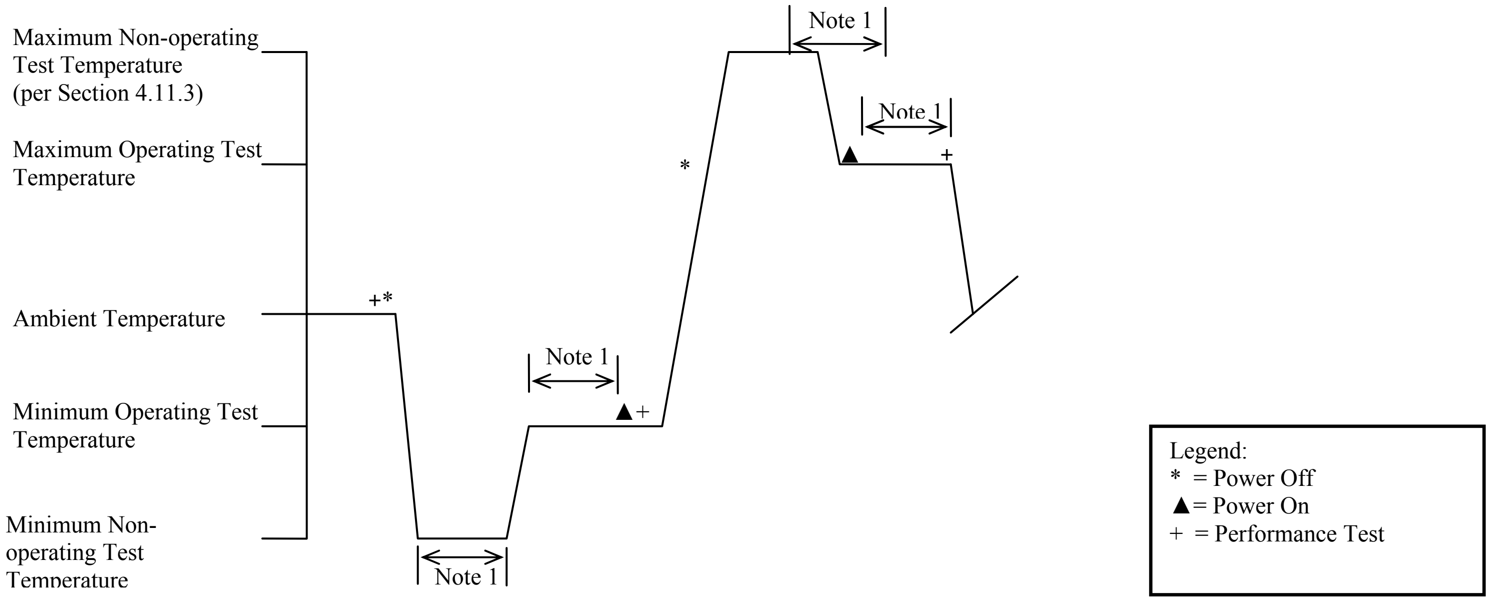
Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of the thermal vacuum qualification test, but in no case shall it be less than 1 hr.

Note 2: Equal to or hotter than +60 °C (+140 °F) for electrical/electronic units.

Note 3: Equal to or colder than -43 °C (-45 °F) for electrical/electronic units.

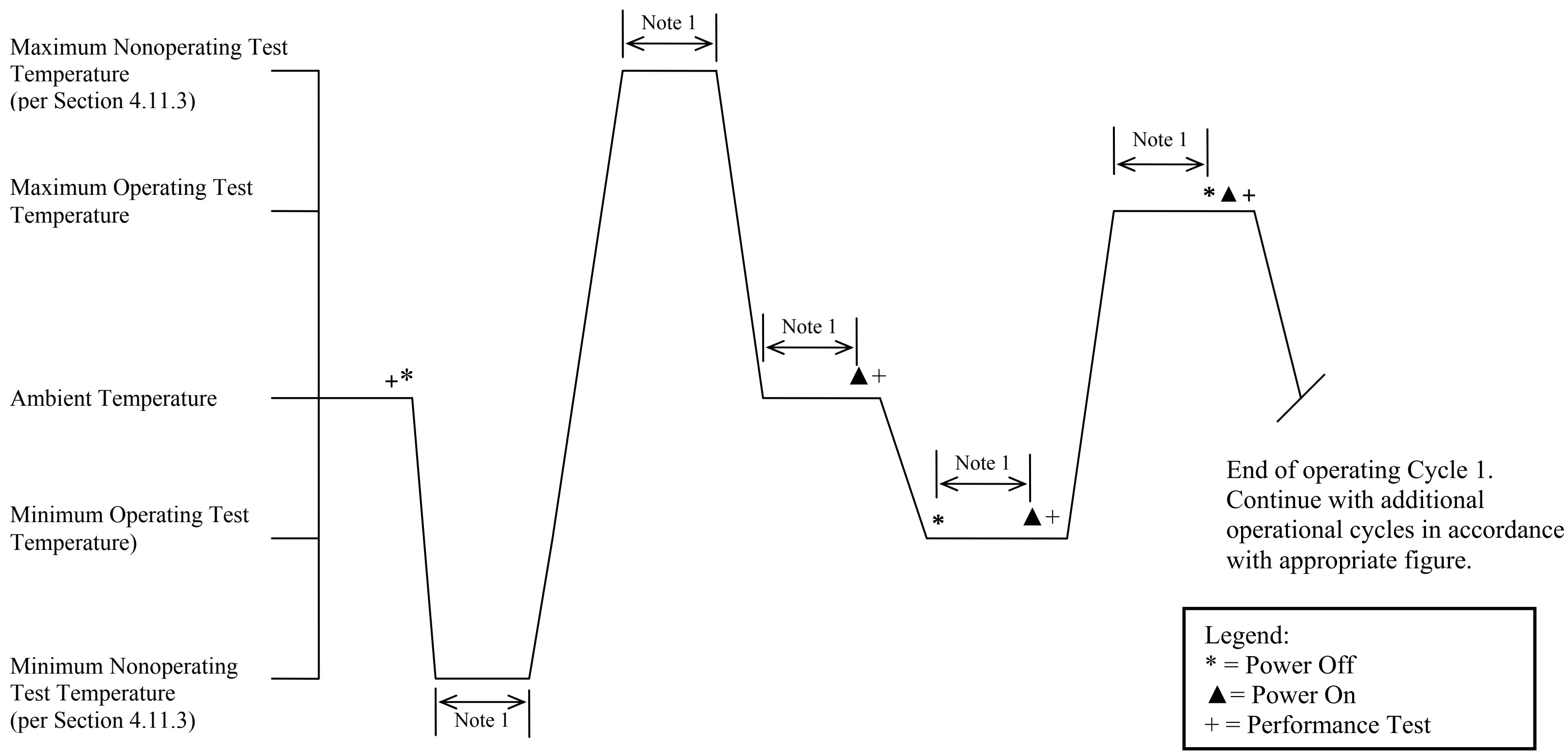
Note 4: For nonelectrical/electronic units, the minimum acceptance test temperature should be below -1 °C (30 °F) whenever possible.

FIGURE 4.11.3-2 ACCEPTANCE THERMAL VACUUM TEST



Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of this test, but in no case shall it be less than 1 hr.

FIGURE 4.11.3-3 COMBINING FIRST NONOPERATIONAL CYCLE WITH FIRST OPERATIONAL CYCLE



Note 1: The minimum dwell period at each temperature extreme shall be the time required for the unit to reach internal thermal equilibrium. This may be determined from development testing or from measurements taken on the first cycle of this test, but in no case shall it be less than 1 hr.

FIGURE 4.11.3-4 SEPARATE NONOPERATIONAL CYCLES PRECEDING FIRST OPERATIONAL CYCLE

c. During qualification and acceptance testing, units shall undergo performance tests in accordance with Section 4.2 at the maximum and minimum test temperatures on the first and last cycles after internal thermal equilibrium has been achieved. The performance test at the high temperature shall occur after the power-off/power-on cycle that occurs after thermal equilibrium is achieved (reference figures 4.11.3-1 through 4.11.3-4). A functional test in accordance with Section 4.2 shall be conducted on intermediate cycles at each temperature extreme after thermal equilibrium is achieved.

d. These functional and performance tests shall include the operation of any manual modes regardless of whether they are primary or backup modes of operation, and they shall be operated in a manner consistent with the operation in service. Perceptive monitoring shall be performed during thermal transition to identify intermittent or anomalous conditions.

e. For units containing optical equipment, thermal control equipment or composite structures, strategically placed witness plates, quartz crystal microbalances, or other instrumentation shall be installed in the test chamber to measure the outgassing from the unit and test equipment.

f. When the unit development specification specifies nonoperational temperatures in excess of the operational temperatures, the thermal vacuum tests shall include a minimum of one cycle of exposure to the nonoperational temperature(s) for acceptance testing and two cycles for qualification. This nonoperational temperature cycle shall either precede the operational temperature test or be combined with the first operational temperature cycle (reference figures 4.11.3-3 and 4.11.3-4). The test temperature conditions for qualification and acceptance testing for nonoperational temperatures shall be as specified in Section 4.11.2.2. These nonoperational temperature cycles are not required during thermal vacuum testing if they are performed during thermal cycle testing (see Section 4.10.3 letter c).

g. Units that have fluids flowing through them and are required to operate over a fluid inlet temperature range of 11 °C (20 °F) or greater shall be tested having a fluid flow inlet temperature varied between the minimum and maximum inlet temperatures during performance tests on the first and last cycle. During the remainder of the test, the inlet fluid temperature may be the nominal inlet temperature level.

4.12 UNIT THERMAL GRADIENT TEST

The unit thermal gradient test verifies the capability of units to operate in the design thermal environment that may induce thermal gradients across or between assemblies.

4.12.1 Test Description

The unit shall be configured in a manner representative of the flight installation. The unit shall be instrumented with one or more temperature sensors (one backup recommended) mounted in locations corresponding to representative locations on the unit thermal model. One or more, as appropriate, of these sensors shall be selected to serve as control sensors for the test and shall be used to confirm compliance with the temperature conditions specified in Section 4.12.2.2.

For units such as docking mechanisms that are required to mate and/or de-mate while exposed to thermal gradients, a mate/de-mate test shall be performed. One half of the interface shall be conditioned to the minimum operating temperature condition and maintained until thermal equilibrium is achieved. The other half of the mechanism shall be conditioned to the maximum operating temperature condition and maintained until thermal equilibrium is achieved. The units shall then be configured for all of the different operational modes and monitored in each case for acceptable performance. Acceptable performance shall be as required per the applicable unit development specification. Known structural deflections and potential misalignments may be simulated with special test equipment, including items such as six-degrees-of-freedom tables.

Units that have close tolerances or other design features or characteristics whose proper functioning may be impaired by thermal gradients across the unit shall undergo a thermal gradient test. The unit shall be thermally conditioned to the specified test conditions and then undergo a functional test in accordance with Section 4.2.

4.12.2 Test Levels and Durations

4.12.2.1 Pressure Levels

For equipment required to operate under space vacuum conditions, the pressure shall be 0.01333 Pa (1 x 10^{-4} torr) maximum. If hardware is covered by multi-layered insulation, the pressure shall be 0.001333 Pa (1 x 10^{-5} torr). Otherwise the pressure shall be at or below the minimum operational pressure specified in the applicable unit development specification.

4.12.2.2 Temperature Levels

Qualification: For units required to undergo an acceptance thermal gradient test, the thermal gradient qualification delta test temperatures shall be 11 °C (20 °F) beyond the acceptance thermal gradient test delta temperature.

For units not requiring an acceptance thermal gradient test, the qualification test delta temperature shall be one of the following:

a. 11 °C (20 °F) beyond the maximum delta temperature specified in the applicable unit development specification.

b. 22 °C (40 °F) beyond the maximum delta temperature as derived analytically from the thermal environments specified in the development specification.

NOTE: This 22 °C level provides for 11 °C of uncertainty associated with the analytically-derived temperatures from an accredited model and an additional 11 °C of qualification margin.

c. 28 °C (50 °F) beyond the maximum delta temperature as derived analytically from the thermal environments specified in the development specification.

NOTE: This 28 °C level provides for 17 °C of uncertainty associated with the analytically-derived temperatures from an unaccredited model and an additional 11 °C of qualification margin.

Acceptance: The acceptance test delta temperature shall be one of the following:

a. As specified in the applicable development specification.

b. 11 °C (20 °F) beyond the maximum delta temperature as derived analytically from the thermal environments specified in the development specification.

NOTE: This 11 °C level provides for 11 °C of uncertainty associated with the analytically-derived temperatures from an accredited model.

c. 17 °C (31 °F) beyond the maximum delta temperature as derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has not been properly accredited in accordance with CxP 70074.

NOTE: This 17 °C level provides for the uncertainty associated with the analytically-derived temperatures when using an unaccredited thermal model.

4.12.2.3 Durations

The number of functional cycles for all tests shall cover all representative service conditions of functional operations and thermal gradients.

4.12.3 Supplementary Requirements

Multiple runs shall be performed with different thermal gradients across the unit where such differing thermal gradient conditions can exist for the unit's functional operation during ground operations or the mission.

4.13 UNIT CORONA/ARCING TEST

Monitoring for corona, arcing, and multipaction as required by CxP 70080, should be performed during the thermal vacuum or depressurization/repressurization testing defined in this document.

4.14 UNIT PLASMA/ARCING TEST

Reference CxP 70080 for plasma arcing test requirements. The plasma tests should be performed during thermal vacuum testing defined in this document.

4.15 UNIT DEPRESSURIZATION/REPRESSURIZATION TEST

The unit depressurization/repressurization test verifies the unit's capability to survive or operate during depressurization and repressurization cycles during its service life.

4.15.1 Test Description

Units shall be subjected to a depressurization and repressurization test if the unit is required to operate in or survive a depressurization/repressurization event in its service life per the applicable unit development specification.

4.15.1.1 Operating

a. The unit shall be mounted in a vacuum chamber in a manner that simulates the flight installation.

b. With the unit powered up and operating, the chamber pressure shall be reduced from ambient to the specified lowest level at a rate consistent with the worst-case operational depressurization event as defined by the applicable development specification. Caution should be taken to not create a more severe differential pressure than required by the applicable specification, which could be harmful to the hardware (e.g., chamber pressure decreasing faster than the box can vent creating an excessive differential pressure across the unit).

c. The unit shall be allowed to stabilize at the chamber conditions.

d. A performance test in accordance with Section 4.2 shall be conducted at the low pressure test condition consistent with specification requirements.

e. The chamber shall then be returned to ambient conditions at a rate consistent with the worst-case repressurization rate as defined by the applicable specification. Caution should be taken to not exceed the design repressurization rate, which could create a negative differential pressure, thus imploding the unit.

4.15.1.2 Power-down

a. The unit shall be mounted in a vacuum chamber in a manner simulating the flight installation.

b. The chamber pressure shall be reduced from ambient pressure to the specified lowest pressure level.

c. If the unit is automatically powered down during the mission, the auto power-down function shall be verified, otherwise manually remove power.

d. The unit shall be monitored until its minimum operating pressure is reached. As the chamber is being repressurized, the unit shall be powered on when its minimum operating pressure level is reached within the chamber.

e. If power is automatically restored during repressurization, this function shall be verified.

f. Perceptive monitoring shall be performed during all powered operations to identify anomalous conditions.

g. The chamber shall then be returned to ambient conditions.

4.15.2 Test Levels and Durations

The unit shall be held at the specified low pressure level for a sufficient duration to ensure that any outgassing or internal pressure leakage has stabilized and to demonstrate required performance, but not less than 12 hr.

For acceptance testing, one depressurization/repressurization cycle shall be performed. For qualification testing, the number of depressurization/repressurization cycles shall be twice the number of depressurization/repressurization cycles required by the applicable unit development specification.

4.15.3 Supplementary Requirements

For the operating test condition defined by Section 4.15.1.1, only those functions that are required under a depressurized condition need to be demonstrated during the low pressure test condition.

A thermal vacuum qualification test, in accordance with Section 4.11, may be substituted for the depressurization/repressurization qualification test if the requirements of the depressurization/repressurization test can be met (e.g., pressure rate-of-change).

For units undergoing an operating test in accordance with Section 4.15.1.1, performance tests in accordance with Section 4.2 shall be conducted on the first and last cycles while at the low pressure test condition. Functional tests in accordance with Section 4.2 shall be required on all intermediate cycles while at the low pressure test condition. Throughout the remainder of the test, the unit shall be operated through various operational modes including power-off/power-on cycles, if required.

4.16 CLIMATIC TESTS

The following tests are typically for qualification only:

a. rain

b. salt fog

c. sand, dust, and lunar/Martian regolith

d. humidity

e. explosive atmosphere compartment

The explosive atmosphere compartment test may be required as an acceptance test if the released energy potential exceeds specified values. These tests demonstrate the unit’s capability to survive exposure to various climatic conditions without excessive degradation or to operate during exposure, as applicable. Exposure conditions shall include those imposed upon the unit during fabrication, test, shipment, storage, mission operations, entry, recovery, and refurbishment.

To the greatest extent practical, the flight hardware should be protected from the potentially degrading effects of extreme terrestrial natural environments by procedural controls and special support equipment. In these cases, the protective measures must be verified to adequately protect the flight hardware. Qualification testing shall be conducted for any remaining environmental conditions (as specified in CxP 70023) that are not mitigated by the protective measures.

4.16.1 Rain

4.16.1.1 Test Description

Buildup of the TA shall be representative of the actual as-fielded configuration without any temporary sealants. At least one water spray nozzle shall be used for each 0.5 m^2

(5.4 ft^2) of surface area, and each nozzle shall be positioned at 0.5 m (20 in) from the test surface. Nozzles shall produce a square spray pattern or other overlapping pattern (for maximum surface coverage) and droplet size predominantly in the 2 to 4.5 mm diameter range at approximately 276 kPa gauge pressure (40 psig).

4.16.1.2 Test Levels and Durations

The initial temperature difference between the TA and the spray water shall be a minimum of 10 °C (18 °F). For temperature-controlled units, the temperature difference between the TA and the spray water shall at least be that between the maximum control temperature and the coldest rain condition in the field.

The test duration shall be determined from an analysis of the service life exposure of the unit to rain. All exposed faces shall be sprayed for at least twice the expected duration, but for no less than 40 minute intervals. The TA's interior shall be inspected for water penetration at the end of each 40 minute exposure. Evidence of water penetration shall constitute a failure.

4.16.1.3 Supplementary Requirements

Reference MIL-STD-810F, Method 506.4, Procedure II for further definition of the test.

4.16.2 Salt Fog

4.16.2.1 Test Description

Buildup of the TA shall be representative of the actual as-fielded configuration. A water solution with 5 ± 1 percent sodium chloride concentration by weight shall be used. The temperature of the exposed hardware shall be maintained at 35 ± 2 °C (95 ± 4 °F). The TA support structure shall not affect the characteristics of the salt fog mist. All parts of the test setup that contact the TA shall not cause electrolytic corrosion. Condensation shall not drip onto the TA. Any liquid that comes into contact with either the chamber or the test item shall not be returned to the salt solution reservoir.

The salt solution reservoir, atomizing nozzles, and piping system shall be made of material that is nonreactive to the salt solution. These atomizers shall inject the salt solution into the chamber to produce a finely divided, wet, dense fog. A minimum of two salt fog collection receptacles shall be used. One receptacle shall be located at the perimeter of the test item nearest the nozzle. The other receptacle shall be located at the perimeter of the TA, but at the farthest point from the nozzle. The receptacles shall be positioned such that they are not shielded by the TA and will not collect drops from the TA or from other sources.

The pH of the salt solution, as collected as fallout in the exposure chamber, shall be maintained between 6.5 and 7.2 with the solution temperature at 35 ± 2 °C (95 ± 4 °F). At a minimum, the pH shall be checked at 24-hr intervals.

Visual inspection of the TA and functional checkout shall be performed prior to the test. The TA shall be conditioned in the test chamber at 35 ± 2 °C (95 ± 4 °F) for a minimum of 2 hr prior to introduction of the salt fog.

4.16.2.2 Test Levels and Durations

Alternating 24-hr periods of salt fog exposure and drying conditions for a minimum of four 24-hr periods (two wet and two dry) shall be the minimum test duration. The air velocity in the test chamber shall be essentially zero. The salt fog fallout rate shall be such that each receptacle collects from 1 to 3 ml of solution per hr for each 80 cm^2 (12.5 in^2) of horizontal collecting area (10-cm diameter circle). The fallout rate shall be between 1 and 3 ml/80 cm^2/hr. During the 24-hr drying periods, the test chamber shall remain at ambient temperature with a Relative Humidity (RH) of 50 percent or less. The TA shall not be disturbed during the drying period.

4.16.2.3 Supplementary Requirements

Subsequent to the test, the TA shall be functionally tested and shall be physically inspected for salt deposits, moisture collection, and corrosion per MIL-STD-810F, Paragraph 509.4.

4.16.3 Sand, Dust, or Regolith

4.16.3.1 Test Description

Qualification testing shall be performed for external hardware or internal habitable volumes where lunar/planetary/terrestrial dust or sand is expected to be deposited or to settle. Qualification testing verifies that detrimental effects do not result from exposure to or introduction of sand, dust, or regolith. These tests are performed to demonstrate that hardware can provide fully specified performance during and after experiencing the cumulative effects of exposure to sand, dust, or regolith.

The potential effects of exposure to any form of sand, dust, or regolith will vary from subsystem to subsystem and unit to unit. Examples of effects are listed below:

a. Abrasion and erosion of surfaces

b. Penetration and degradation of seals

c. Degradation of electrical circuits

d. Obstruction/clogging of openings and filters

e. Physical interference with mating parts

f. Fouling/interference of moving parts

g. Reduction of thermal conductivity or radiation capability

h. Interference with optical characteristics

i. Overheating and fire hazard due to restricted ventilation or cooling

These potential effects of exposure to sand, dust, or regolith are determined during the design process. Consequently, each hardware item has a unique sand, dust, or regolith control requirement or a different susceptibility to sand, dust, or regolith contamination depending on the design configuration. This is particularly true of hardware exposed to lunar regolith.

As a result, no one test requirement can be defined that will be suitable for all hardware units. Further, this test shall not be required for hardware units protected from exposure to sand, dust, or regolith by contamination control procedures, protective shipping and storage containers, external filters, or covers. However, in cases where protections are in place, tests demonstrating the adequacy of those control measures shall be performed rather than a test on the hardware unit.

Figure 4.16.3.1-1 describes the notional process for establishing test requirements and procedures for demonstrating equipment resistance to sand, dust, or regolith.

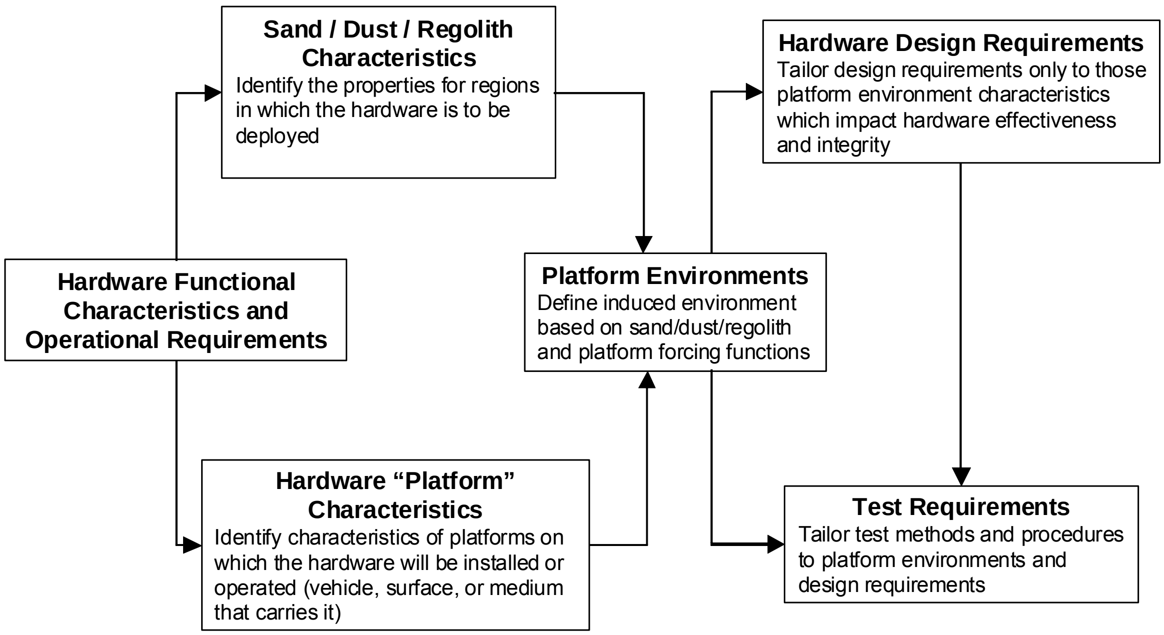


FIGURE 4.16.3.1-1 SAND, DUST, OR REGOLITH TEST REQUIREMENTS PROCESS

4.16.3.2 Test Levels and Duration

The TA shall be exposed to environmental test conditions that are appropriate and traceable to realistically encountered service life conditions as defined in CxP 70023. Verification by test shall be performed as follows:

a. Terrestrial: See MIL-STD-810F, Method 510.4, Procedures I and III (Blowing and Settling dust only) for guidance on determining the appropriate sand/dust composition and concentration.

b. Lunar: Regolith qualification testing shall use a lunar regolith simulant.

c. Martian: Regolith qualification testing shall use Martian regolith simulant.

The rate at which dust or sand will settle and the test duration will be determined by analysis of the lunar/planetary/terrestrial environment and of the operational scenarios, and it will be defined in the development specification.

4.16.3.3 Supplementary Requirements

This test shall be combined with the unit life test if the hardware must operate or is exposed to a lunar/planetary/terrestrial dust and sand environment throughout its operational life.

If exposure to terrestrial dust and sand is not precluded by environmental controls during processing, shipping, and operations, the unit shall be verified compliant to those environments during testing. Buildup of the TA shall be representative of the actual as-fielded configuration without any temporary sealants. Other environmental conditions may need to be combined with the dust and sand testing to qualify the unit, as specified, in the development specification.

Subsequent to the test, the TA shall be functionally tested and physically inspected for incursion of sand and dust, material degradation, jammed mechanisms, and corrosion per MIL-STD-810F, Paragraph 510.4.

4.16.4 Humidity (Moisture and Water Vapor Testing)

NOTE: Do not implement the following humidity test until a separate authorizing revision notice is approved. These requirements have been extensively reviewed by the aerospace community but have not been validated by actual testing. This section may be used for planning purposes as required.

Humidity testing qualifies hardware that may be exposed to high water vapor extremes and accumulation of moisture. High-moisture environments potentially cause the following problems:

a. Corrosion and electrical failures

b. Accelerated wear on moving parts

c. Infiltration of plastics and coatings

Corrosion, defined as “the destructive attack of a metal caused by either a chemical or an electrochemical reaction with the various elements in the environment,” is the primary failure mechanism of high concentrations of moisture.

This qualification test verifies the design features that protect equipment from the degrading effects of high concentrations of water vapor and exposure to condensate.

These environments are encountered during storage, transportation, ground operations, and flight.

Units installed in external vehicle applications will be exposed to natural diurnal cycles of high-temperature and high-moisture content followed by decreasing temperatures and the potential for condensing conditions. Units installed in interior applications, where there is typically human presence, will also see high humidity environments due to perspiration and exhaled water vapor. Cold-plate cooled equipment may be susceptible to condensation if powered off while cooling is being applied. Equipment or structure that can get colder than the dew point temperature of the surrounding air may also present a condensate dripping hazard to adjacent equipment.

The relationship of actual vapor density of air to the saturated vapor density of air at a given temperature (generally expressed as grams of moisture per cubic meter) is defined as RH. RH will vary as air temperature changes, with the same amount of incumbent moisture.

The following factors shall be considered when developing detailed test procedures.

There are three basic categories of units:

a. Electrical/electronic (vented chassis)

b. Electrical/electronic (hermetically sealed chassis)

c. Nonelectrical/electronic

The electrical/electronic units will have one or more of the following categories of thermal control:

a. Passive

b. Forced-air

c. Cold-plate

Hardware will typically be installed in one of the following operational environments:

a. Internal-controlled

b. Sheltered-uncontrolled

c. External-uncontrolled

The configurations defined above shall then be evaluated in the following three modes to determine worst-case test environments:

a. Mission (prelaunch, flight, landing, postlanding) - Unpowered

b. Mission (prelaunch, flight, landing, postlanding) - Powered

c. Nonoperational (storage, repair, transportation)

4.16.4.1 Test Description

Two basic humidity/moisture tests are required for electrical/electronic equipment that is exposed to high moisture content environments (Constant Temperature/Humidity/Bias [THB] test and the Cyclic THB test).

a. The Constant THB test provides an environment that assesses the potential for development of dendrites, which can induce failures. Functional testing is performed prior to the start of testing. Then the TA is subjected to high-moisture, high-temperature environments for extended durations while powered and monitored. It is then exposed to the high-moisture environment in an unpowered state to represent operationally quiescent periods and the storage and transportation environments.

b. The Cyclic THB test (see note below) assesses the ability of the product to operate reliably under high-humidity environments and potentially condensing conditions (dew point). The cyclic nature of this test increases the potential for electrochemical migration between insulated conductors. It also verifies that hermetic sealing properties are adequate for high-moisture conditions.

   After inspection and functional verification, the article is environmentally cycled while powered and monitored to represent potential service-life exposure. This test determines if intrusion or exposure to elevated atmospheric moisture impacts functional performance. Following completion of the high-humidity cycles, a performance test is performed to demonstrate that no degradation has occurred. A detailed physical inspection determines if corrosion, dendrite, moisture accumulation, or tin whisker growth is present.

   NOTE: Condensation occurs when the temperature of the TA is less than the dew point temperature of the surrounding environment. Condensation does not occur if the article’s temperature is 5 °C or greater than the ambient dew point temperature. If the unit is always powered and the delta T is always greater than 5 °C, then there is no value in performing the cyclic test. However, if there are periods of lower power consumption or periods when power is removed, then the cyclic test shall be performed.

Simplified versions of these tests are performed for nonelectrical/electronic equipment such as mechanical assemblies and optics. Nonelectrical/electronic TAs are subjected to high-moisture environments to ensure that they will survive service-life exposure to mission and non-mission environments. Corrosion susceptibility to high-moisture content is assessed under high- and low-temperature environments with operability verified by functional test during and after multiple cycles.

4.16.4.2 Test Levels and Durations

Initial Test Conditions are described below:

a. Install the TA in a chamber with the axis consistent with operational orientation and protected from dripping condensation sources unless this is a potential during operational use.

b. The chamber shall be vented to maintain site ambient pressure. For electrical/electronic units, power and instrumentation shall be connected and verified prior to test.

c. Apply baseplate or forced-air cooling, if required, at the minimum cooling levels (least amount of cooling) defined by the design specification. Apply power to electrical/electronic units.

d. Adjust the chamber temperature to 22 ± 1 °C and atmospheric moisture content at 10 ± 1 °C dew point (approximate RH of 50 percent). Allow parameters to stabilize.

e. Perform a functional test to ensure the article is properly operating at room ambient conditions.

The Constant THB (Static High Moisture Exposure) test conditions are described below:

a. Warm/Moist Ramp Powered

    1. Ramp the chamber conditions from ambient conditions to 40 °C +3/-0 °C.

    2. Raise the atmospheric moisture content to a dew point of 1 °C less than the atmospheric dry bulb temperature (approximate 93 percent RH, not to exceed 95 percent), maintaining constant chamber temperature and site ambient pressure. Perform this temperature/humidity ramp at a rate not to exceed the predicted platform rate and ensure that the atmospheric dew point does not exceed the TA temperature, causing condensation.

b. Warm/Moist Dwell Powered

1. Maintain the 40 °C +3/-0 °C and 93 +2/-0 percent RH for 12 +.25/-0 hr. Monitor for intermittent or anomalous behavior during the 12-hr period.

2. At the end of 12 hr, perform a functional test.

3. If the unit is actively cooled, adjust the cooling to maximum cooling mode for power-on conditions, as defined in the design specification. Maintain these conditions for 12 +0.25/-0.0 hr. Monitor for intermittent or anomalous behavior during the 12-hr period.

c. Return to Ambient: Reduce temperature to room ambient at no more than 3 °C ±1 °C per min average, while simultaneously reducing humidity levels such that condensation does not form while returning the chamber and TA to ambient conditions. Do not disturb or move the TA.

d. Posttest Inspection: Perform a functional test of the unit while the article is still installed in the chamber.

e. Simulate Multiple Exposures: Repeat the cycle (steps a thru d above) four more times for a total of five cycles.

The Cyclic THB (Operating Under Condensing Conditions) test conditions are described below:

NOTE: This test is only required for hardware that may experience condensing conditions.

a. Initial Test Conditions: Establish initial test conditions on the TA.

b. Minimum Operating Temperature

1. Adjust chamber temperature to minimum ground or compartment operating temperature level, as defined in the development specification +0/-3 °C, while maintaining RH at 50 percent or less.

2. Allow the temperature to stabilize for at least 1 hr. Continuously monitor the TA for intermittent or off-nominal performance.

c. Cold Atmosphere, Condensing Moisture

1. While maintaining the chamber atmospheric temperature at the stabilized cold-case level, inject moisture into the air stream until saturation occurs and condensation begins to form on the TA.

2. Continue to add moisture, as required, to maintain condensate on the TA.

3. Cycle the atmospheric temperature and moisture injection to maintain these conditions for 3 +.25/-0 hr.

4. Continuously monitor the TA for intermittent or anomalous performance.

d. Baseplate Active Cooled Only (Cold atmosphere, condensing moisture-maximum cooling)

1. While the TA is covered with condensate, decrease the baseplate temperature to maximum cold-case specified while continuing to add atmospheric water vapor to maintain condensate on the TA.

2. Cycle the atmospheric temperature and moisture injection to maintain these conditions for 3 +.25/-0 hr.

3. Continuously monitor the TA for intermittent or anomalous performance.

e. Functional Test (cold soaked unit exposed to saturated cold atmosphere while operating): Perform a functional test and monitor for anomalous conditions.

f. Unpowered Cold Soak: Remove power from the TA and maintain atmospheric conditions at the levels established in step c above for 3 +.25/-0 hr.

g. Cold Power Up (Cold Start [CS] and cold damp conditions): Apply power to the TA and perform a functional test.

h. Ramp to Warm/Moist Atmosphere (Condensing)

1. Ramp the chamber conditions to the maximum predicted operating temperature +3/-0 °C.

2. Increase the atmospheric moisture content of the test chamber to maintain saturation with 100 percent RH. Perform this temperature/humidity ramp at a rate not to exceed the predicted platform rate. The predicted humidity increase rate shall simulate the worst-case dew point transition from a daily diurnal cycle.

3. Maintain these conditions for 3 +.25/-0 hr. Continuously monitor the TA for intermittent or anomalous performance (cold, damp unit exposed to a warm, moisture-condensing environment, while operating).

i. Warm Case Power-On/Power-Off Condensing Cycle

1. Remove power from the TA and maintain active cooling to maximum levels specified in the development specification.

2. Maintain these conditions for 3 +.25/-0 hr.

3. Apply power and perform a functional test, monitoring for intermittent or anomalous performance.

j. Warm/Moist to Ambient Condensing Cycle

1. Ramp the chamber from the maximum operating temperature to room ambient temperature without adjusting moisture levels. Perform this temperature/pressure ramp at the maximum facility rate, not to exceed the predicted platform rate.

2. Maintain these conditions for 3 +.25/-0 hr. Continuously monitor the TA for intermittent or anomalous performance.

3. Following the 3-hr soak, perform a functional test monitoring for intermittent or anomalous performance.

k. Simulate Multiple Exposures: Repeat the cycle (steps a through k above) nine more times for a total of 10 cycles.

4.16.4.3 Supplementary Requirements

The pass/fail criteria for unit testing are primarily based on compliance with functional test requirements during and after exposure to high-moisture content environments. Visual inspection shall be performed within 1 hr of test completion. When the integrity of the unit may be permanently impaired by access cover removal, this moisture/humidity testing should be performed last in the sequence of testing, or the inspection should be deferred until all other testing is completed.

The following conditions are indicative of design deficiencies and shall be assessed following testing:

a. Dendrite growth (electrical/electronic units) - Inspection and functionality

b. Corrosion - Inspection and functionality

c. Tin whiskers - Inspection and functionality

d. Water intrusion - Verified by precise weight measurement or visual inspection prior to and following humidity testing.

4.16.5 Explosive Atmosphere Compartment

This test verifies that units operating in closed compartments, which may be subject to accumulations of leaking flammable gases, do not provide an ignition source. This test demonstrates that the unit is incapable of igniting the gasses either by electrical arc or surface temperatures of internal components or external surfaces. This test shall be applicable to all electrical and nonelectrical units that may serve as an ignition source within the compartment.

Surface temperatures of units and internal components are generally verified by analysis, but if the analysis is based on a nonvalidated model, testing shall be the primary method of design verification.

This test shall be performed for acceptance of hardware for units in compartments where accumulation of fuels could result in an ignition that creates a hazard to the vehicle, grounds systems, or personnel.

4.16.5.1 Test Description

The explosive atmosphere compartment test shall be performed in accordance with the explosion-proof test described in MIL-STD-810F, Method 511.4, except that it uses butane rather than hexane as a fuel.

4.16.5.2 Test Levels and Durations

None

4.16.5.3 Supplementary Requirements

None

4.17 UNIT OXYGEN COMPATIBILITY ACCEPTANCE TEST

This test exposes flight production units to the design oxygen environment before flight and screens them for workmanship and quality. Oxygen compatibility qualification is normally conducted by analysis per the requirements documented in NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft. Qualification testing is required only when the analysis results are uncertain. When qualification testing is required, the test shall be in accordance with NASA-STD-(I)-6001A, Flammability, Offgassing, and Compatibility Requirements and Test Procedures, Appendix A.6.

4.17.1 Test Description

Oxygen system units shall be exposed to 100 percent oxygen at the MDP as specified in the applicable unit development specification.

Functional tests, other than leakage, shall be conducted while the unit is pressurized with oxygen (e.g., functional tests include opening and closing of valves, connecting and disconnecting of quick disconnects). Units shall be subjected to oxygen flow in forward and reverse flow directions where reversible flow is within the operational capability of the unit.

4.17.2 Test Levels and Duration (Acceptance only)

4.17.2.1 Test Levels

Pressure: Ambient to MDP; if MDP is > 265 psia

Rate: The unit shall be subjected to oxygen pressurization cycles from ambient pressure to the specified MDP within 100 ms maximum.

4.17.2.2 Durations

Number of Cycles: 10 minimum

Duration of Cycles: During each pressure cycle, the unit shall be maintained at the MDP for a minimum of 30 s.

4.17.3 Supplementary Requirements

Oxygen compatibility testing shall be required for the following types of units that operate in a 100 percent gaseous or liquid oxygen environment. Testing is not required for any unit when MDP is below 265 psia.

a. Metal flex hoses with an MDP of ≥ 3,000 psia

b. Nonmetal lining flex hoses

c. Quick disconnects

d. Valves (including pressure relief valves)

e. Temperature, pressure, and flow sensors

f. Fluid fittings with nonmetallic seals

g. Pressure regulators

A functional test and leak test as specified in the unit specification shall be conducted after the oxygen compatibility acceptance test.

Visual inspection shall be performed after the oxygen compatibility acceptance test is conducted and shall be verified to the level specified in the unit specification. This visual inspection shall not require disassembly of the unit other than access ports or covers to aid internal inspection. Use of borescopes, special lighting, and magnification aids as needed to assess the integrity of the unit is permissible. If disassembly of the unit occurs after the oxygen compatibility acceptance test, the oxygen compatibility acceptance test shall be redone in full.

Cleanliness shall be maintained to the level specified in the assembly development specification. Hydrocarbon detection analysis shall be performed as specified in MSFC-PROC-404, Marshall Space Flight Center: Procedure, Gases, Drying and Preservation Cleanliness Level and Inspection Modes, prior to performing the oxygen compatibility test. When Isopropyl Alcohol (IPA) or other flammable solvents are used for cleaning, flushing, or testing any portion of an assembled gaseous oxygen system, the residual concentration of solvent must be verified within acceptable limits prior to the introduction of fluids for the oxygen compatibility test. After purging with an inert gas, a 24-hr “lock-up” of the system is required to ensure that enough time is provided for contaminant solvent to volatilize, thus achieving concentration equilibrium so that gas sampling will provide an accurate reflection of the residual solvent concentration. The solvent concentration in lock-up gas samples shall not exceed 18 ppm when measured as methane (CH_4).

4.18 UNIT LIFE TEST

The life test applies to units that may have a wear-out, drift, material decomposition, fatigue-type failure mode, or performance degradation. The test demonstrates that units have the capability to perform within specification limits for the maximum duration or cycles of operation during repeated ground testing and in flight. Life testing shall not be performed on flight hardware.

4.18.1 Test Description

The unit shall be set up to operate under the environmental conditions that it will be subjected to during its service life. These environmental conditions shall be selected for consistency with end-use requirements and the significant life characteristics of the particular unit. Typical environments are ambient, thermal extremes, thermal cycling, thermal vacuum, and vibration. The test shall be designed to demonstrate the ability of the unit to withstand the maximum operating time and the maximum number of operating cycles predicted during the unit’s service life with suitable margin. Any acceleration of the test conditions shall be adequately justified in the applicable test plan. Parameters shall be monitored throughout the test to ensure proper unit operation in accordance with the requirements of the applicable development specification.

4.18.2 Test Levels and Durations

4.18.2.1 Pressure Level

Ambient pressure shall be used except for unsealed articles where degradation due to a vacuum environment may be anticipated. In those cases, a pressure of less than 0.0133 Pa (1 x 10^{-4} torr) shall be used. If the hardware is covered by multi-layer insulation, the pressure shall be at or below 0.001333 Pa (1 x 10^{-5} torr).

4.18.2.2 Environmental Levels

The extreme predicted environmental levels shall be used as defined in the applicable unit development specification. For accelerated life tests, environmental levels may be selected that are more severe than specification levels if the resulting increase in the rate of degradation is well established and unrealistic failure modes are not introduced. The applicable test plan shall provide clear and complete justification for any test acceleration strategy used.

4.18.2.3 Durations

The total operating time or number of operational cycles for a unit life test shall be a minimum of twice that predicted during its service life (including ground testing) to demonstrate adequate margin. The test duration shall be at least four times the specified service life for units that have a fatigue-type failure mode and for safety-critical soft goods (e.g., straps, cords, and structural cables).

4.18.2.4 Functional Duty Cycle

At a minimum, performance tests shall be conducted in accordance with Section 4.2 immediately upon the start of the life test and at the very conclusion of the life test. Functional tests shall also be conducted in accordance with Section 4.2 at established periods throughout the test based on time of operation or number of cycles, as appropriate, to demonstrate acceptable unit operation. Perceptive monitoring shall be conducted continuously throughout the remainder of the test to ascertain that the unit is functioning within specification limits and to establish trends.

4.18.3 Supplementary Requirements

For statistically-based life tests, the duration is dependent upon the number of samples, confidence levels, and reliability requirements to be demonstrated.

Mechanisms shall be disassembled and inspected for anomalous conditions at the end of the life test or earlier if warranted. The critical areas of parts that may be subject to fatigue failure shall be inspected to determine their integrity.

Life testing shall be required for pressure vessels using bellows or other flexible fluid-delivery devices or lines. Life testing on a lot basis shall be performed for silver-zinc batteries to verify capacity and voltage response at the end of wet stand life for at least one charge cycle.

5.0 MAJOR ASSEMBLY TEST BASELINE

This section defines the qualification and acceptance testing for major assemblies. A major assembly is characterized by its size, complexity, weight, and ability to perform a unique set of functions. For a detailed definition of major assembly, reference Appendix A.

The hardware developer is required to develop a major assembly test program in accordance with the requirements specified in tables 5-1 and 5-3. The recommended order of testing is defined in tables 5-2 and 5-4 for acceptance testing. Some tests identified in these tables are not governed by this document, but should be tested in the correct order to ensure maximum effectiveness.

TABLE 5-1 MAJOR ASSEMBLY QUALIFICATION TEST BASELINE

Test (3)	Earth Launch Assy(s)	Lunar/Mars Surface Assy(s)	Space Assy(s)
Functional/Performance (1)	R	R	R
Leak	R	R	R
Shock	R	ER	R
Random Vibration (2)	ER	ER	R
Acoustic Vibration (2)	ER	ER	R
High-Force Vibration (2)	ER	ER	R
Thermal Vacuum	-	ER*	R
Thermal Balance	-	ER*	R
Climatic (4)	ER	ER	ER

LEGEND: Reference figure 3.1-1 for explanation of R, ER, and ER* designations. The dashes mean the test is generally not required unless specific aspects of the unit design, sensitivity to environment, or environmental severity warrant conducting the test.

NOTES:

(1) A performance test shall be the first and last test conducted for the baseline qualification program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall qualification test sequence.

(2) Either 1) a random vibration test, 2) an acoustic test plus high-force vibration test, or 3) all three tests are required, as applicable.

(3) This testing is performed at the largest practical level of assembly.

(4) Primarily only for items exposed to terrestrial environments. See Section 5.10 for specific applications.

TABLE 5-2 MAJOR ASSEMBLY QUALIFICATION RECOMMENDED TEST SEQUENCE

Test	Sequence	Requirement Document	Document Section
Functional/Performance (1)	1, 12	CxP 70036	5.1
Proof Pressure	2	CxP 70135	
Leak	3, 6, 9	CxP 70036	5.2
EMC (3)	4, 10	CxP 70080	
Random Vibration (2)	5	CxP 70036	5.3
Acoustic Vibration (2)	5	CxP 70036	5.4
High-Force Vibration (2)	5	CxP 70036	5.5
Shock	7	CxP 70036	5.6
Thermal Vacuum	8	CxP 70036	5.7
Thermal Balance	8	CxP 70036	5.8
Climatic	11	CxP 70036	5.10

NOTES:

(1) A performance test shall be the first and last test conducted for the baseline qualification program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall qualification test sequence.

(2) Either 1) a random vibration test, 2) an acoustic test plus high-force vibration test, or 3) all three tests are required, as applicable.

(3) It is highly recommended that EMC qualification testing be accomplished prior to and following dynamic and thermal testing to identify mechanical design and manufacturing deficiencies. However, if only one EMC test is feasible, it should be performed after the dynamic and thermal tests to ensure that these environments did not induce failures. Since perceptive monitoring is performed during these environmental tests, problems with electrical system installations should be discernible. This provides substantial assurance that recycling of these environmental tests will not be required due to EMC-related problems.

TABLE 5-3 MAJOR ASSEMBLY ACCEPTANCE TEST BASELINE

Test (3)	Earth Launch Assy(s)	Lunar/Mars Surface Assy(s)	Space Assy(s)
Functional/Performance (1)	ER	R	R
Leak	R	R	R
Shock	-	-	-
Random Vibration (2)	ER	ER*	ER*
Acoustic Vibration (2)	ER	ER*	ER*
High-Force Vibration (2)	ER	-	ER*
Thermal Vacuum	ER	ER*	ER*
Oxygen Compatibility	ER	ER	ER

LEGEND: Reference figure 3.1-1 for explanation of R, ER, and ER* designations. The dashes mean the test is generally not required unless specific aspects of the unit design, sensitivity to environment or environmental severity warrant conducting the test.

NOTES:

(1) A performance test shall be the first and last test conducted for the baseline acceptance test program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall acceptance test sequence.

(2) Either 1) a random vibration test, 2) an acoustic test plus high-force vibration test, or 3) all three tests are required, as applicable.

(3) This testing is performed at the largest practical level of assembly.

TABLE 5-4 MAJOR ASSEMBLY ACCEPTANCE RECOMMENDED TEST SEQUENCE

Test	Sequence	Requirement Document	Document Section
Functional/Performance (1)	1, 10	CxP 70036	5.1
Proof Pressure	2	CxP 70135	
Leak	3, 5, 7	CxP 70036	5.2
Random vibration (2)	4	CxP 70036	5.3
Acoustic vibration (2)	4	CxP 70036	5.4
High-Force vibration (2)	4	CxP 70036	5.5
Thermal Vacuum	6	CxP 70036	5.7
EMC (3)	8	CxP 70080	
Oxygen Compatibility	9	NASA-STD-6016	

NOTES:

(1) A performance test shall be the first and last test conducted for the baseline acceptance test program. Functional tests shall be conducted prior to and following each environmental test, except for the first and last tests in the overall acceptance test sequence.

(2) Either 1) a random vibration test, 2) an acoustic test plus high-force vibration test, or 3) all three tests are required, as applicable.

(3) It is highly recommended that EMC qualification testing be accomplished prior to and following dynamic and thermal testing to identify mechanical design and manufacturing deficiencies. However, if only one EMC test is feasible, it should be performed after the dynamic and thermal tests to ensure that these environments did not induce failures. Since perceptive monitoring is performed during these environmental tests, problems with electrical system installations should be discernible. This provides substantial assurance that recycling of these environmental tests will not be required due to EMC-related problems.

5.1 MAJOR ASSEMBLY FUNCTIONAL AND PERFORMANCE TESTS

The major assembly functional/performance tests verify the capability of the major assembly to meet the functional and performance requirements of the applicable major assembly development specification.

For performance tests, input parameters shall be varied throughout their full specification range, including environmental extremes, with internal and output performance of the major assembly being verified.

Functional tests shall be performed using nominal or expected input parameters to equipment with internal and output performance of the major assembly being verified.

5.1.1 Test Descriptions

5.1.1.1 Mechanical Functional/Performance Test

Mechanical functional/performance tests shall verify that the major assembly performs within maximum and minimum performance specification limits. For each mechanical operation such as appendage deployment, the tests shall verify positive margins of strength, torque, and related kinematics and clearances. All redundant mechanisms and modes of operation shall be verified. Mechanical units such as valves, pumps, and deployable assemblies shall be functionally tested at the major assembly level with the flight major assembly in a configuration appropriate for the function considering ground and mission operations.

Alignment and dimensional checks shall be made where appropriate. Fit checks shall be made of the major assembly physical interfaces using master gauges or interface assemblies. The most adverse tolerance accumulation, including thermal effects, shall be considered in these fit checks.

Where operation in Earth's gravity cannot be performed, a suitable ground test fixture may be used to permit operation and performance evaluation. The success criteria shall be adjusted, as appropriate, to account for worst-case maximum and minimum limits that have been modified to adjust for ground test conditions.

5.1.1.2 Electrical and Fiber Optics Functional/Performance Test

Electrical and fiber optic functional/performance tests shall verify the integrity of end-to-end circuits (including functions, redundancies, deployment circuitry, and end-to-end paths) and specification performance (including radio frequency and other sensor inputs). The major assembly shall be in its flight configuration with all units and subsystems connected except explosive ordnance devices.

End-to-end sensor testing may be accomplished with self-test or coupled inputs. Autonomous functions shall be verified. Continuous monitoring of equipment and system parameters, including input and output parameters, shall be provided to detect intermittent failures.

The test shall operate all units, primary and redundant, and exercise all commands and operational modes to the greatest extent practical. The operation of all thermally-controlled units, such as heaters and thermostats, shall be verified. End-to-end performance testing shall be conducted where control of such units is implemented by sensors, electrical or electronic devices, coded algorithms, or a computer.

The test shall verify that all commands with precondition requirements (such as enable, disable, a specific equipment configuration, and a specific command sequence) cannot be executed unless the preconditions are satisfied.

5.1.1.3 Fluid Subsystem Functional/Performance Test

The performance of the subsystem, including flow, leakage, and regulation shall be measured while operating applicable valves, pumps, motors, and other appropriate subsystem equipment. Flow checks shall be performed to verify that the plumbing configuration is correct and it meets specified performance requirements prior to leak and proof tests. Tests and inspections for subsystem cleanliness, moisture levels, and fluid pH levels shall also be made as required.

5.1.2 Supplementary Requirements

The specific modes and sequences of operation that are expected to occur in the mission shall be duplicated to the greatest extent practical. The performance test should be a “test like you fly” test that captures the entire service life of the hardware, including acceptance testing, preflight checkout, servicing, maintenance, and repair.

Performance tests shall be conducted as the first and the last test in the major assembly environmental test program to ensure that performance meets specification requirements.

Functional tests shall be conducted prior to and following each major assembly environmental test to detect equipment problems. These preenvironmental and postenvironmental functional tests shall not require the mission profile sequence. Sufficient data shall be analyzed to verify the adequacy of the testing and the validity of the data before any change is made to the environmental test configuration, so that any required retesting can be readily accomplished.

Limited major assembly level functional checks shall be conducted prior to all major assembly environmental tests. These checks shall be conducted after final installation in the test facility (e.g., vacuum chamber or acoustic facility) and prior to conducting the major assembly environmental test. The checks shall be sufficient to establish confidence in the major assembly’s integrity and to verify that no damage has occurred during transport, handling, or installation into the facility or during removal from the facility from a prior environmental test.

For at least one test in the qualification sequence, the major assembly shall be operated through a simulated mission profile with all events typically occurring in the actual flight sequence. The sequence shall include prelaunch, final countdown, launch, ascent, separation, upper-stage operation, all appropriate space-mission operational modes, and return to Earth, as applicable. All explosive ordnance-firing circuits shall be energized and monitored during these events to verify that the proper energy density is delivered to each device and in the proper sequence. All measurements shall also be monitored and trended during appropriate portions of these events to verify proper operation.

For at least one test in the acceptance test sequence, the major assembly shall be subjected to a "plugs-out" test. This test verifies that all major assembly systems are in an "as near a flight configuration" as is practical. At the start of the test, umbilicals are disconnected and the major assembly is powered internally. The major assembly shall be operated through a basic set of functional checkouts and telemetry responses.

5.2 MAJOR ASSEMBLY LEAK TEST

The major assembly leak test verifies the capability of the major assembly (including pressurized compartments, pressurized structures, and pressurized subsystems) to meet specified leakage requirements and to ensure acceptable quality and workmanship.

5.2.1 Test Description

a. Pressurized subsystems shall be pressurized to the specified test pressure.

b. An SLT method shall then be used to verify the total subsystem leakage. If appropriate, local leak tests of joints, fittings, plugs, etc. shall be made.

c. Evacuated subsystems shall be leak tested by evacuating the internal area to the specified vacuum level. An SLT method shall then be used to verify the total external-to-internal leakage rate.

d. Pressurized compartments and pressurized structures shall be pressurized to the specified test pressure.

e. An SLT method shall then be used to verify the total leakage rate of the structure or compartment (reference Section 4.4, Unit Leak Test, Methods I, II, and IV).

5.2.2 Test Levels and Durations

5.2.2.1 Pressure Levels

For leak tests of pressurized structure, pressurized compartments, and pressurized subsystems, the leak test shall be conducted at the MDP. Low pressure tests shall be conducted when high pressure assists the sealing mechanism. The test's low pressure limit shall be established by development testing that verifies this test's capability to detect the necessary defects.

For evacuated systems, the test pressure shall be at or below the minimum operating pressure of the subsystem.

5.2.2.2 Durations

The duration shall be sufficient to detect the test-specified pass/fail leakage rate in accordance with the criteria for an SLT method.

5.2.3 Supplementary Requirements

All major assembly leak tests shall be confirmed as constituting an SLT as defined in Appendix A. The basis for this confirmation shall be documented in the applicable major assembly leak test plan.

All leak test pass/fail criteria shall be based on expected performance of the major assembly design and unit seal design. Leakage rate measurements shall be properly adjusted for pressure, temperature, tracer gas, and humidity, as appropriate. A proof pressure test (reference CxP 70135) shall be completed prior to the final acceptance leak test of the major assembly or associated fluid subsystems.

Leak tests should be conducted at operational temperature with the representative fluid commodity to account for dimensional and viscosity changes where necessary to demonstrate adequate confidence in leak integrity. Leakage detection and measurement methods may require the use of vacuum chambers, local bell jars, and bagging of the entire major assembly or localized areas or other special techniques to achieve the required sensitivity.

Thermal vacuum leak tests on major assemblies should be used when feasible to ensure that leak rates are within tolerance in all operational modes and environmental conditions.

5.3 MAJOR ASSEMBLY RANDOM VIBRATION TEST

The major assembly random vibration test verifies the capability of the major assembly to withstand and to meet applicable functional/performance requirements during or after exposure to the service life random vibration environments (including acceptance random vibration testing), as applicable. In addition, this test screens the flight major assemblies for latent manufacturing and workmanship defects and provides data to support evaluation of the acceptability of the unit-level random vibration requirements and qualification test levels.

Random vibration testing effectiveness is limited by the size and mass of the assembly under test, in addition to limitations of existing test equipment. As such, acoustically induced vibration testing should be considered for large-scale articles in configurations compatible with existing technical capabilities.

5.3.1 Test Description

The baseline major assembly random vibration test program is comprised of AVT, QAVT, and QVT.

The configuration of the major assembly (e.g., pressurized/unpressurized, operating/nonoperating) shall be in accordance with development specification requirements for the applicable environment.

The major assembly shall be vibrated using one or more shakers through appropriate vibration fixtures. The same test fixtures (or those of identical design) and overall test setup shall be used for AVT and QAVT. Vibration shall be applied in each of three orthogonal axes, with one direction being consistent with and parallel to the Earth-launch major assembly thrust axis. Instrumentation shall be installed to measure the vibration inputs and the vibration responses at critical attachment points and unit interfaces. Unit interface measurements shall be taken in the three axes corresponding to the three excitation axes of the applicable unit random vibration test.

Performance testing shall be conducted during the qualification random vibration test in accordance with Section 5.1 when the major assembly is required to operate during exposure to random vibration during the mission. At a minimum, all electrical/electronic units are required to be powered during the test and perceptive monitoring shall be performed for failure or intermittence during all random vibration testing (AVT, QAVT, and QVT). Only those subsets of functions that are required to be executed during exposure to the mission random vibration environment need to be demonstrated during testing. This performance test requirement is not applicable to propulsion subsystems (i.e., no firing of thrusters) or operation (firing) of pyrotechnics.

Operating time shall be divided equally between redundant modes of operation except for manual modes that require direct human operation. Extended testing (using a spectrum no lower than 6 dB below the nominal test spectrum) shall be conducted as necessary to complete functional testing when insufficient test time is available at the full test level to test redundant circuits, functions, and modes.

5.3.2 Test Levels and Durations

5.3.2.1 Acceptance Vibration Test (AVT)

The test level and spectrum shall envelop all of the design service life random vibration environments (as defined in the applicable major assembly development specification) and the minimum workmanship screening level and spectrum (defined by table 5.3.2.1-1 and figure 5.3.2.1-1). The duration shall be 1 minute per axis.

TABLE 5.3.2.1-1 MINIMUM MAJOR ASSEMBLY AVT WORKMANSHIP SCREENING LEVEL

Frequency Range (Hz)	Level/Slope
20	0.01 g^2/Hz
20-80	3 dB/Octave
80-800	0.04 g^2/Hz
800-2,000	-4.55 dB/Octave
2,000	0.01 g^2/Hz
Composite (grms)	7.33

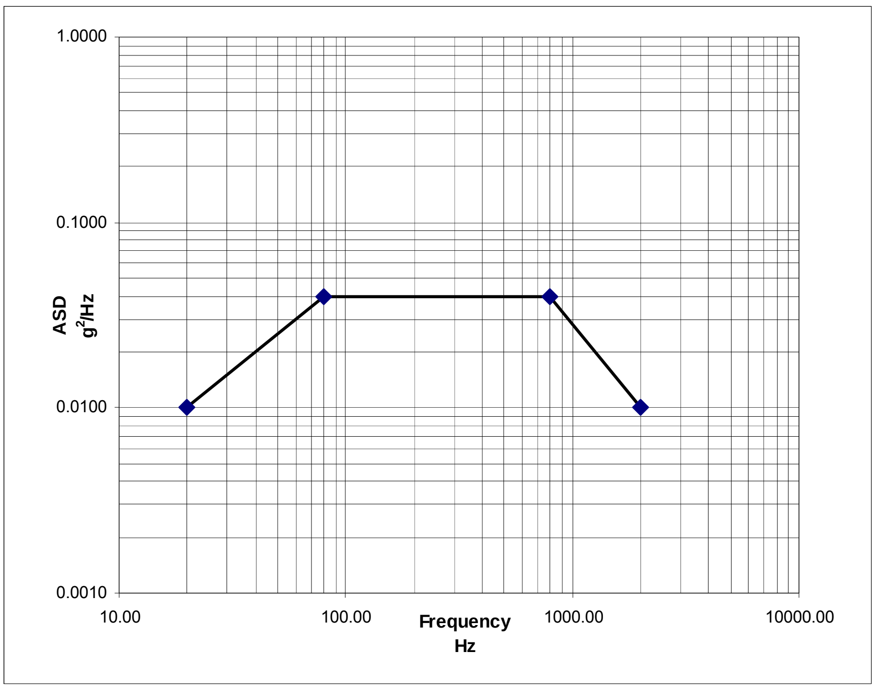


FIGURE 5.3.2.1-1 MAJOR ASSEMBLY MINIMUM WORKMANSHIP VIBRATION TEST SPECTRUM

5.3.2.2 QAVT

The test input ASD shall be 3 dB above the AVT ASD. The duration per axis shall be 1 minute times the number of AVTs to be qualified (e.g., if qualifying for five AVTs, the total duration per axis shall be 5 minutes). The number of AVTs to be qualified shall be as specified in the applicable major assembly development specification or as defined by a Logistics Supportability Analysis, but it shall not be less than two.

5.3.2.3 QVT

One of the four methods below shall be used for performing QVT. The QVT TA shall be the same model/serial number as used for QAVT and shall not be refurbished between the two tests. The QVT and QAVT tests may be performed in any sequence, and both tests may be accomplished in a given axis before repositioning to another axis. Service life random vibration environment input ASDs as defined in the applicable unit development specification shall be increased by 3 dB for all test methods except Method 4. When Method 4 is chosen, the test input ASD shall be 6 dB higher than the envelope of all of the service life environments.

a. Method 1

   1. Each applicable service life random vibration environment (except for acceptance testing as identified in the applicable major assembly development specification) shall be applied individually.

   2. The overall test level and spectrum shall be no less than the level and spectrum defined in the development specification.

   3. The test duration for each environment shall be four times the exposure duration for that environment as defined in the development specification. The sum total test duration for each axis for all environments shall be no less than 2 minutes. If the sum total of the four times exposure durations for each environment is less than 2 minutes in any axis, then the time required to reach 2 minutes shall be divided proportionally across the environments being tested and that amount of time shall be added to the required test duration for each environment such than the sum total duration for each axis is 2 minutes.

   4. The configuration of the TA (e.g., pressurized/unpressurized, operating/nonoperating) shall be in accordance with specification requirements for the applicable environment. Units that are required to be pressurized during the test shall be monitored for leakage during the test.

b. Method 2

   1. A test level and spectrum enveloping all service life random vibration environments, except for acceptance testing, shall be applied to each of the three orthogonal axes.

   2. The test duration in each axis shall be the greater of four times the total equivalent duration of exposure to all of the environments defined in the development specification or 2 minutes.

c. Method 3

Method 3 is a combination of Methods 1 and 2 where the major assembly is not required to operate during exposure to some mission random vibration environments but is required to operate during exposure to other mission random vibration environments. If Method 3 is chosen, the nonoperating test shall be conducted prior to the operating test.

This method may be appropriate to use when one or more of the nonoperating environments is more severe than the operating environments and it could be expected that the major assembly may not meet functional/performance requirements while exposed to the higher nonoperating environment(s).

For this method, a single nonoperating random vibration environment that envelops all of the nonoperating mission environments as defined in the development specification shall be applied to each of the three axes.

1. The test duration in each axis shall be the greater of four times the total lifetime exposure time to the nonoperating environments defined in the development specification or 2 minutes.

2. Major assemblies that are pressurized but otherwise nonoperational during exposure to the mission vibration environments shall be pressurized to the maximum or minimum operating pressure, as appropriate, during the test and monitored for evidence of leakage.

3. After completion of all three axes, the major assembly shall then undergo a functional test in accordance with Section 5.1.

4. In addition to the nonoperating random vibration test, an operating random vibration test shall be conducted. A single operating random vibration environment that envelops all of the operating random vibration mission environments as defined in the development specification shall be applied to each of the three axes.

5. The test duration in each axis shall be the greater of four times the total lifetime exposure time to the operating environments defined in the development specification or 2 minutes.

d. Method 4

1. A test level and spectrum enveloping all service life random vibration environments (including acceptance testing) shall be applied to each of the three orthogonal axes.

2. The test duration in each axis shall be the greater of four times the total equivalent duration of exposure to all of the service life environments including a minimum of two acceptance tests or 2 minutes.

3. Units shall be hard mounted to the shaker through a rigid test fixture when using this method.

NOTE: When using Method 4, a QAVT is not required.

5.3.3 Supplementary Requirements

Interfaces to other major assemblies through equipment such as wire harnesses, hydraulic and pneumatic lines up to the first attachment point, and other connecting items shall be included in the test configuration. These items shall be connected using flight-like connectors.

For AVT where the minimum workmanship spectrum governs the required input test level, the input may be limited or notched to prevent unrealistic input forces or responses, but in no case shall the input be less than the maximum design service level in that frequency range.

AVT and QAVT shall be conducted with the major assembly hard mounted to the shaker via rigid test fixtures. For QVT, major assemblies may be mounted on appropriate shock or vibration isolators or other attenuation systems representing the actual flight installation. In this case, test control shall be at the test fixture to isolator interface. The same test fixture (or multiple fixtures of identical design) shall be used for all random vibration testing of major assemblies of a given part number, including QAVT. The fixture shall be designed to preclude fixture-induced resonances throughout the test frequency range. Bare fixture surveys shall be conducted prior to each random vibration test. As a goal, input ASD in the off-axes should be maintained at least 10 dB below the input ASD in the primary excitation axis.

Subsystems and units that are pressurized during exposure to random vibration during the mission shall be pressurized to their maximum or minimum operating pressure, as appropriate, for this test and monitored for internal pressure decay. The test plan shall clearly and fully explain the derivation of the required test parameters to demonstrate compliance with these requirements.

At a minimum, all electrical/electronic units on the major assembly shall be powered and monitored for failures or intermittence during all random vibration testing except for nonoperating tests during QVT when Method 3 is being used.

For AVT, where the minimum workmanship spectrum governs the required input test level, the input may be limited or notched to prevent unrealistic failures due to excessively high response levels. However, in no case shall the notched input acceleration spectral level be less than the mission design level as defined in the applicable development specification.

As an alternative to input acceleration notching as defined above, avoidance of unrealistic failures may be accomplished by force limiting as defined in Appendix C. The fixture shall be designed to preclude fixture-induced resonances throughout the test frequency range. Bare fixture surveys shall be conducted prior to each major assembly vibration test. As a goal, input ASD in the off-axes should be maintained at least 10 dB below the input ASD in the primary excitation axis.

The test plan must clearly and fully explain the derivation of the required test parameters to demonstrate compliance with these requirements.

5.3.3.1 Tolerances

Maximum allowable tolerances for random vibration testing shall be as follows:

a. AVT: +1.5/-3.0 dB

b. QAVT: +3.0/-1.5 dB

c. QVT (methods 1 through 3): ± 3.0 dB

d. QVT (method 4): +3.0/-1.5 dB

Excursions from the specified tolerance bands are permissible provided all of the criteria below are met:

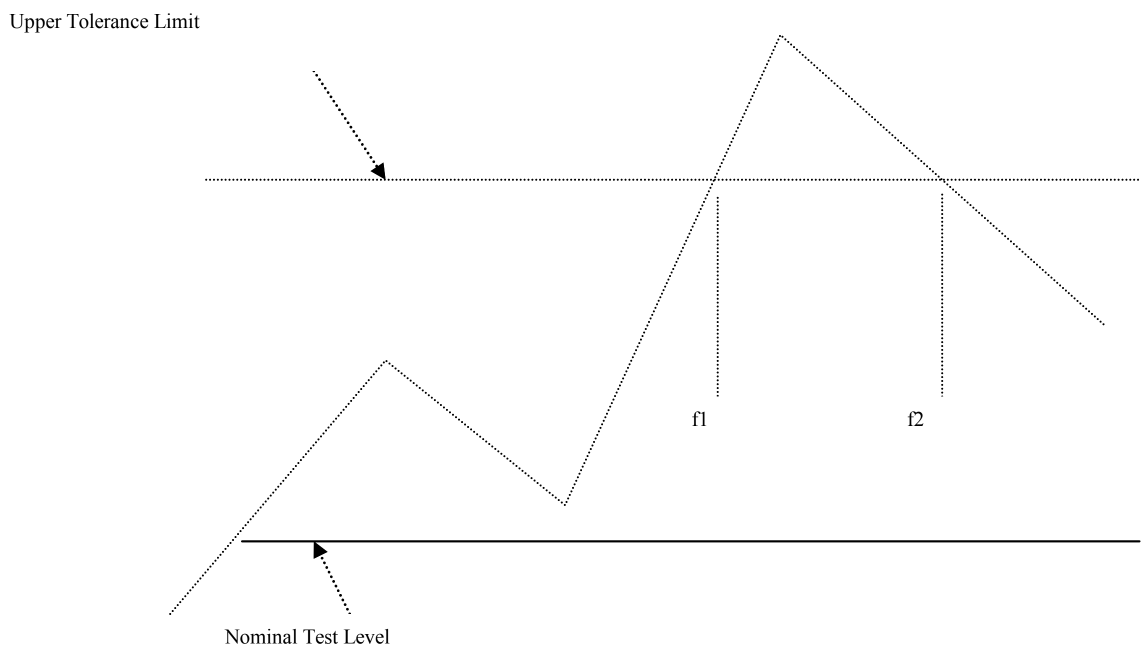
a. The total number of excursions in any test shall not be greater than four.

b. The total number of excursions in any test on either the low side or high side shall not exceed three.

c. No excursion peak shall exceed the tolerance limit by more than 1.5 dB

d. No excursion shall have a bandwidth greater than 10 Hz or 10 percent of the geometric mean frequency of the excursion, whichever is greater.

The geometric mean frequency shall be defined as the square root of the product of the lower and upper crossing frequencies at the tolerance limit (see figure 5.3.3.1-1 for an example).



Geometric mean frequency = $\sqrt{(f1)(f2)}$

FIGURE 5.3.3.1-1 GEOMETRIC MEAN FREQUENCY EXAMPLE

5.4 MAJOR ASSEMBLY ACOUSTIC VIBRATION TEST

The major assembly acoustic vibration test verifies the capability of the major assembly to operate during, or survive as applicable, the mission flight acoustic environment. In addition, it screens for latent manufacturing and workmanship defects during major assembly acceptance testing and serves to validate unit-level random vibration requirements and qualification test levels.

5.4.1 Test Description

a. The major assembly shall be installed in an acoustic test setup capable of generating the sound fields or fluctuating surface pressures that induce vibration environments sufficient for major assembly qualification.

b. The major assembly shall be mounted on a flight-like support structure or reasonable simulation thereof.

c. Significant fluid and pressure conditions shall be replicated to the greatest extent practical.

d. The major assembly shall be configured in a manner representative of its configuration during exposure to the flight acoustic environment.

e. Appropriate instrumentation shall be installed to measure vibration responses at major assembly attachment points and at interfaces of critical or representative units.

f. Control microphones shall be placed at a minimum of four well-separated locations around the TA. They shall be no closer than 0.5 m (20 in) from any acoustically reflective surface such as chamber walls or the TA. For free-field acoustic testing, the control microphones shall be no farther than 1 m (39 in) from the TA surfaces.

g. If the TA size exceeds the capability of existing test facilities, the major assembly may be appropriately subdivided and acoustically tested as one or more subsystems or assemblies.

5.4.2 Test Levels and Durations

5.4.2.1 Qualification

Levels: The SPL at ⅓ octave band center frequencies shall be 3 dB above the acceptance test level (when acceptance acoustic testing is required) or 3 dB above the envelope of the ⅓ octave band center frequency levels defined in the applicable major assembly development specification (when acceptance acoustic testing is not required).

Duration: The test duration shall be sufficient to demonstrate the greater of four times the total equivalent duration of exposure to all service life acoustic environments (including acceptance testing and reacceptance testing) as defined by the applicable development specification or 3 minutes.

5.4.2.2 Acceptance

Levels: The SPL at ⅓ octave band center frequencies shall be the envelope of the ⅓ octave band center frequencies as specified in the applicable major assembly development specification but not less than a level of 138 dB OASPL whose spectrum shape is identical to the envelope of the specification acoustic environments.

Duration: The duration shall be 1 minute.

5.4.3 Supplementary Requirements

Electrical and electronic units shall be electrically energized and monitored for failures and intermittences during the test regardless of whether they are powered or operating during acoustic exposure in flight.

Subsystems and units that are required to operate during exposure to the specified acoustic environment shall undergo performance testing during the acoustic test. Only those functions that are required to be performed while the unit is exposed to acoustic excitation during the mission need to be verified during the test.

Perceptive monitoring of all equipment shall be performed to detect defects to the maximum extent possible.

The test plan shall clearly and fully explain the derivation of the required test parameters to demonstrate compliance with these requirements.

5.5 MAJOR ASSEMBLY HIGH-FORCE VIBRATION TEST

For qualification, the major assembly high-force vibration test demonstrates the capability of the major assembly to withstand and meet applicable functional/performance requirements during or after exposure to representative flight low- and mid-frequency transients or sustained sine environments.

For acceptance, this test provides a workmanship screen for flight hardware whose response to the acoustic vibration test is not sufficient to precipitate latent defects. This test should be performed to augment the acoustic vibration test for major assembly verification in order to adequately test in the low- to mid-frequency ranges when equivalent static test methodologies are not sufficient to verify strength or demonstrate functional/performance requirements.

5.5.1 Test Description

a. The major assembly shall be vibrated using base-drive or point excitation at various locations on the structure.

b. The test shall be a response-limited test based on the flight load predictions with the required test factor defined in table 5.5.2.1-1.

c. The major assembly shall be configured in a manner representative of its configuration during exposure to the flight vibration environment, such as fluid and pressure conditions, stowed and unstowed equipment, and shock or vibration isolator mounting provisions.

d. Instrumentation shall be installed to measure the vibration inputs (acceleration, displacement, and force levels) and the vibration responses (acceleration, displacement, and strain) at critical attachment points, unit interfaces, and on critical structures. The instrumentation shall be sufficient to achieve the objective of the response-limited test, provide data to assist model correlation, and provide monitoring of flight article integrity in uninspectable areas.

5.5.2 Test Levels and Duration

5.5.2.1 Test Levels

The nominal excitation for the high-force vibration test is assumed to be sinusoidal sweep; however sine dwell, broadband random, or a combination thereof may be considered to achieve the derived response-limited test levels. The test levels shall be derived based on dynamic loads analysis responses at the TA interface or internal units as dictated by test objectives for all flight-loading conditions. Equivalent test levels may be developed using Shock Response Spectrum (SRS) or statistical techniques for combined dynamic flight events. For flight events with sinusoidal input, SRS techniques are generally not required. The test frequency range shall be consistent with the coupled loads forcing functions so that the TA can be response limited. Test input conditions are not intended to induce flight-like steady state load conditions at the major assembly level.

The following test factors, applied to flight limit load conditions, shall be used:

TABLE 5.5.2.1-1 HIGH-FORCE VIBRATION TEST FACTORS

Test Type	Test Factor
Acceptance	1.0
Protoflight	1.2
Qualification	1.4

5.5.2.2 Durations

The duration of the qualification test shall be sufficient to produce four times the cumulative fatigue damage of all applicable service life loading events (including acceptance, transportation, and mission). Equivalent fatigue calculation for random vibration environments shall be per the methodology defined in Section 4.6.4. Combined equivalent loads shall be evaluated using the equation below:

$$t_{hf} = \sum_{i}^{n} t_i \left(\frac{dll_i}{dll_{hf}} \right)^b$$

where

t_{hf} is the equivalent duration for the high force test
t_i is the time of exposure for load condition i
dll_i is the design limit load for condition i

dll_{hf} is the total flight limit load test level
b fatigue exponent

A value of four shall be used for the fatigue exponent b.
The duration of the acceptance and protoflight tests shall be sufficient to exercise the TA for the equivalent exposure of one flight.

5.5.3 Supplementary Requirements

A functional test in accordance with Section 5.1 shall be conducted prior to and following qualification, acceptance, or protoflight high-force vibration testing. Electrical and electronic units powered/operating during exposure during flight shall be electrically energized and monitored for failures and intermittences during the test.

Subsystems and units that are required to operate during exposure to the specified vibration environment shall be performance tested during the qualification high-force vibration test.

For acceptance high-force vibration testing, performance shall be verified to the maximum extent possible during the limited exposure time. When the full performance test cannot be completed due to the duration of the acceptance test, the force levels shall then be reduced 6 dB during completion of the performance verification. Only those functions that are required while the assembly is exposed to low- and mid-frequency vibration excitation during the mission need to be verified during the test.

Perceptive monitoring of all equipment shall be performed to detect defects to the maximum extent possible.

NOTE: This monitoring shall not be done if the application of power to the unit could result in damage due to switch or relay bounce or similar phenomena.

5.6 MAJOR ASSEMBLY SHOCK TEST

The major assembly shock test verifies the capability of the major assembly to withstand and, when required, operate in the induced shock environment. This test serves as an electrical and mechanical functional demonstration of the shock source device and provides data to validate the design specification environment for associated units. Shock events to be considered shall include, but are not limited to, the following sources:

a. Separations and deployments initiated by explosive ordnance and other devices

b. Impacts and suddenly applied or released loads that may be significant for unit dynamic response (such as an engine start-up or shut down transient, parachute deployment, or major assembly landing)

All devices of the major assembly capable of imparting significant shock excitation to major assembly units shall be exercised during this test.

Those potentially significant shock sources that are not part of the major assembly under test, such as on an adjoining major assembly or a nearby staging joint, shall also be actuated or simulated and shall be applied through appropriate interfacing structures.

5.6.1 Test Description

5.6.1.1 Validation of Flight Assembly

The major assembly shall be in the flight configuration. The major assembly shall be supported and configured to allow a flight-like dynamic response of the major assembly to the induced shock environment with respect to amplitude, frequency content, and paths of transmission. Reconfiguration of the test support shall be permitted if it is needed to accurately reflect the major assembly configuration at the time of each shock event. Test setups shall avoid undue influence of test fixtures and shall prevent recontact of any separated items. Units that are powered during exposure to the mission shock event shall be present and in the operational mode applicable to the shock event.

5.6.1.2 Transfer Functions Validation (Shock Attenuation at the Unit)

The major assembly shall be configured such that the mechanical transmission paths and mass distribution are flight-like. The objective is to measure the input source and response accelerations in order to validate the design specification SRS levels at the various unit locations and directions of interest.

5.6.1.3 Functional Demonstration

The electrical and mechanical function of the shock source device shall be demonstrated. Mechanical motion of the hardware (e.g., interferences and tip-off rates) shall be verified as defined by the design specification. Dynamic instrumentation shall be installed to measure shock responses in three orthogonal directions at the attachments of selected shock-sensitive units.

5.6.2 Test Levels and Durations

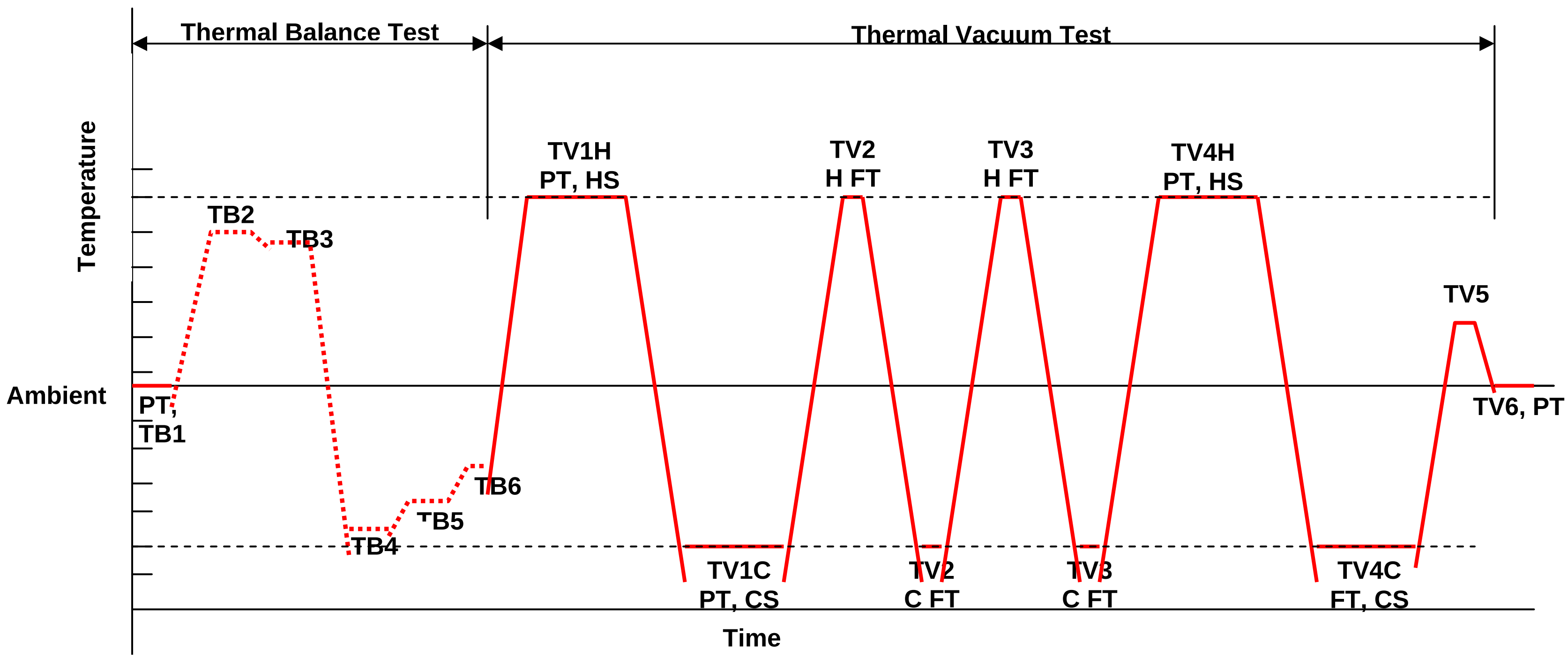
During the series of shock tests, the major assembly shall be subjected to shock transients representative of the expected shock events. All explosive ordnance devices and other potentially significant shock-producing devices or events (including those from sources not installed on the major assembly under test) shall be activated or simulated, as appropriate, a minimum of two times. Additional application (or simulation) of shock events may be performed in order to account for variability in the transmission of the shock through the major assembly and to meet the system test objectives defined in Section 5.6.1.

5.6.3 Supplementary Requirements

Electrical and electronic units shall be operating and monitored during the shock test regardless of whether it is powered/operating during exposure to the mission shock environment. Perceptive monitoring shall be performed during shock events to identify intermittent or anomalous conditions. Units that are required to operate during exposure to mission shock events shall be operating in the applicable functional mode and monitored throughout the shock test series for proper performance.

5.7 MAJOR ASSEMBLY THERMAL VACUUM TEST

The major assembly thermal vacuum test verifies capability of the major assembly to meet specified performance requirements under simulated space thermal vacuum conditions during qualification and serves as a screen for latent workmanship and material defects during major assembly acceptance. The test shall be performed in accordance with figure 5.7-1.



PT – Performance Test
FT – Functional Test
HS – Hot Start
CS – Cold Start

TB1 – Chamber Pumpdown
TB2 – Outgas Conditioning
TB3 – Hot TB Operational Phases (Steady State)
TB4 – Cold TB Non-Operational Phase (Steady State, Heater Verification)
TB5 – Cold TB Operational Phase (Steady State)
TB6 – Cold TB Simulations of Eclipse, Transfer Orbit, Safe Mode, etc.

TV1H – TV Cycle 1 Hot
TV1C – TV Cycle 1 Cold
TV2H – TV Cycle 2 Hot
TV2C – TV Cycle 2 Cold
TV3H – TV Cycle 3 Hot
TV3C – TV Cycle 3 Cold
TV4H – TV Cycle 4 Hot
TV4C – TV Cycle 4 Cold
TV5 – Prep for Ambient
TV6 – Ambient, Open Chamber

FIGURE 5.7-1 TYPICAL VEHICLE THERMAL BALANCE/THERMAL VACUUM TEST PROFILE

5.7.1 Test Description

a. The major assembly shall be placed in a thermal vacuum chamber, and an abbreviated functional test shall be performed to ensure readiness for chamber closure.

b. The major assembly shall be divided into separate equipment zones based on the thermal limits of the temperature-sensitive units and similar unit qualification temperatures within each zone.

c. Units and other areas shall be instrumented with one or more temperature sensors (one backup recommended) that will permit validation of the major assembly thermal math model.

d. Electrical and electronic units that operate during periods of atmospheric pressurization or depressurization (e.g., during ascent after Earth launch or during Earth atmospheric entry) shall be operating and monitored for corona and multipacting, as applicable, as the pressure is reduced to the lowest specified level or during chamber repressurization back to ambient conditions.

e. The rate of chamber pressure reduction and repressurization shall be no greater than mission pressure change rates and may have to be slower to allow sufficient time to monitor for corona and multipacting.

NOTE: Equipment that does not operate during pressure changes during the mission shall not require power application except at vacuum pressure levels.

f. A thermal cycle begins with the major assembly at ambient temperature. The temperature is raised or lowered to the specified maximum or minimum level and stabilized.

g. Following a temperature soak, the temperature shall be changed to the opposing maximum and minimum temperature to complete one thermal cycle.

h. Performance specification tests shall be conducted during the first and last thermal cycle at both the hot and cold temperature limits with functional operation and monitoring of perceptive parameters during all other cycles.

i. In addition to the thermal cycles, the test shall simulate various space mission operations. Execution of operational sequences shall be coordinated with the operating and monitoring of redundant units and paths.

j. Electrical and electronic units and other electrical equipment shall be operating and monitored throughout the test. Temperature monitors shall ensure attainment of temperature limits.

k. Strategically placed witness plates, quartz crystal microbalances, or other instrumentation shall be installed in the test chamber to measure the outgassing from the major assembly and test equipment.

5.7.2 Test Levels and Durations

5.7.2.1 Pressure Levels

For major assemblies required to operate under space vacuum conditions, the pressure shall be at or below 0.01333 Pa (1 x 10^{-4} torr). If hardware is covered by multi-layered insulation, the pressure shall be 0.001333 Pa (1 x 10^{-5} torr). Otherwise the pressure shall be at or below the minimum operational pressure specified in the applicable major assembly development specification.

5.7.2.2 Temperature Levels

At each temperature extreme on each cycle, the major assembly shall undergo a soak period. The soak period shall be no less than 8 hr at hot and cold on the first and last temperature cycles and no less than 1 hr at hot and cold on all intermediate cycles.

Qualification: For major assemblies required to undergo an acceptance thermal vacuum test, the minimum and maximum thermal vacuum qualification test temperatures shall be 11 °C (20 °F) beyond the minimum and maximum acceptance thermal vacuum test temperatures.

For major assemblies not requiring an acceptance thermal vacuum test, the minimum and maximum qualification test temperatures shall be one of the following:

a. 11 °C (20 °F) beyond the minimum and maximum temperatures specified in the applicable major assembly development specification.

b. 22 °C (40 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification.

NOTE: This 22 °C level provides for 11 °C of uncertainty associated with the analytically-derived temperatures and an additional 11 °C of qualification margin.

c. 28 °C (50 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has not been properly accredited in accordance with CxP 70074.

NOTE: This 28 °C level provides for 17 °C of uncertainty associated with the analytically-derived temperatures from an unaccredited model and an additional 11 °C of qualification margin.

Acceptance: The minimum and maximum acceptance temperature limits shall be one of the following:

a. The minimum and maximum temperature levels specified in the applicable major assembly development specification.

b. 11 °C (20 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the major assembly development specification.

NOTE: This 11 °C level provides for 11 °C of uncertainty associated with the analytically-derived temperatures.

c. 17 °C (31 °F) beyond the minimum and maximum temperatures that are derived analytically from the thermal environments specified in the development specification when the analytical model used to predict unit temperatures has not been properly accredited in accordance with CxP 70074.

NOTE: This 17 °C covers the uncertainty associated with the analytically-derived temperatures when using an unaccredited thermal model.

The rate of temperature change should duplicate the maximum predicted rate of temperature change in critical areas to the greatest extent practical.

5.7.2.3 Durations

Qualification: 8 temperature cycles minimum

Acceptance: 4 temperature cycles minimum

5.7.3 Supplementary Requirements

Performance tests shall be conducted after unit temperatures have stabilized at the hot and cold temperatures on the first and last cycle. For intermediate cycles, functional tests at hot and cold temperatures shall be performed. During these tests, electrical and electronic units, including all redundant circuits and paths, shall be cycled through all operational modes. Perceptive parameters shall be monitored for failures and intermittence. The major assembly shall be operated through various operational modes throughout the balance of the test including during temperature transitions.

5.8 MAJOR ASSEMBLY THERMAL BALANCE TEST

The major assembly thermal balance test demonstrates the capability of the major assembly thermal control subsystem to maintain specified temperature limits of units for various operational scenarios throughout the entire major assembly. In addition, this test provides data for validation of the major assembly thermal model.

NOTE: The thermal balance test should be combined with the thermal vacuum test.

5.8.1 Test Description

a. The qualification major assembly shall be exposed to thermal environments expected by the major assembly during its service life in a thermal balance test.

b. Test instrumentation shall be installed that will produce data that can be correlated to the thermal model over the full range of seasons, equipment duty cycles, ascent conditions, solar angles, maximum and minimum unit thermal dissipations (including effects of bus voltage variations), and eclipse combinations.

c. At a minimum, three test conditions shall be imposed: a hot operational case, a cold operational case, and a cold nonoperational case. Two additional cases should be imposed: a transient case and a case chosen to check the validity of the thermal model. Other cases that are commonly simulated include: eclipse, ascent, safemode, and “day-in-the-life” conditions.

d. Reference figure 5.7-1 for the thermal balance test profile.

e. Thermal balance test phases need not be worst-case expected flight conditions, but they should not be significantly different from these conditions. Special emphasis shall be placed on defining the test conditions expected to produce the maximum and minimum temperatures of sensitive units such as batteries.

f. Sufficient measurements shall be made on the major assembly internal and external units to verify the major assembly thermal design, hardware, and analyses.

g. The operation and power requirements of all thermostatically- or electronically-controlled heaters and coolers shall be verified during the test, and appropriate control authority shall be demonstrated on the primary and redundant circuits.

h. Where appropriate, provisions should be made to prevent the test item from “viewing” warm chamber walls by using black-coated cryogenic shrouds of sufficient area and shape that are capable of approximating liquid N_2 temperatures. The major assembly thermal environment may be supplied by one of the following methods:

1. Absorbed Flux: The absorbed solar, albedo, and planetary irradiation is simulated using heater panels or Infrared (IR) lamps with their spectrum adjusted for the external thermal coating properties or using electrical resistance heaters attached to major assembly surfaces.

2. Incident Flux: The intensity, spectral content, and angular distribution of the incident solar, albedo, and planetary irradiation are simulated.

3. Equivalent Radiation Sink Temperature: The equivalent radiation sink temperature is simulated using IR lamps and calorimeters with optical properties identical to those of the major assembly surface.

4. Combination: The thermal environment is supplied by a combination of the above methods.

The selection of the method and fidelity of the simulation depends upon details of the major assembly thermal design such as geometry, the size of internally produced heat loads compared with those supplied by the external environment, and the thermal characteristics of the external surfaces.

i. Instrumentation shall be incorporated down to the unit level to evaluate total major assembly performance within operational limits as well as to identify unit problems.

j. The major assembly shall be operated and monitored throughout the test.

k. Dynamic flight simulation of the major assembly thermal environment should be provided unless the external major assembly temperature does not vary significantly with time.

l. Temperature measurement channels used to define thermal equilibrium shall have stabilities with time (noise level evidenced by varying readings at constant temperature, including bias and precision) commensurate with the time rate of change of temperature (dT/dt) used to define equilibrium. This capability shall be defined as a requirement and demonstrated before test.

5.8.2 Test Levels and Duration

Test conditions and durations for the thermal balance test are dependent upon the major assembly configuration, major assembly design, and mission details. Boundary conditions for evaluating the thermal control hardware and design shall include the following:

a. Maximum external absorbed flux plus maximum internal power dissipation

b. Minimum external absorbed flux plus minimum internal power dissipation

c. Minimum external absorbed flux plus minimum nonoperating or stand-by power dissipation

The thermal time constant of the subsystems and the mission profile influence the time required for the major assembly to achieve thermal equilibrium and hence the test duration.

The test chamber, with the test item installed, shall provide a pressure of no higher than 13.3 mPa (1 x 10^{-4} torr) for space assemblies, or a pressure commensurate with service altitude for launch major assemblies.

5.8.3 Supplementary Requirements

Success criteria depend on survival and operation of each item within specified temperature limits and on correlation of the test data with analytic thermal models. Correlation of test results to the thermal model predictions shall be within ± 3 °C (5.4 °F). Lack of correlation with the analytic model may indicate either a deficiency in the model, test setup, or space major assembly hardware. In regions where the correlation exceeds ± 3 °C (5.4 °F), either the thermal model shall be modified to achieve the correlation or an explanation shall be provided for why the correlation cannot be achieved. The correlated thermal math model shall be used to make the final temperature predictions for the various mission phases (such as prelaunch, ascent, on-orbit, and disposal orbit). These temperature predictions verify the thermal control design and thermal uncertainty margins.

5.9 MAJOR ASSEMBLY OXYGEN COMPATIBILITY TEST

The major assembly oxygen compatibility test exposes major assembly flight subsystems to the design oxygen environment before flight and screens them for workmanship and quality.

A major assembly oxygen compatibility test will not be conducted unless the need for such a test is identified in the detailed oxygen compatibility analysis per the requirements documented in NASA-STD-6016. In most cases, hardware is not sensitive to ignition by assembly contamination, or the major assembly test would not detect contamination hazards that were present. However, in some cases, the combination of complex hardware with significant assembly manufacturing activities (such as cutting and welding) and high operational pressures makes a major assembly test necessary. Hardware receives a detailed oxygen compatibility analysis as specified by NASA-STD-6016 and oxygen acceptance testing at the unit level, as specified by Section 4.18.

NOTE: The major assembly oxygen compatibility test is never required for portions of the assembly that operate at pressures below 265 psia.

5.9.1 Test Description

Oxygen subsystems shall be operated in 100 percent oxygen at the MDP or the maximum pressure that will not cause relief valves to open, as specified in the applicable system development specification. Operational tests other than leakage (e.g., opening and closing valves) shall be conducted while units are pressurized with oxygen. Subsystems shall be subjected to oxygen flow in both the forward and reverse flow directions where reversible flow is within the operational capability of the subsystem.

5.9.2 Test Levels and Duration

Acceptance: A minimum of 10 operational cycles shall be conducted on the system while at maximum pressure.

5.9.3 Supplementary Requirements

A leak test shall be performed after conducting the oxygen compatibility acceptance test and shall be verified to the levels specified in the development specifications.

Cleanliness shall be maintained to the level specified in the assembly development specification. Hydrocarbon detection analysis shall be performed as specified in MSFC-PROC-404 prior to performing the oxygen compatibility test. When IPA or other flammable solvents are used for the cleaning, flushing, or testing of any portion of an assembled gaseous oxygen system, the residual concentration of solvent must be verified within acceptable limits prior to the introduction of fluids for the oxygen compatibility test. After purging with an inert gas, a 24-hr lock-up of the system is required to ensure that enough time is provided for the contaminant solvent to volatilize, thus achieving concentration equilibrium so that gas sampling will provide an accurate reflection of the residual solvent concentration. The solvent concentration in lock-up gas samples shall not exceed 18 ppm when measured as methane (CH_4).

If partial disassembly of the subsystem occurs after the major assembly oxygen compatibility test, a delta oxygen compatibility analysis shall be conducted to determine whether it is necessary to repeat the test.

5.10 MAJOR ASSEMBLY CLIMATIC TESTS

These climatic tests demonstrate the major assembly’s capability to survive exposure to various climatic conditions without excessive degradation or to operate during exposure, as applicable. Exposure conditions shall include those imposed upon the major assembly during fabrication, test, shipment, storage, mission operations, entry, recovery, and refurbishment.

To the greatest extent practical, the flight hardware is normally protected from the potentially degrading effects of extreme terrestrial natural environments by procedural controls and special support equipment. In these cases, the protective measures are verified to adequately protect the flight hardware. However, qualification testing shall be conducted for the applicable remaining environmental conditions (as specified in CxP 70023) that are not mitigated by the protective measures.

The following major assembly climatic tests are typically for qualification only:

a. Rain

b. Salt fog

c. Sand, dust, or lunar regolith

d. Humidity

e. Explosive atmosphere compartment

The explosive atmosphere test may be included in acceptance criteria if the released energy potential exceeds specified values.

5.10.1 Rain

5.10.1.1 Terrestrial

Perform testing as specified in Section 4.16.1.

5.10.1.2 Lunar

Not applicable

5.10.1.3 Martian

Not applicable

5.10.2 Salt Fog

5.10.2.1 Terrestrial

Perform testing as specified in Section 4.16.2.

5.10.2.2 Lunar

Not applicable

5.10.2.3 Martian

Not applicable

5.10.3 Sand, Dust, or Lunar Regolith

5.10.3.1 Terrestrial

Perform testing as specified in Section 4.16.3.

5.10.3.2 Lunar

Perform testing as specified in Section 4.16.3.

5.10.3.3 Martian

Perform testing as specified in Section 4.16.3.

5.10.4 Humidity

5.10.4.1 Terrestrial

Perform testing as specified in Section 4.16.4.

5.10.4.2 Lunar

Perform testing as specified in Section 4.16.4 (for internal habitable volumes only).

5.10.4.3 Martian

Perform testing as specified in Section 4.16.4 (for internal habitable volumes only).

5.10.5 Explosive Atmosphere Compartment

Not Applicable

6.0 REQUIREMENTS AND GUIDELINES FOR RETEST

Retest is the repeat of all or part of previously conducted tests because of events such as a failure, design or manufacturing process changes, change in manufacturing source or facility, or changes in predicted service environments. Discrepancies may occur at any point in the qualification or acceptance test sequences or other times during the TA's service life.

When a discrepancy occurs, the test shall be interrupted and a determination shall be made as to whether the discrepancy is because of a failure of the TA or due to other causes such as a failure of the test support system performing the test (test setup, software, or equipment). If the discrepancy is due to the latter, and a determination is made that no overstress of the test item exists, the test may be continued after repairs of the test system have been made. If the test item has failed or has been (or potentially has been) overstressed, such as pressure or voltage in excess of qualified values, then test activities shall resume only after a preliminary failure analysis determines the cause and remedial or corrective action has been taken. Failure analysis, remedial/corrective action(s) taken, and resumption of test activities shall be in accordance with appropriate contractual provisions.

Final failure analysis may be a continuing function because initial evaluations are sometimes inconclusive and further action may be required, particularly if the failure represents a generic or lot-related problem. For long-term corrective action, a determination shall be made if the failure could have been detected at a lower level of assembly or in an earlier test.

The degree of retest shall be determined on a case-by-case basis and shall take into account the following factors:

a. The results of the failure analysis, which may indicate that more thorough functional or performance testing is required.

b. The specifics of any manufacturing process or design changes and their potential impact to the unit's performance, reliability, or its sensitivity to environments.

c. Changes in predicted service environments including transportation and storage.

d. The degree of disassembly/reassembly required to achieve rework/redesign objectives.

Retesting may reduce previously baselined test durations (e.g., reduced number of thermal cycles or only one axis of random vibration versus three) when deemed reasonable and technically justifiable. Previously baselined test levels (e.g., minimum/maximum test temperatures and vibration amplitudes) shall not be reduced without prior approval of the CxP. If a thermal vacuum or thermal cycle retest is required, and the unit's nonoperating temperature range is outside its required operating temperature range, a minimum of one nonoperational temperature cycle shall be conducted during the retest. The nonoperational cycle shall either precede or be combined with the first operational temperature cycle (reference figures 4.10.3-3 and 4.10.3-4).

APPENDIX A
ACRONYMS AND ABBREVIATIONS
AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
AFSPCMAN	Air Force Space Command Manual
ASD	Acceleration Spectral Density
atm	atmosphere
AVT	Acceptance Vibration Test
CARD	Constellation Architecture Requirements Document
CEQATR	Constellation Environmental Qualification and Acceptance Testing Requirements
CH_4	Methane
CIL	Critical Items List
CM	Crew Module
cm	centimeter
cm^2/hr	square centimeters per hour
COPV	Composite Overwrapped Pressure Vessel
CR	Change Request
CS	Cold Start
Cx	Constellation
CxP	Constellation Program
dB	decibel
DP	Decision Package
DSNE	Design Specification for Natural Environments
dt	delta time
dT	delta temperature
E3	Electromagnetic Environmental Effects
EDS	Earth Departure Stage
EEE	Electrical, Electronic, and Electromechanical
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference

ESS	Environmental Stress Screening
f	frequency
FMEA	Failure Modes and Effects Analysis
FT	Functional Test
ft	foot
ft^2	square foot
FTS	Flight Termination System
g	gravity
grms	gravity root mean square
Gs	Gravity Acceleration
HALT	Highly Accelerated Life Testing
HASS	Highly Accelerated Stress Screening
Hg	Mercury
hr	hour
HS	Hot Start
Hz	Hertz
ID	Identification
in	inch
in^2	square inch
IPA	Isopropyl Alcohol
IR	Infrared
IRD	Interface Requirement Document
ISS	International Space Station
kHz	kilohertz
kPa	kilopascal
lb	pound
LEO	Low Earth Orbit
m	meter
m^2	square meter
m^3/s	cubic meter per second
M&P	Materials and Processes
MDP	Maximum Design Pressure
MIL-STD	Military Standard

MIVP	Master Integration and Verification Plan
ml	milliliter
mm	millimeter
MMOD	Micro Meteoroid Orbital Debris
mPa	millipascal
ms	millisecond
MSFC-PROC	Marshall Space Flight Center Procedure
MUM	Multi-Unit Module
MVP	Master Verification Plan
N_2	nitrogen
NASA	National Aeronautics and Space Administration
OASPL	Overall Sound Pressure Level
OPR	Office of Primary Responsibility
Pa	pascal
pH	measure of acidity
PHS&T	Packaging, Handling, Storage, and Transportation
ppm	parts per million
PRACA	Problem Reporting, Analysis and Corrective Action
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PT	Performance Test
QAVT	Qualification for Acceptance Vibration Test
QVT	Qualification Vibration Test
RH	Relative Humidity
s	second
sccs	standard cubic centimeters per second
scim	standard cubic inches per minute
SE&I	Systems Engineering and Integration
SECB	Systems Engineering Control Board
SLT	Suitable Leak Test
SPL	Sound Pressure Level
SR&QA	Safety, Reliability, and Quality Assurance
SRS	Shock Response Spectrum

STD Standard

TA Test Article
TB Thermal Balance
TBD To Be Determined
TBR To Be Resolved
THB Temperature/Humidity/Bias
TPS Thermal Protection System
TRER Test Requirement Evaluation Report
TRR Test Readiness Reviews
TVR Test Verification Requirement

UTC Coordinated Universal Time

A2.0 GLOSSARY OF TERMS

Term	Description
Acceptance	The activity performed on all production articles and generally consisting of inspections, measurements, and tests that demonstrate that each article was manufactured as designed and with acceptable quality and workmanship; performs in accordance with specified requirements; and is acceptable for delivery.
Acceptance Testing	Testing performed to demonstrate acceptability of each deliverable item to meet performance specifications and demonstrate acceptable quality of workmanship in manufacturing. This testing typically is intended to stress screen items to precipitate incipient failures due to latent defects in parts, processes, materials, and workmanship.
Acceptance Vibration Test (AVT)	AVT detects latent manufacturing, material, and workmanship defects and aids in verifying overall acceptability and flight worthiness of production units and major assemblies. This test is required for all production units.
Ambient Environment	The ambient environment for ground tests is defined as a temperature of 23 ± 10 °C (73 ± 18 °F); atmospheric pressure of 101 +2/–23 kPa (29.9 +0.6/–6.8 in Hg); and a relative humidity of 50 ± 30 percent). This encompasses sea level to 7,000 ft.

Term	Description
Antenna	A device used to couple energy from a guiding structure (transmission line, waveguide, etc.) into a propagation medium, such as free space, and vice versa. It provides directivity and gain for the transmission and reception of electromagnetic waves.
Background	In leak testing, the steady or fluctuating output of the leak detector caused by the presence of residual tracer gas or other substance to which the detecting sensor responds.
Battery	An electrochemical energy storage device used to store electrical power.
Component	(See Unit)
Detector Probe	In leak testing, a device used to collect tracer gas from an area of the test article and feed it to the leak detector at the reduced pressure required. Also called a sniffing probe.
Development Specification	The documentation that specifies the functional/performance requirements, environmental conditions, and other “design-to” requirements imposed on a product. The term, as used in this document, means the documentation specifying such requirements regardless of its formal title such as “Design Specification,” “End Item Specification,” “Source Control Drawing”, etc.
Electrical/Electronic Unit	A “black box” consisting of electrical or electronic subassemblies such as circuit boards housed in a single chassis and removable from its next higher assembly as a single-chassis entity. Usually equipment used for electrical power distribution and control, avionics equipment and electromechanical actuators.

Term	Description
Environment	The combination of physical, chemical, and biotic conditions experienced during the service life of units, assemblies, and major assemblies beginning with the completion of manufacturing, followed by test, storage, transportation, launch, space missions, and entry, descent, and landing as applicable. Environments include vibration, shock, acoustic noise, acceleration, electromagnetic, temperature, humidity, pressure, radiation, orbital density and composition, orbital debris, meteoroids, magnetic and gravitational fields, plasma, contamination, and others.
Environmental Acceptance Testing	The application of environments such as random vibration and temperature cycling during acceptance testing to serve as environmental stress screens to precipitate and detect latent manufacturing and workmanship defects.
External-to-Internal Total Leakage	The combined leakage rate through all the existing pathways from the outside to the inside of the item or system being tested.
Failure	The inability of a test article to perform its required function within specified limits, under specified conditions or for a specified duration.
Flight Hardware	A production article (including spares) intended for an operational flight mission. Included is hardware intended for extra-terrestrial surface installation.
Fluid Equipment	Equipment used to control, regulate, dispense, distribute, or expel fluids. Pertains only to the equipment through which the fluids flow.
Functional Test	A test of a unit, system, or major assembly whereby input parameters such as voltage, current, power, load, force, motion, etc. are only input at their nominal or expected level; they are not varied through their full specification range (compare to performance test). General functionality and operability within requirements are verified with a functional test.
Internal-to-External Total Leakage	The combined leakage rate through all the existing pathways from the inside to the outside of the item or system being tested.

Term	Description
Internal-to-Internal Total Leakage	The combined leakage rate through all the existing pathways across an internal barrier in the item or system being tested.
Leak	A pathway permitting the flow of fluid from one side of a barrier to the other independent of the quantity of fluid flowing.
Leak Detector	A device for detecting, locating, or measuring leakage.
Leakage	The flow of a fluid through a leak.
Leakage Rate	The rate of fluid passing through a leak at a given temperature as a result of a specified pressure difference across the leak. Examples of rates are sccs, m^3/s, or scim.
Major Assembly	A physical entity that has functional capabilities allocated to it necessary to satisfy system-level mission objectives within the Cx Architecture. A major assembly can typically perform all system functions within a mission phase (e.g., launch, ascent, on-orbit, reentry), or through mated operations with other Cx major assemblies (e.g., Orion, Earth Departure Stage [EDS], and Altair). Major assemblies will fall into one of the following four categories: a. Elements, such as the Crew Module (CM) b. Systems, such as the Orion c. Combined systems, such as the Orion/Ares I integrated vehicle d. Any large, complex hardware article that is determined by the Project to require qualification or acceptance testing prior to integration at the element level
Maximum Design Pressure (MDP)	The pressure for which a pressurized unit or system is required to be qualified for and certified to as defined by the applicable development specification.

Term	Description
Mechanism	A unit in which one part moves relative to another part. Examples are gimbals, actuators, de-spin mechanism, separation mechanism, deployment mechanisms, valves, pumps, motors, latches, clutches, springs, quick-release pins, dampers, and bearings. Also included are bolts and associated threaded fittings which are required to operate during the mission.
Multi-Unit Module (MUM)	A Multi-Unit Module (MUM) is an intermediate level-of-assembly between the lowest level unit (as defined in this document) and the system level-of-assembly referred to in this document as a major assembly. It is comprised of units connected through common support structure, wiring harnesses, electrical cables, or fiber optic cables. Examples are a docking ring or an electronic box consisting of a large chassis in which are housed smaller electronic units (i.e., a “superbox”). MUMs have their own requirement specifications and are qualified and acceptance tested at the MUM level-of-assembly. They are also to be tested as “units” in accordance with this document.
Nonoperating Maximum/Minimum Temperature	The maximum (or minimum) temperature to which an item may be exposed in a nonoperational state as documented in the applicable development specification or as derived analytically from the thermal environments specified in the applicable development specification. The item is usually required to meet all specification requirements at operational environmental extremes after exposure to the required nonoperational environments.
Operational Maximum/Minimum Temperature	The maximum (or minimum) temperature to which an item may be exposed in an operational state as documented in the applicable development specification. The item may be required to meet all or only some of the functional/performance requirements while exposed to the temperature extremes.

Term	Description
Operational Modes	The operational modes for a unit, assembly, subsystem or major assembly include all combinations of operational configurations or conditions that can occur during its service life. Some examples are power condition, command mode, readout mode, attitude control mode, redundancy management mode, safe mode, and spinning or de-spun condition. Includes automated and manual as well as primary and redundant modes of operation.
Optical Equipment	Sensors or devices requiring or using any portion of the light spectrum. Does not include windows.
Part	A part is a single piece or two or more joined pieces that are not normally subject to disassembly without destruction or impairment of the design use. Examples are resistors, integrated circuits, relays, and roller bearings.
Perceptive Monitoring	Monitoring of appropriate equipment parameters such as voltage, current, force, motion, etc., such that behavior that is not in accordance with test pass/fail criteria or is not within expected ranges can be identified and appropriate nonconformance reporting and investigation can be conducted.
Performance Test	A test of a unit, system, or major assembly whereby input parameters such as voltage, current, power, load, force, motion, etc., are input throughout their full specification range (compare to functional test). Mission operational modes and sequences are duplicated to the greatest extent practical. Full specification performance and operability within requirements are verified with a performance test.
Pressure Vessel	Reference CxP 70135.
Pressurized Compartment	A pressurized compartment is an enclosed and sealed volume of a major assembly intended to provide the habitable environment for the crew of a space mission or other pressurized environment for equipment or payloads.
Pressurized Structure	Reference CxP 70135.
Pressurized System	Reference CxP 70135.

Term	Description
Pressurized Unit	A unit in a pressurized system other than a pressure vessel that is structurally designed largely by the acting pressure. A pressurized unit is designed to retain its leak tightness at standard atmospheric and differential pressure conditions. Examples are lines, tubes, fittings, valves, bellows, hoses, regulators, pumps, and accumulators.
Production Article	An article manufactured using the engineering drawings, manufacturing processes and materials, and all quality controls and inspections as qualified and certified for flight per the applicable development specification. All flight hardware (including spares), qualification articles, and certain special dedicated test hardware are production articles.
Proof Pressure	The Maximum Design Pressure times a factor of safety.
Proof Pressure Test	Reference CxP 70135 [Proof Test].
Qualification	The activity that demonstrates that a product's design, manufacturing, and assembly have resulted in hardware/software that complies with imposed design and performance requirements. The qualification activity consists of various tests, analyses, demonstrations, and inspections as required to verify conformance of the design to the specified requirements.
Qualification Article	Hardware and associated firmware and software, if applicable, which is used for qualification testing and is identical in configuration and production processing and assembly to the flight hardware except for specifically allowed variances to accommodate the qualification test program (e.g., addition of response instrumentation and associated provisions for its installation). The qualification article is not intended for flight unless refurbished and acceptance tested in accordance with program guidelines or otherwise approved by the appropriate Program authority.
Qualification for Acceptance Vibration Test (QAVT)	QAVT demonstrates design margin for AVT during hardware service life. This may include multiple acceptance vibration test events due to repair, rework, or refurbishment.

Term	Description
Qualification Margin	An increase in an environmental condition (such as temperature or vibration) or input parameter (such as voltage, current, load, or torque) beyond specification requirements or acceptance test conditions in order to show sufficient robustness in the design and its implementation. A qualification margin may be an increase in level or range, or an increase is cycles of operation or duration of exposure. Qualification margins are intended to demonstrate the ability to satisfy both of the following on a single qualification test article: a. Tolerance of the unit to unit differences in flight articles and the qualification article due to reasonable variations in parts, manufacturing tolerances, material properties, and manufacturing processes. b. Immunity to excessive degradation such as fatigue, wear, loss of properties, or functionality after experiencing a specified maximum amount of acceptance testing and operational usage.
Qualification Test	A formal test conducted on flight-configured hardware for the purposes of qualifying the product design.
Qualification Vibration Test (QVT)	QVT demonstrates design margin for exposure to hardware service environments other than AVT, such as transportation, launch, atmospheric flight, lunar ascent/descent, etc. This includes operating and nonoperating conditions.
Reusable Item	A reusable item is a unit, assembly, subsystem, or major assembly that is to be used for multiple missions. The service life of reusable hardware includes all planned reuses, refurbishment as required, and retesting.
Sealed Unit	A unit designed to retain its leak tightness at standard atmospheric and negative differential pressure (i.e., external pressure higher than internal pressure).
Sensitivity of Leak Test	The smallest leakage rate that an instrument, method, or system is capable of detecting under specified conditions.

Term	Description
Service Life	The life of an equipment item starting at the completion of fabrication and continuing through all levels of acceptance testing, handling, transportation, storage, prelaunch processing, all phases of flight, recovery, rework/refurbishment, retest, and reuse as required or specified.
Solar Panel	A collection of Photovoltaic cells mounted on structural material and used to convert solar energy to electrical power.
Standard Leak	A device that permits a tracer gas to be introduced into a leak detector or leak test system at a known rate to facilitate calibration of the leak detector or to confirm the sensitivity of the test system.
Subassembly	A subassembly is a unit containing two or more parts, which is capable of disassembly or part replacement. Examples include a printed circuit board with parts installed or a gear train.
Subsystem	An assembly of units, including any associated software that performs a dedicated function. It consists of two or more units and may include interconnection items such as cables or tubing, and the support structure to which they are mounted. Examples include electrical power, attitude control, telemetry, thermal control, propulsion subsystems. The subsystem level is directly below the element level in the Constellation architecture terminology.
Suitable Leak Test (SLT)	A Suitable Leak Test (SLT) method shall exhibit, at a minimum, the following: Sensitivity - An SLT method shall be defined as one that establishes the sensitivity of the end-to-end leak test setup such that the setup is demonstrated to be capable of detecting a leakage rate of at least one-half the specified pass/fail leakage rate as defined in the applicable test procedure. Where necessary, compensation for atmospheric conditions such as temperature, pressure, and humidity shall be provided. For leak test standard tools such as graduated flasks, columns, and pipettes purchased at standard scientific suppliers, the calibration of the graduations shall be accepted. Tracer gas standard leaks shall bear a

Term	Description
	calibration certification sticker from metrology or the vendor and shall be within the prescribed dates and, if equipped with a pressure gauge, within the appropriate pressure range. Characterization - An SLT method shall demonstrate the appropriate duration to establish confidence in the ability to detect leakage rates above background and establish a stable time period to allow for permeation, multiple leak paths, etc. The duration established to calibrate the leak test setup for demonstrating the ability to detect leakage will be accepted as the (one) time constant. To demonstrate leakage rate stability during the performance of the actual leak test, the leak test setup shall require continuous monitoring until the measured leakage rate result exhibits less than 10 percent variation for a duration of three time constants. Documentation - Appropriate documentation shall include at a minimum: the operator, the inspector, the method of calibration and sensitivity of the leak test setup, a detailed sketch/description of the leak test setup, number of test data points measured, and the respective time intervals of the measurements. The test report and procedures shall also include information on any training and/or certification of the inspectors and technicians.
Test Discrepancy	A test discrepancy is a functional, performance, or structural anomaly that occurs during testing, which may reveal itself as a deviation from specification requirement for the test item. A test discrepancy may be a momentary, unrepeatable event, or it may be a permanent failure to respond in the predicted manner to a specified combination of test environment and functional test stimuli. Test discrepancies include those associated with specification performance, premature operation, failure to operate or cease operation at the prescribed time, and others that are unique to the item under test. A test discrepancy is considered to be a failure of the test article unless it can be demonstrated that the discrepancy was due to an unintended cause such as

Term	Description
	improper test setup, improper test execution, or failure of test support equipment.
Test Item Failure	A failure of a test item is defined as a test discrepancy that is due to a design, workmanship, process, or any quality deficiency in the item being tested. Any test discrepancy is considered to be a failure of the test item unless it can be determined to have been due to some unintended cause.
Thermal Dwell	Thermal dwell of a unit at the hot or cold temperature extreme is the time required to ensure that internal parts and subassemblies have achieved thermal equilibrium.
Thermal Equilibrium	Thermal equilibrium is achieved when the unit internal part with the largest temperature constant is within 3 °C (5.4 °F) of its equilibrium temperature, as determined by extrapolation of test temperatures and/or previous analysis/test data, and its rate of change is less than 3 °C (5.4 °F) per hr.
Thermal Equipment	Equipment such as valves, pumps, heat exchangers, and other units using fluids that collect or dispose of thermal energy.
Unit	A unit is a functional item (hardware and, if applicable, software) that is viewed as a complete and separate entity for purposes of manufacturing, maintenance, and record keeping. Examples: hydraulic actuator, valve, battery, transmitter, heat exchanger, “black box.” Specifically excluded are instrumentation and sensors such as strain gauges, strip and patch heaters, thermocouples, wiring, cables, tube runs, etc., although these items are required to undergo environmental qualification and acceptance testing as part of their higher levels of assembly. Also excluded from definition as a unit are primary and secondary structure (as defined in CxP 70135) and Thermal Protection System (TPS).

APPENDIX B
OPEN WORK

B1.0 TO BE DETERMINED

Table B1-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is numbered based on the document number, including the annex, volume, and book number, as applicable (i.e., **<TBD-XXXXX-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

TABLE B1-1 TO BE DETERMINED ITEMS

TBD	Section	Description
N/A	N/A	N/A

B2.0 TO BE RESOLVED

Table B2-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is numbered based on the document number, including the annex, volume, and book number, as applicable (i.e., **<TBR-XXXXX-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

TABLE B2-1 TO BE RESOLVED ISSUES

TBR	Section	Description
N/A	N/A	N/A

APPENDIX C
FORCE LIMITED VIBRATION TESTING

Force limiting alleviates the severe overtest at TA resonances inherent in conventional shaker vibration tests. NASA-HDBK-7004B, Force Limited Vibration Testing (http://standards.nasa.gov), establishes a methodology for conducting force limited vibration tests for all NASA flight projects, including approaches for developing force-limit specifications. A force limited vibration test is any vibration test in which the force between the test item and shaker is measured and controlled. The recommended means of measuring the force is with piezoelectric force gauges, but other means such as strain gauges may be useful in special circumstances. Similarly, the control of the force is preferably accomplished in real time (employing the external control feature available in most vibration controllers) but iterative. Off-line control may be employed in special circumstances. If the force is not measured, the test is not considered a force limited vibration test.

Force limiting may be employed for the unit QVT, QAVT, and AVT random vibration tests of Section 4.6, but it may be appropriate to limit the resultant acceleration spectrum notches in order to maximize the workmanship benefits of the tests. Specifically, QVT, QAVT, and AVT test force limiting should be constrained such that the minimum unit AVT workmanship screening level of table 4.6.2.1-1 is not notched more than 6 dB, while maintaining specified minimum test spectrum margins between the three types of tests. NASA customer approval is required if deeper force limit vibration notching is necessary to protect the test item.

Approval of test item force limit specifications by a NASA vibration force limiting technical specialist is required. This prior approval shall be processed as a “tailoring” activity in accordance with Section 3.1. Preliminary approval of the force specification can be given prior to testing based on estimated mass, fundamental frequencies, and damping of the test item. However, a force limited vibration finite-element method analysis of the test item is preferred. Final approval of the force limit specification is contingent on receipt of shaker low-level run force and acceleration control measurement data for each axis. Approval can be provided real time via facsimile and phone with prior arrangement.