METRIC/INCH-POUND

KSC-STD-164
Revision C

ENVIRONMENTAL TEST METHODS FOR GROUND SUPPORT EQUIPMENT, STANDARD FOR

Export Control Determination

NOT EXPORT CONTROLLED
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Engineering Directorate

National Aeronautics and
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John F. Kennedy Space Center

KSC FORM 16-12 (6/95) PREVIOUS EDITIONS MAY BE USED

RECORD OF REVISIONS/CHANGES

REV LTR	CHG NO.	DESCRIPTION	DATE
		Basic issue.	September 17, 1964
A		General revision.	May 16, 1989
B		General revision.	July 6, 1992
C		1. Added requirement to follow NASA-STD-5008B for qualification of protective coatings in 1.1. 2. Replaced NASA TM 82473 with NASA TM 2008-215633 in 1.2.2 and 1.2.3. 3. Revised list of Applicable Documents in 2.1 and 2.2. 4. Replaced U.S. Bureau of Standards with NIST and deleted 12-month time frame in 3.1.2. 5. Deleted reference to KSC-STD-128 and replaced with the testing agency's policies in 3.2.7. 6. Deleted reference to Table 1 and replaced it with a reference to KSC-STD-E-0022 in 3.3.1.2.1. 7. Added exception for field characterization testing in 3.3.1.2.2. 8. Deleted Table 1 and replaced reference to MIL-STD-462 with KSC-STD-E-0022 in 3.3.1.2.4.e. 9. Deleted rationale statement and reference to IERB-2274 in 3.3.5.3.e. 10. Added Pre T-0 for the hold-down period and Post T-0 for during lift-off, and modified vibration environment paragraphs in 3.3.6.4.1. 11. Deleted references to cases a, b, and c in 3.3.6.4.4. 12. Added recommendation for using a second accelerometer to verify signal integrity in 3.3.6.5.3. 13. Modified vibration control signal test procedure in 3.3.6.5.4. 14. Modified data analysis for total rms acceleration time history in 3.3.6.5.4.1.a. 15. Added references to NASA/TM-2008-215633 and MIL-STD-810 in 3.3.8.1. 16. Included reference to test procedures in MIL-STD-810 for testing the effects of exposure of rain and ice on GSE objects in 3.3.9.1 and 3.3.10.1. 17. Deleted Sunshine in title and replaced with UV in 3.3.11. 18. Added reference to ASTM G155 and MIL-STD-810 in 3.3.11.1. 19. Added reference to solar radiation procedures in MIL-	April 18, 2022

REV LTR	CHG NO.	DESCRIPTION	DATE
		STD-810, modified test requirements and conditions, and deleted Table 2 in 3.3.11.2. 20. Revised procedure for testing effects of light sources on materials in 3.3.11.3. 21. Deleted 3.3.11.4. 22. Added reference to fungus procedures in MIL-STD-819, modified fungus test procedures in 3.3.12.1. 23. Deleted Sections 3.3.12.2, 3.3.12.2.1, 3.3.12.2.2, and Table 3. 24. Added reference to MIL-STD-810 for fungus procedures to 3.3.12.2.3 and 3.3.12.3. 25. Added reference to ASTM B117 as a guide to operating a salt fog apparatus, and a reference to MIL-STD-810 for testing the object using the salt fog procedures in 3.3.13.1. 26. Deleted Sections 3.3.13.2 and 3.3.13.3. 27. Added testing of object per sand and dust procedures in MIL-STD-810 in 3.3.14.1. 28. Deleted Section 3.3.14.2. 29. Replaced NFPA 493 with UL 913 in 3.3.15.1. 30. Updated preparing activity in 6.2.	

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Abbreviation	Definition
ANSI	American National Standards Institute
ATCC	American Type Culture Collection
dB/oct	decibels per octave
DE	Engineering Development Directorate
DOF	degree of freedom
ft	foot
FRF	Flight Readiness Firing
g	acceleration due to gravity
GHz	gigahertz
g-rms	root mean square acceleration in units of g
GSE	Ground Support Equipment
Hz	Hertz
kg	kilogram
kHz	kilohertz
kPa	kiloPascal
KSC	Kennedy Space Center
m	meter
MHz	megahertz
MIL	military
MLP	Mobile Launcher Platform
mm	millimeter
N	newton
NFPA	National Fire Protection Agency
NIST	National Institute of Standards and Technology
OASPL	Overall Sound Pressure Level
OBSPL	Octave Band Sound Pressure Level
oct/min	Octave per minute
Pa	Pascal
PSD	Power Spectral Density
Psi	pound per square inch
RF	radio frequency
RH	relative humidity
rms	root mean square
SiO2	silicon dioxide
SPL	Sound Pressure Level

STD	Standard
TM	Technical Manual
UL	Underwriters Laboratories
USDA	U.S. Department of Agriculture
µm	micrometer
W/m^2 °C	watt per square meter degree C
°F	degree Fahrenheit

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1. SCOPE

This standard establishes test methods for determining the capability of ground support equipment (GSE) and other facility hardware to function when exposed to the natural and induced environments peculiar to the prelaunch and launch conditions at KSC. The test methods contained herein specify conditions obtainable in the laboratory that will give test results similar to actual service conditions. This standard provides requirements and guidelines for the preparation of detailed test procedures and for the preparation of the environmental test portions of design specifications. This standard provides the environmental test methods that are applicable for qualification of components in accordance with KSC-STD-G-0003, Launch Support and Facility Components, Qualification of, Standard for. Test requirements and conditions may be tailored according to program and project requirements.

1.1 Applicability

The temperature and rain conditions described are based upon the extreme conditions experienced in the KSC, Florida area. The accelerated tests (humidity, sand and dust, fungus, and salt fog) were kept in close conformance with MIL-STD-810 to allow the greatest possible standardization of test methods. This was considered possible since these tests are not intended to reproduce actual service conditions but are intended to show the effects of long exposure to these environments. For qualification of protective coatings for launch structures, facilities, and ground support equipment, the test criteria in NASA-STD-5008B shall be followed in lieu of other salt fog, solar radiation, and humidity testing found in this document.

1.2 Design and Testing Considerations

1.2.1 Severity and Testing Considerations

The environmental conditions to which GSE is exposed in the KSC area vary considerably by virtue of its location on the Center. The environmental conditions of computer equipment installed in an air-conditioned, sound-absorbent room on vibration-isolated floors is negligible compared to the severe conditions a hold down system experiences; i.e., the daily natural environments and the blast of the launch vehicle during lift-off. Designing or testing all equipment to the most severe of these conditions is impractical and expensive. The difficulty of designing equipment to meet the design specification is greatly compounded when the specification includes requirements excessive to the actual service environment. This is not meant to imply, of course, that overdesigning or over-testing to ensure that reliability goals are met is not desirable. Rather, design and testing must be accomplished with both the actual environmental and reliability requirements in mind. Consequently, the high-temperature test, temperature shock test, acoustic test, and vibration test require considerable judgment to ensure the proper selection of the specification level and test procedure.

1.2.2 Excluded Tests

Wind, immersion, and earthquake tests have been excluded from this standard. The definition of a standard test method for these environments is not considered practical or desirable at this time; however, these environments should be considered when applicable to a specific design. Design winds and seismic environments are defined in NASA TM 20008-215633. Generally, KSC facilities and GSE are designed to hurricane wind loads in accordance with KSC-STD-Z-0004. Testing to this environment should not be a normal requirement, but some critical systems, such as service arms, will require specific consideration of wind load tests.

1.2.3 Manufacturing and Engineer Test Locations

As previously stated, the environmental limitations depicted by this standard are intended for GSE located at KSC. Consideration must also be given to the environmental conditions at the site of equipment manufacture and engineering (system) testing as well as during transportation to KSC. If the acceptance is made at the launch site, the manufacturer is responsible for ensuring that the GSE meet environmental requirements at the manufacturing site, during transport and storage, and at KSC. Environmental conditions for major areas of the United States are given in document NASA TM 2008-215633.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specified revision levels, amendments, and approval dates of said documents shall be specified in an attachment to the Solicitation/Statement of Work/Contract.

2.1 Governmental

2.1.1 Standards

John F. Kennedy Space Center (KSC), NASA

KSC-STD-E-0002	Hazard Proofing of Electrically Energized Equipment
KSC-STD-G-0003	Qualification of Launch Support and Facility Components, Standard for
KSC-STD-Z-0004	The Design of Structural Steel Buildings and Other Structures, Standard For
KSC-STD-E-0022	Bonding, Grounding, Shielding, Electromagnetic Interference, Lightning and Transient Protection, Design Requirements for Ground Systems

K00000283895	Standard for Mobile Launcher Ground Support Equipment Vibration Qualification
NASA-STD-5008B	Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment

Military

MIL-STD-461	Measurement of Electromagnetic Interference Characteristics
MIL-STD-810	Environmental Test Methods and Engineering Guidelines

2.1.2 Technical Documents

National Aeronautics and Space Administration (NASA)

TM 2008-21563	Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 2008 Revision

John F. Kennedy Space Center (KSC), NASA

KSC-DF-107	DE Technical Documentation Style Guide

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

2.2 Non-Governmental

Industry Publications

American National Standards Institute (ANSD/National Fire Protection Association (NFPA)

ANSI/NFPA 70	National Electrical Code
ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM G155	Standard Practice for Operating Xenon Arc Apparatus for Exposure of Non-metallic Materials

National Fire Protection Association

NFPA 496	Standard for Purged and Pressurized Enclosures for Electrical Equipment

(Application for copies should be directed to the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.)

American National Standards Institute (ANSI)/Underwriters Laboratories (UL)

ANSI/UL 913	Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division I, Hazardous (Classified) Locations

Underwriters Laboratories

ANSI/UL 1203	Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations

(Application for copies should be directed to the Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062.)

3. REQUIREMENTS

3.1 General Requirements

3.1.1 Tolerances of Test Conditions

The maximum allowable tolerances of test conditions (exclusive of accuracy of measuring instrumentation) shall be as stated in the applicable test method or detailed specification.

3.1.2 Tolerances of Instrumentation

All instruments and test equipment used to control or monitor the test parameters shall have an accuracy of at least one-third the tolerance of the variable to be measured. The instruments and test equipment shall be calibrated to laboratory standards whose calibration is traceable via prime standards to the National Institute of Standards and Technology (NIST). Their accuracy shall have been verified to be current at the time of the test.

3.1.3 Ambient Conditions

Unless otherwise specified herein or in the detailed test requirements, all measurements and tests shall be made at normal room temperature, atmospheric pressure, and relative humidity. Whenever these conditions must be closely controlled to obtain reproducible results, a reference temperature of 23±2 degrees Celsius (°C) [73±3.6 degrees Fahrenheit (°F)], a relative humidity (RH) of 50± 5 percent, and an atmospheric pressure of 96.5 +6.8/ -10.2 kilopascals (kPa) (28.5, +2.0/-3.0 inches of mercury) shall be used together with whatever tolerances are required to obtain the desired precision of measurement. Actual ambient test conditions shall be recorded periodically throughout the test program.

3.1.4 Test Chamber Volume

The volume of test chambers shall be at least three times the volume of the test item and shall be of such dimensions to allow proper operation of both the chamber and test item.

3.1.5 Temperature Stabilization

Temperature stabilization shall be considered obtained when the temperature of a test item does not vary more than 2 °C (4 °F) over a 1-hour period. The temperature sensors utilized to determine temperature stabilization shall be mounted on the largest mass of the test item and located as far as practical from the walls of the chamber. The test item and temperature sensors shall be protected from the direct impingement of conditioned air or radiant heat source, except where application of radiant heat is one of the test conditions.

3.2 Testing Procedures

3.2.1 Test Requirements

The anticipated environmental conditions should be carefully considered before determining which tests are to be conducted. Generally, only those conditions that reflect launch and prelaunch usage of the test item should be considered. Where possible, data shall be obtained on actual operating and field environments to which the GSE will be exposed to aid in the test selection process. Exceptions to this are the common items which are likely to be used throughout the launch complex. In such cases, a judgment should be made as to the desirability of conducting additional or more severe tests considering both time and costs. However, additional or more severe tests should be conducted after completion of the test simulating the anticipated environmental conditions thereby avoiding the possibility of a failure that would jeopardize the timely completion of the original test program. When considering the applicable environmental conditions, combined environmental testing should also be considered as a means for more closely simulating service conditions, and in fact, may be the only method of attaining valid test results.

3.2.2 Test Sequence

Those tests that require the successful operation of the test item during exposure to the environment should normally be conducted first, and those tests where the test item remains static throughout the environment should be conducted last. In either case, the test should be conducted in the order of the likely severity on the item; the least severe being conducted first. Unless otherwise stated in the test requirements, the following sequence should be used:

a. Electromagnetic interference (see 3.3.1)

b. Low temperature (see 3.3.2)

c. High temperature (see 3.3.3)

d. Temperature shock (see 3.3.4)

e. Acoustics (see 3.3.5)
f. Vibration (see 3.3.6)
g. Shock (see 3.3.7)
h. Humidity (see 3.3.8)
i. Rain (see 3.3.9)
j. Icing (see 3.3.10)
k. Solar radiation (see 3.3.11)
l. Fungus (see 3.3.12)
m. Salt fog (see 3.3.13)
n. Sand and dust (see 3.3.14)
o. Explosion (see 3.3.15)
p. Lift-off blast (see 3.3.16)

3.2.3 Receiving Inspection

Prior to conducting any tests, the test item shall be subjected to a receiving inspection. This inspection shall be made to determine conformance with applicable drawings and specifications to the extent possible without disassembly of the test item. When quality acceptance tests are specified, they shall be conducted as part of the receiving inspection.

3.2.4 Functional Test

The functional test is the means by which it can be determined whether or not the environmental test is adversely affecting the performance capabilities of the test item. Because the functional test is required to monitor the very "pulse" of the test item, it is obvious that it must be comprehensive enough to include all possible aspects which could affect the operation of the item. Conducting an environmental test without sensing the deterioration of the item’s performance can invalidate the entire test program. The determination of what checks to make as part of the functional test requires a good understanding of the operation and application of the test item and its possible failure modes. Prior to conducting a functional test, the functional parameters to be monitored shall be specified and shall include allowable limits on permissible degradation.

3.2.4.1 Installation in Environmental Facilities

The test item shall be installed in the test facility at ambient conditions in a manner that will simulate service usage. Install instrumentation in, on, or around the item as required by the test. Plugs, covers, and inspection plates used in service shall remain in place. When mechanical or electrical connections are not used, the connections normally protected in service shall be adequately covered in the same manner as service usage. The test item shall then be functionally tested to determine that no malfunction or damage was caused due to faulty installation or handling. The requirement to conduct a functional test following installation is applicable only when a functional test is required during exposure to the specified environments.

3.2.4.2 Frequency

Functional tests shall be conducted at least three times before and after each test environment. If the functional test performed after an environmental test is satisfactory, the test item shall be qualified for the succeeding environment without further testing, provided (1) the succeeding test is started within 72 hours after the previous functional test and (2) installation changes are not required. When a test environment simulates conditions under which the test item would be required to operate during service, the item shall be functionally tested at least three times during the test environment. However, this is not true for accelerated tests such as sunshine, humidity, sand and dust, salt fog, rain, and icing, since they do not simulate actual service conditions. The requirement for conducting functional tests during a test environment is stated in the applicable test methods.

3.2.4.3 Failure

Determining the importance of a failure requires a thorough knowledge of the test item's intended use. An apparent minor failure of a specimen may be of major consequence because of its intended use; likewise, an apparent major failure could be of little consequence. The technical representative is cognizant of a test item's critical failure modes and, therefore, is responsible for determining the disposition required when failure is experienced. Generally, common items should be searched to determine the failure envelope.

3.2.5 Characteristic Tests

The tests described in this standard should not be considered conclusive of all tests required for a comprehensive test program. Tests to establish the basic design characteristic of the item are also required. These tests should not be confused with the functional-type test which is repeated throughout the test program. Characteristic tests are conducted once, generally prior to the environmental tests, unless they are destructive in nature. Examples of characteristic tests for pneumatic components may include proof test, flow test, surge test, and the burst test which is destructive. For electrical components, characteristic tests may include voltage drop test, ampere test, resistance test, and repeatability test.

3.2.6 Life Cycle Reliability Testing

Testing is conducted to provide statistical data for determining the reliability of the test item with a reasonable degree of confidence. Failures that would occur "once-in-a-thousand" are looked for in the life-cycle test. After exposure to all the environments the item would normally be exposed to during use with no deterioration of operation found, the life-cycle test can provide a valid method for determining reliability. Failures that occur due to wearing out of parts beyond service life expectancy must not be considered a design failure, but may be considered for establishing maintenance time periods. The number of life cycles to be conducted shall be established by the testing agency.

3.2.7 Documentation

The environmental tests required for a particular hardware item shall be documented in a test plan or test requirements document. The tests necessary to determine the suitability of the item for use shall be specified in the sequence specified in 3.2.2. Inspections, data requirements, test tolerances, functional tests, and installation requirements shall be indicated along with any deviations from the standard tests established herein. KSC-DF-107 may be used as a guide in preparing the plan. The testing agency shall develop a detailed test procedure based upon the test requirements specified in the test plan. Test results shall be documented, approved, and published in accordance with the testing agency's policies.

3.3 Test Methods

3.3.1 Electromagnetic Interference

3.3.1.1 General

The electromagnetic interference tests are performed to determine if the electronic or electrical equipment under test will exhibit malfunction or degradation in performance when subjected to undesired external signals. Electrical and electronic equipment includes components that are susceptible to malfunction from external electromagnetic interference. Such interference can change the calculations of a computer, alter the sequence of planned commands of computer programs, and cause recorders to erroneously indicate that a function occurred, failed, or even altered the time of the recording function. Components, such as solenoid valves, power contacts, and signal relays that are not susceptible to malfunction from external electrical interference, generate transient pulses when de-energized. These impulses may exceed the normal operating voltage ratings of much associated connecting circuitry as well as transmit electromagnetic interference to external electronic circuits. Approaches to electromagnetic interference control worthy of consideration are:

q. Incorporation of suppression devices on all components that are capable of producing transients above an acceptable level; e.g., use of diodes in parallel with the circuit to the coil of relays and solenoid valves.

r. Reduction of induced effects by incorporating radio frequency (RF) shielding in the form of shielded wire and RF tight enclosures. RF shielding may be used on the producing circuits, the susceptible circuits, or on both circuits.

s. Strict compliance with applicable specifications in the design and manufacture of electrical and electronic components.

t. Reduction of the possibility of interference by properly programming periods of "RF SILENCE" into the countdown sequence.

The practicability of off-line testing a unit of equipment or a component for electromagnetic interference is questionable since the exact electromagnetic environment and installation cannot be readily reproduced at a test facility. A general description of the test methods for such tests is provided herein.

3.3.1.2 Test Conditions

3.3.1.2.1 Interference Tests

KSC-STD-E-0022 lists the types of electromagnetic interference tests and the applicable frequency range for each type.

3.3.1.2.2 Ambient Electromagnetic Environment

The ambient electromagnetic environment in both shielded-room and non-shielded-room test areas shall be at least 6 dB below the allowable specification limit for the particular test being performed. If the ambient electromagnetic environment plus the test specimen levels are below the applicable specification limit at the time of measurement, the test specimen shall be considered to have met the specified requirement. No test shall be performed in any area where the ambient electromagnetic environment creates doubt about the validity of the test results except for field characterization testing.

3.3.1.2.3 Measurement Equipment Utilization

All measurement equipment shall be calibrated and operated as prescribed by their respective instruction manuals.

3.3.1.2.4 Test Procedure

a. The test specimen shall be placed in the test facility as specified in 3.2.4.1.

b. The test specimen shall be loaded with the full mechanical and electrical load, or equivalent, for which it was designed. When known, the loads used shall simulate the resistance, inductance, and capacitance of the actual load. When unknown, a resistive load shall be used and noted in the test record.

c. The signal generating and monitoring equipment shall be connected in the configuration dictated by the applicable interference test.

d. The test specimen shall be set to its most susceptible mode of operation. When this mode is unknown, the test specimen controls shall be varied during the test. If necessary, the control shall be adjusted for different operational modes during various portions of the test. The most susceptible side of the test specimen shall be turned toward the antenna during all tests.

e. The transients or signals at the applicable frequency shall be applied to the test specimen in the manner prescribed in KSC-STD-E-0022.

f. The output level, frequency, and test specimen operational mode shall be recorded for each susceptible condition. The output level of the signal source shall be gradually reduced until the minimum susceptible output is determined.

g. The test facility shall be returned to ambient conditions upon completion of the test.

h. The test specimen shall be visually inspected and functionally tested within 1 hour following the establishment of ambient conditions at the test facility.

3.3.2 Low Temperature

3.3.2.1 General

The low-temperature test is performed to determine the operational performance of the item at low temperatures which might be encountered during its life cycle. The test item shall be functionally tested during exposure to ascertain whether or not the environment causes degradation of performance. Some of the difficulties which may result from low-temperature exposure are binding due to differential contraction of parts, loss of resiliency of gaskets, and congealing of lubricants. Testing to this environment is applicable to components not installed in a temperature-controlled environment. Program or project requirements shall be given priority over the specific values given here.

3.3.2.2 Test Conditions

A temperature of -18 °C +0/-2 °C (2 °F +0/-4 °F) shall apply to all equipment except that equipment installed close to cryogenic equipment, which is exposed to lower temperatures. In cases of the latter, the procedures described herein shall be followed as prescribed with the chamber temperature changed only to correspond with the expected low-temperature extreme. The low-temperature test shall be substituted by the temperature shock test (see 3.3.4) for pneumatic equipment that is chilled by the expansion of gases through or upstream of the component. The maximum temperature change rate shall be 1 °C (1.8 °F) per minute as determined from the instrumentation monitoring the test item. A low temperature of 11 °C (51.8 °F) shall be used for all equipment that is in a temperature controlled area.

3.3.2.3 Procedure

a. The item shall be placed in the test chamber as specified in 3.2.4.1 and temperature sensors shall be installed near the item in the air.

b. The chamber shall be adjusted to the specified test conditions.

c. When a stabilized temperature is maintained, the test item shall be functionally tested. When a fluid is involved in the functional test, the fluid temperature shall be maintained between -18 °C (-2 °F) and 25 °C (77 °F) and the actual fluid temperature shall be recorded.

d. The chamber temperature shall be returned to ambient conditions upon completion of the functional tests.

e. The test item shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions, unless the next step is to another temperature.

3.3.3 High Temperature

3.3.3.1 General

The high-temperature test is performed to determine the operational performance of the item at high temperatures that might be encountered during its life cycle. The test item shall be functionally tested during exposure to ascertain whether or not the environment causes degradation of performance. High-temperature conditions may cause permanent setting of packings and gaskets, binding of parts due to differential expansion, and cracking or bulging of rubber and plastic. This test is applicable to components that are not installed in a temperature-controlled environment. Program or project requirements shall be given priority over the specific values given here.

3.3.3.2 Test Conditions

A temperature of 52 °C +2/-0 °C (125 °F +4/-0 °F) shall apply for all items except those exposed to direct solar radiation or confined in an enclosure exposed to solar radiation. In these cases, a temperature of 71 °C +2/-0 °C (160 °F +4/-0 °F) shall apply for a prolonged exposure and a temperature of 88 °C +2/-0 °C (190 °F +4/-0 °F) shall apply for the functional test. Procedure I defines the method to be used for equipment not exposed to solar radiation; Procedure II defines the method for equipment exposed to solar radiation. A relative humidity of 20 ±5 percent shall not be exceeded in either test. The maximum rate of temperature change shall be 0.5 °C (1 °F) per minute as determined from the instrumentation monitoring the test specimen.

3.3.3.3 Test Procedure

3.3.3.3.1 Procedure I Non-solar Radiation

a. The item shall be placed in the test chamber as specified in 3.2.4.1 and temperature sensors shall be installed on the item.
b. The chamber shall be adjusted to the specified test condition of 52 °C (125 °F), and this temperature shall be maintained for a period of 72 to 74 hours.
c. The test specimen shall be brought to operating temperature and functionally tested while the chamber temperature is maintained.
d. The chamber temperature shall be returned to ambient conditions.
e. The test specimen shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions and the results shall be recorded.

3.3.3.3.2 Procedure II Solar Radiation

a. The item shall be placed in the test chamber as specified in 3.2.4.1 and temperature sensors shall be installed on the item.

b. The chamber shall be adjusted to applicable specified test temperature of 71 °C (160 °F), and this temperature shall be maintained for a period of 72 to 74 hours.

c. The chamber temperature shall then be raised to 88 °C (190 °F), and temperature stabilization shall be obtained.

d. The test item shall be brought to operating temperature and functionally tested while this chamber temperature is maintained.

e. The chamber temperature and test item shall be returned to ambient conditions.

f. The test item shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions, and the results shall be recorded.

NOTE

The high temperature of 88 °C (190 °F) is an extreme and is valid for items located in small enclosures with a high emissivity. For items located in large enclosures, located in enclosures of low emissivity, or located where there is air circulation, this temperature should be reduced accordingly.

3.3.4 Temperature Shock

3.3.4.1 General

The temperature shock test is performed to determine the effect of an anticipated sudden change in temperature on the operational performance of an item. Cracking or rupturing of materials (particularly valve seats) due to changes in material characteristics and dimensions is the principal difficulty to be anticipated. A thermal shock is experienced when (1) gases expand upstream or immediately downstream of a pneumatic component, (2) hydraulic fluid is forced through restrictions at high flow, and (3) when cryogenic fluids are used in items that are not gradually chilled down. The procedure for testing pneumatic components is given in Procedures I and Ia and is applicable to all components that are exposed to expansion of gases of sufficient flow to cause sudden and extremely low temperatures. Procedures II and IIa provide the test methods for testing hydraulic components used in high-flow hydraulic systems. Procedure Ia or IIa is to be used when Procedure I or II is not practical due to test facility limitations. No separate temperature shock test procedure is described for cryogenic components as the functional tests conducted during the high-temperature test (see 3.3.3) adequately simulate this condition. Program or project requirements shall be given priority over the specific values given here.

3.3.4.2 Test Conditions

3.3.4.2.1 Pneumatic Components

The applicable temperature specified in 3.3.3 shall apply for the high temperature; -40 °C +0/-14 °C (-40 °F +0/-25 °F) shall apply for the media low temperature; and -54 °C +0/-3 °C (-65 °F +0/-5 °F) shall apply for the chamber low temperature (Procedure Ia only). When the thermal shock is obtained by the flow media, the gas can be cooled by either a heat exchanger or expansion. In either case, the test setup shall allow for flow to bypass the test item until the required gas temperature is established.

3.3.4.2.2 Hydraulic Components

A temperature of 149 °C +17/-0 °C (300 °F +30/-0 °F) shall apply for the high temperature and -15 °C +0/-2 °C (5 °F +0/-4 °F) shall apply for the low temperature.

3.3.4.3 Test Procedure

3.3.4.3.1 Procedure I Pneumatics

a. The test item shall be placed in the test chamber as specified in 3.2.4.1, and temperature sensors shall be installed on the item.

b. The chamber shall be adjusted to the specified chamber temperature used in the high-temperature test (see 3.3.3).

c. When temperature stabilization occurs, the test item shall be functionally tested using the service media at a temperature of 16 °C +16/-0 °C (60 °F +30/-0 °F).

d. While maintaining the chamber temperature, fluid flow will be established through the test item using the service media cooled to -40 °C (-40 °F). The established fluid flow rate shall be at least that specified during normal service usage and shall be at service pressure.

e. Fluid flow shall be maintained for a period of 1 minute. Immediately thereafter, the test item shall be functionally tested using the service media at the established low temperature.

f. Completion of steps 3.3.4.3.1.b through 3.3.4.3.1.d constitutes one cycle. The number of cycles conducted shall be as specified in the applicable test requirements.

g. The chamber temperature and test item shall be returned to ambient conditions.

h. The test item shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions, and the results shall be recorded.

3.3.4.3.2 Procedure Ia Pneumatics

a. The item shall be placed in the test chamber as specified in 3.2.4.1, and temperature sensors shall be installed on the item.

b. The chamber temperature shall be increased to the applicable high temperature specified in 3.3.3 until temperature stabilization is obtained.

c. The item shall then be transferred to a low-temperature environment of -54 °C (-65 °F) within a 5-minute period.

d. When a stabilized temperature is obtained, the test item shall be functionally tested.

e. Completion of steps 3.3.4.3.2.b through 3.3.4.3.2.d constitutes one cycle. The number of cycles conducted shall be as specified in the applicable test requirements.

f. The chamber temperature shall be returned to ambient conditions upon completion of the functional tests.

g. The test item shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions, and the results shall be recorded.

3.3.4.3.3 Procedure II Hydraulics

a. The test item shall be placed in the test chamber as specified in 3.2.4.1, and temperature sensors shall be installed on the item.

b. The chamber shall be adjusted to -15 °C (5 °F).

c. When temperature stabilization occurs, the test item shall be functionally tested using fluid at a temperature of 16 °C +16/-0 °C (60 °F +30/ -0 °F).

d. While maintaining the chamber temperature, fluid flow will be established through the test item using the service media heated to 149 °C (300 °F). The established fluid flow shall be at least that specified during normal service usage and shall be at service pressure.

e. Fluid flow shall be maintained for a period of 1 minute. Immediately thereafter, the test item shall be functionally tested using the service media at the established high temperature.

f. Completion of steps 3.3.4.3.3.b through 3.3.4.3.3.e constitutes one cycle. The number of cycles conducted shall be as specified in the applicable test requirements.

g. The chamber temperature and test item shall be returned to ambient conditions.

h. The test item shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions, and the results shall be recorded.

3.3.4.3.4 Procedure IIa Hydraulics

a. The item shall be placed in the test chamber as specified in 3.2.4.1 and temperature sensors shall be installed on the item.

b. The chamber temperature shall be decreased to -15 °C (5 °F) until temperature stabilization is obtained.

c. The item shall then be transferred to a high-temperature environment of 149 °C (300 °F) within a 5-minute period.

d. When a stabilized temperature is obtained, the test specimen shall be functionally tested.

e. Completion of steps 3.3.4.3.4.b through 3.3.4.3.4.d constitutes one cycle. The number of cycles conducted shall be as specified in the applicable test requirements.

f. The chamber temperature shall be returned to ambient conditions upon completion of the functional tests.

g. The test item shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions, and the results shall be recorded.

3.3.5 Acoustics

3.3.5.1 General

The acoustic test is performed to determine the effects on performance that acoustics will have on GSE and other facility hardware located at or near the launch pad at the time of launch vehicle hold down and lift-off. In an acoustic noise field, pressure fluctuations impinge directly on the equipment providing a distributed type of dynamic load. Broadband spectra of these loads contain resonance frequencies of most, if not all, structural components of equipment. The resulting resonant vibration is generally different from that which occurs when excitation is applied only at discrete points. Further, components that are effectively isolated from a mechanical transmission of vibration from the supporting structure will be excited directly. Electronic chatter at friction-held contacts, chafing of wires, cracking and collisions of printed circuit boards, and malfunction/failure of waveguides and Klystron tubes are examples of acoustically induced problems. Acoustic test specifications provide guidance for the performance of acoustic tests on GSE or other facility hardware. Acoustic tests are subject to constraints imposed by the capabilities of existing test facilities.

3.3.5.2 Test Limitations

Acoustic test specifications are a compromise between a simulation of a launch environment that is not attainable in existing acoustic test facilities and the effect of a prolonged exposure to an achievable intense acoustic environment. The existing acoustic test facilities generally cannot simulate the frequency composition and intensities of pressure waveforms measured on and in the proximity of the launch pad during a launch or a launch-supporting test, such as a flight readiness firing (FRF) test, at KSC. A test facility can, however, simulate the effect of prolonged exposure of equipment to an intense acoustic environment. The results of the prolonged exposure are necessary for the initial acceptance of equipment and for the estimate of its expected service life. Prolonged exposure may uncover inherent deficiencies of tested equipment and may affect its acceptance.

3.3.5.3 Criteria

A hardware item shall be the subject of an acoustic test if the item meets the following conditions:

a. The hardware is critical to a launch. In order to require acoustic testing, equipment must be defined as being launch critical and must be functioning (operational) during launch.

b. The hardware is susceptible to damage due to the launch acoustic environment. This condition is a judgment based on past experience with similar equipment and its components.

c. The hardware is susceptible to damage due to the launch acoustic environment. This condition is a judgment based on past experience with similar equipment and its components.

d. The hardware is exposed to a severe launch acoustic environment, as measured by the overall sound pressure level (OASPL) in decibels (dB) (re: 20 x 10^{-6} Pa). During a launch, a substantial part of acoustic energy occurs at the low-frequency end of the spectrum, defined here to be below 100 hertz (Hz). Acoustic inputs below 100 Hz are responsible for most vibration response of large structures on the launch pad but cause less vibration response to acoustic-susceptible electronic components. Moreover, sound pressure levels (SPLs) below 100 Hz that have been measured in the proximity of the launch pad cannot be reproduced in existing acoustic test facilities. Therefore, an operational acoustic environment is considered to be severe enough to require an acoustic test if the OASPL above 100 Hz exceeds 140 dB. If the equipment is judged to be susceptible to acoustic inputs below 100 Hz, the effect of these inputs shall be simulated by a vibration test. Vibration and acoustic testing are complimentary. Vibration and acoustic environment, test parameters and test equipment limitations should be evaluated together. Vibration test parameters based on the capability of the equipment may encompass lower frequency (< 2 kHz) acoustic affects and should be considered when specifying acoustic testing parameters.

3.3.5.4 Guidelines for Establishing Environment and Test Specifications

3.3.5.4.1 General

During launch, rocket exhausts generate a relatively short (less than 15 seconds total duration) but intense (up to 178 dB, 1-second peak average near exhausts) pressure transient. Pressure intensities [measured by root mean square (rms) pressures within a short interval] and their frequency composition vary during the launch. Processing of such nonstationary measurement records is performed by special procedures. These procedures idealize the launch acoustic environment by means of a power spectral density (PSD) having a mean square value (rms^2) equal to that of a short transient peak and having a frequency composition (resolution of rms^2 in the frequency domain) equal to an average, and sometimes preferentially weighted, frequency composition of the launch environment within the total processing interval. Such idealization defines the acoustic environment of a launch at a sensor location.

A mean PSD and a two-sigma-limit PSD are derived from multiple launch measurements by combining all available PSDs from sensors at nearby and/or similar locations that are judged to represent an acoustic zone. A mean PSD is a computed average of all constituent PSDs. At each frequency where a mean PSD is defined, a standard deviation (sigma) of the sample is computed from all constituent PSDs.

The limit PSD is defined within the same frequency range as the mean PSD. It is equal to the mean plus two standard deviations of the sample. Because the sample of available measurements is usually small, the term "limit PSD" does not imply a statistical significance. The value and significance of a two-sigma-limit PSD is that this PSD is essentially equal to the upper envelope of all constituent PSDs of the sample and is nearly independent from the size of available samples in practice. In small samples (minimum five measurements), limit PSD's tend to slightly exceed the envelope PSD. In samples co11taining over 20 measurements, the envelope may exceed the limit PSD in narrow frequency bands. Because the total rms pressure of a two-sigma-limit PSD usually exceeds rms pressures of individual constituents in the sample, the approach to specify a limit PSD rather than an envelope provides a consistent criterion for the entire frequency range, without an unnecessary increase in the specification.

A similar definition of a limit PSD should be used whenever the number of sigma in the definition of the limit may be other than two. The number of sigma in a design specification may vary between 2 and 2 1/2. The choice of a two-sigma limit is based on judgment and reflects present experience at KSC.

3.3.5.4.2 Design and Test Specification

A smoothed two-sigma-limit PSD and, if necessary, an adjusted two-sigma-limit PSD (to reflect location of the test item relative to that of sensors) which are in units of Pa2/H z (psi2/Hz) are considered to be a design specification for the hardware. An example of a design specification is shown in Figure 1.

Acoustic test specifications are derived from design specification PSDs in the form of either 1/6, 1/3, or 1/1 octave band sound pressure levels (OBSPLs), in relative units (decibels) referenced to a pressure 20 x 10·6 Pa. Each of the forms (PSD, 1/6- OBSPLs, 1/3-OBSPLs, or 1/1-OBSPLs) contains the same basic information (such as a total rms pressure), except for a difference in presentation format and in the frequency domain resolution of the total rms2 pressure provided by each format.

The highest resolution is contained in the source PSD, and it is decreasing in 1/6- OBSPL, 1/3-OBSPL, and 1/1-OBSPL in the same order as fractional OBSPLs are listed. An example of a test specification is shown in Figure 2. SPLs are shown up to the frequency of the anti-aliasing filter (500 Hz) used to process PSDs. The decay of SPLs beyond the frequency of the anti-aliasing filter is not important to a test specification and may be governed by the capability of the test facility.

The choice of a test specification format depends on the capability of a test facility to reproduce specifications within desired tolerances. The preferred format is a 1/3-OBSPL curve.

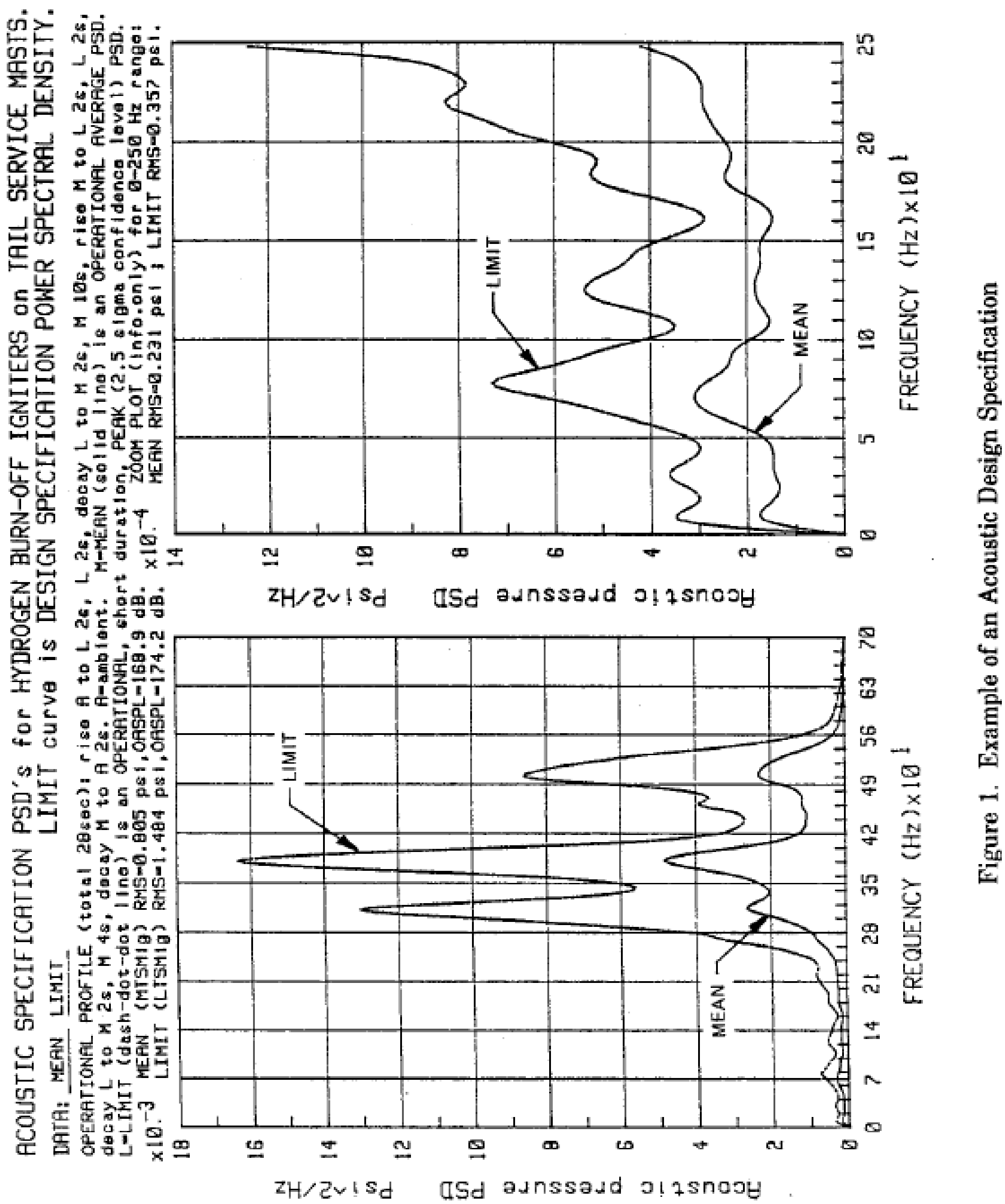

Figure 1. Example of an Acoustic Design Specification

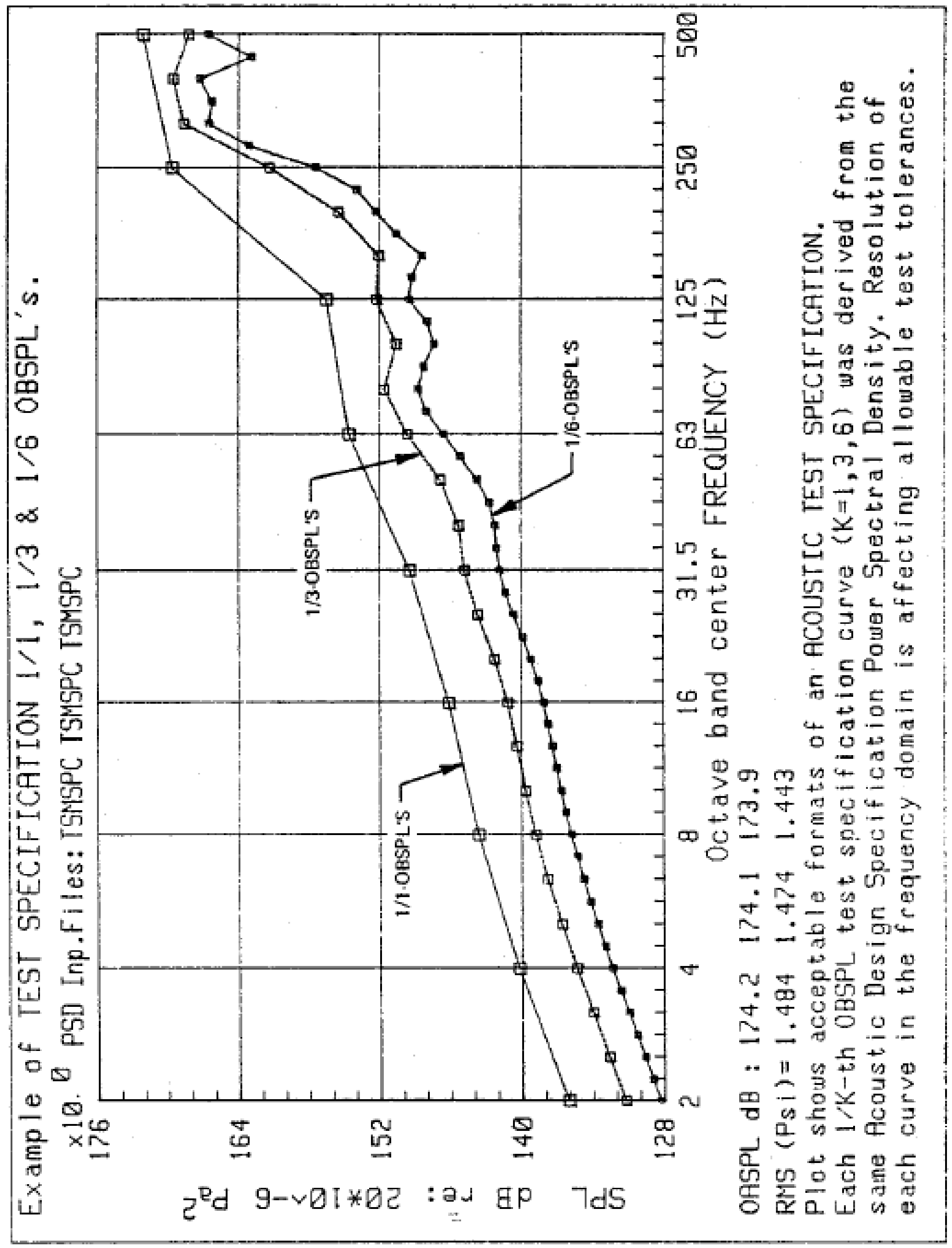

Figure 2. Example of an Acoustic Test Specification

Figure 2. Example of an Acoustic Test Specification

NOTE

Subsections 3.3.5.4.1 and 3.3.5.4.2, describing how to derive an acoustic design and test specification, are based on the assumption that pertinent acoustic measurements are available. If the launch vehicle is new and/or measurements are not available, the definition of a design specification shall involve a study of the expected acoustic environment. As an example, many studies were made during the transition between the Saturn V and Shuttle programs; these methods are beyond the scope of these specifications. This study shall define acoustic design criteria in the form of a generalized PSD from which a test criteria in terms of 1/3-OBSPLs can be derived.

3.3.5.4.3 Test Duration

The duration of an acoustic test depends upon the expected operational and maintenance conditions of the test item and on its projected service life. The test duration shall be specified for each item using the following guidelines (items a and b are exceptions; item c is the most common guideline).

a. For single-use launch operational items, the test duration may be as short as 10 seconds. Under no circumstance will the test duration be shorter than 10 seconds. The 10IO-second minimum test duration does not include the time required by the test facility to reach specification level from starting ambient. The end of a test is the instant the power to the acoustic source is cut off.

b. Multiuse items with scheduled maintenance involving disassembling, inspection of parts, and a functional test between launches can be considered as a single-use item. If inspection procedures are not expected to be performed between each launch, the minimum test duration (10 seconds) shall be increased by 5 seconds for each additional launch between inspections, not to exceed a total of 3 minutes.

c. A test of 3-minute duration is considered sufficient to qualify an item for a service life of approximately 100 launches.

A specified test duration may deviate from these guidelines if it can be justified by accumulated experience and a specific operational profile of the test item.

3.3.5.4.4 Test Tolerances

The following tolerances represent desired tolerances that ensure a correspondence between the test and the peak (envelope) operational environment. Tolerances can be adjusted to reflect the purpose of a test and the capability of available acoustic noise source. Test results shall be evaluated considering how well the test environment simulates an operational environment. All test tolerances will be per K00000283895.

3.3.5.4.4.1 Tolerance on OASPL

Tolerance pertinent to an attainable OASPL and a corresponding total rms pressure applies within the frequency range from 100 Hz to the maximum frequency of the test specification (this is usually the cutoff frequency of an anti-aliasing filter used to define the source PSD). This tolerance is -1 to +4 dB for the OASPL.

3.3.5.4.4.2 Tolerance on 1/K OBSPLs

Tolerance pertinent to attainable 1/K-th OBSPLs defines how well attainable SPLs fit the specification curve and the source PSD. These tolerances depend on the format of the test specification whether it is in the form of 1/1-OBSPLs, 1/3-OBSPLs, or 1/6-OBSPLs.

The frequency ranges in which these tolerances apply is from 125-Hz center frequency of 1/K-OBSPL specification curve to the maximum center frequency of the specification curve.

There are two criteria that ensure an acceptable fit between the test and specification curves, either of which should be satisfied. The first tolerance criterion is simple but biased toward the specification curve with the lowest resolution (1/1- OBSPLs). By this criterion, when test SPLs in specification format are within -1 to +4 dB of the specification, the test is simulating specification environment and no other tolerances apply. The second tolerance criterion applies when the tolerances of the first criterion (-1 to +4 dB) are not satisfied and when the specification curve is in a format other than 1/1-OBSPLs. Application of the second criterion requires computation of two curves from the acoustic pressure PSD attained in the test, 1/1-OBSPL and 1/K-OBSPL, required by the specification. Both curves shall lie within tolerances provided in Table 2. These tolerances are relative to the 1/K-OBSPLs specification curve and apply at standard center frequencies of 1/1-OBSPLs and 1/K-OBSPL. Table 1 includes both tolerance criteria for an acceptable fit between specification and test curves.

Table 1. SPL Tolerance Criteria

If Specification Formant (1/K-OBSPLs) is:	Then Tolerances on SPLs (Computed From Acoustic Pressure PSD Attained in Test) dB (re: 20 x 10-a Pa), Relative to 1/K.-OBSPL Specification Curve Are:		
	1/1-OBSPLs	1/3-OBSPLs	1/6-OBSPLs
1/1-OBSPLs	-1, +4		
1/3-OBSPLs	+2, +10	-3, +8	
1/6-OBSPLs	+4, +14		-5, +10

NOTE

Specification frequency range where tolerances apply seldom exceeds three octaves above 125 Hz. Tolerances do not apply below 100 Hz.

3.3.5.4.4.3 Documentation Requirements

The agency performing an acoustic test shall provide documentation of an achieved test environment consisting of the following plots and data:

a. 1/1-OBSPLs and 1/K.-OBSPLs measured during the test. The frequency range of these plots should begin at or below 16 Hz and end at or above the maximum frequency of the test specification.

b. Numerical value (dB) of measured peak OASPL and either an OASPL or rms pressure time history plot for the duration of the test. These data ensure that test-generated pressures were uniform.

c. An optional PSD [in units (Pa2/Hz (psi2/Hz)] plot if 1/1-OBSPL and 1/K.-OBSPL were derived from the PSD.

The averaging interval (a data block) may be between 0.2 and 1.0 second. The total analysis interval shall be greater than 10 seconds. The choice of averaging and total analysis intervals should ensure a minimum of 50 data blocks (100 degrees of freedom) in the definition of the PSD, 1/1-OBSPLs, and 1/K.-OBSPLs

3.3.5.4.4.4 Tolerance Adjustment

All tolerances shall be within K000028389. If attainable SPLs are outside the tolerance specified in 3.3.5.4.4.1 and 3.3.5.4.4.2, then the purpose and usefulness of the test shall be reevaluated. Whether a test with adjusted tolerances is useful depends on the magnitude and on the frequency range of the required tolerance adjustment. For evaluation, the capability of the acoustic test facility shall be defined by documentation similar to that in 3.3.5.4.4.3 and 3.3.5.5.1.1.

Generally, upper tolerance limits (while desirable to be retained) are not critical for qualification of the test item. Over-testing may result if limits are exceeded.

When required, over-testing can be compensated by a reduction of the test duration. The rationale for reduction may be to keep the product (rms 2 pressure) (test duration) constant. Upper tolerance limits cannot be exceeded within the entire frequency range of the test specification since such a condition is easily corrected by reducing the power of the acoustic noise source and/or by other means, such as shielding, etc.

If SPLs attainable in a test fall below the lower tolerance limits of the test specification, the usefulness of the test is impaired. A test item cannot be unquestionably qualified for intended operation if test SPLs are below the lower tolerance limits; however, the test can still remain useful by providing assurance that the test item can operate and survive the severity of an average launch environment rather than the peak environment reflected in the test specification. An average launch-severity environment is defined by a mean PSD (see Figure 1) and 1/K-OBSPLs derived from this mean. If the 1/K-OBSPL curve were plotted against the examples of Figure 2, it would lie approximately 5.3 dB below the corresponding specification curve.

The lower limit of the adjusted specification can generally be derived from the measured mean PSD in the same manner as the original specification was derived from the limit PSD. All tolerances defined in 3.3.5.4.4.1 and 3.3.5.4.4.2 apply to the lower limit 1/K-OBSPL derived from the mean PSD. A test is considered to remain useful whenever attainable SPLs satisfy requirements and tolerances of the lower-limit adjusted specifications. If the requirements and tolerances of the adjusted specification remain above the capability of the test facility, the test is not considered to be useful and should not be performed. In this case, acoustic testing must be simulated by vibration testing, accepting the difficulties and inadequacies of such a simulation.

A final valuation of the test usefulness shall be based on the original test specification (from the limit PSD), test-attained SPLs, and the adjusted specification (from the mean PSD). Pertinent documentation and plots defined in 3.3.5.4.4.3 shall be provided by the testing organization.

3.3.5.5 Testing

A rocket launch generates a complex acoustic environment. In an open, free field in the proximity [between 15 to 300 meters (50 to 1,000 feet)] of rocket exhausts (plumes), the acoustic field has the characteristics of a progressive wave field and is affected by multiple reflections from structures comprising the launch pad. Inside the enclosed structures (rooms and containers), the acoustic field is reverberant with an intensity affected by the configuration and content of the enclosures. Inside relatively empty enclosures, the intensity of the acoustic field is nearly uniform; that is, SPLs are nearly constant and independent from a location inside an enclosure.

Both progressive wave and reverberant fields have common characteristics: pressures are random and the distribution of instantaneous fluctuating pressure amplitudes during a short-duration peak environment (1 to 2 seconds) is nearly normal (Gaussian) with instantaneous pressures seldom exceeding three to four times the rms pressure. Thus, a test facility is expected to simulate randomly fluctuating pressures with an amplitude distribution approaching a normal distribution.

In the free field at distances less than 3 meters (10 feet) from the boundary of exhaust plumes, the distribution of pressure amplitudes becomes noticeably asymmetric with positive amplitudes exceeding negative amplitudes. Inside the exhaust plumes, the asymmetry of measured pressure amplitudes becomes significant-positive peaks may exceed negative peaks (available records show ratios up to five times). Such conditions are not expected to be simulated in a controlled environment. These conditions are presented in case a jet or a rocket engine is used as a test facility.

3.3.5.5.1 Noise Sources and Testing Facilities

Practical considerations of availability and the capability of existing acoustic testing facilities are imposing restrictions on requirements of these specifications. These restrictions have previously affected requirements on the test frequency range and tolerances, where it was tacitly assumed that acoustic testing will be made in a reverberation chamber.

The existing reverberation chambers usually employ air sirens and/or air choppers where a jet of air passing through the device (multiple rotors and orifices) can be additionally modulated in order to broaden the generated noise spectrum. Sirens alone tend to produce narrow line-type spectra at discrete frequencies.

The location and the maximum size of the test item are usually predetermined and limited by the configuration of the facility.

Some progressive wave facilities allow only normal (frontal) incidence or only grazing incidence of acoustic pressures on the test item.

The control of frequency range, bandwidths, and intensities of generated noise spectra is limited, and a change of the existing spectrum to match the specification spectrum may require a configuration change of existing equipment.

3.3.5.5.1.1 Testing Facility Data Requirements

Because of constrained capabilities of testing facilities, these specifications require that the following test facility parameters be included in test planning:

a. Lower and upper limits of sustained, generated noise spectra (this data shall be in the form of PSDs and 1/3-OBSPL) and distribution of pressure amplitudes (histograms or probability densities).
b. The type of generated acoustic field (progressive waves, reverberant) and allowable incidence of acoustic pressures on the test item (normal, grazing, reverberant).
c. Uniformity of the generated acoustic field within the test chamber. Data supplied in 3.3.5.5.1.1.a shall be referenced to the same spatial points within the test chamber where the information on the uniformity of the acoustic field is supplied.

d. Restrictions on allowable dimensions of test items in order to sustain data in 3.3.5.5.1.1.a and 3.3.5.5.1.1.c.
e. Allowable and recommended types of test item mounts.

3.3.5.5.1.2 Testing Planning and Measurement Requirements

Based on testing facility data in 3.3.5.5.1.1, the organization requesting and planning an acoustic test shall define:

a. Feasibility and usefulness of the planned test.
b. Location and orientation of the test item inside the test chamber, and the required number of tests (in case only one side of the test item is exposed to acoustic pressures satisfying requirements in 3.3.5.4).
c. Preferable item mount to be used (such as a free suspension, etc.).
d. Placement of control microphones to monitor the test, and the method to establish/verify attained test spectrum (single or multiple measurements, averaging, or weighting if multiple measurements) for comparison with the specification.
e. Any additional measurement requirements during the test. These should include any functional measurements on the test item if the test item must be operational during the test. Additional vibration and/or strain measurements may be beneficial to an assessment of test results.
f. Testing procedure, sequence, and test interruption requirements in case a malfunction or a failure pf the test item occurs.
g. Any deviations or waivers from the requirements and tolerances of these specifications that are necessitated by the capability of the testing facility.

3.3.5.5.2 Test Procedure

a. The test item and measuring instrumentation shall be placed in a test chamber as specified in 3.3.5.5.1.2 and in accordance with 3.2.4.1.
b. Expose the test item to the required acoustic levels and spectra for the specified amount of time with the item functioning as if it were in actual service. Monitor the performance of a functioning item.
c. Examine the item for loose parts, chafed wires, and other obvious damage. Document the test results.

3.3.5.5.3 Consideration of Other Testing Methods

Consideration should be given to using rocket engine test firing facilities to conduct acoustic tests on launch-critical items that cannot be adequately tested in other facilities. Static firings generate an acoustic environment of sufficient duration to simulate a multiple launch exposure of GSE on the launch pad. By proper placement of the test item relative to the test engine exhaust, the required intensity of acoustic pressures is attainable to satisfy specified/predicted OASPL, and the spectral composition of acoustic pressures is closer to an operational environment than simulations in existing acoustic chamber facilities.

3.3.6 Vibration

3.3.6.1 General

Vibration test specifications provide guidance for the performance of vibration tests on GSE or other facility hardware used to support the launch of a space vehicle. These specifications apply to a vibration environment occurring during a launch for the purpose of providing criteria for acceptance and qualification of GSE. The extent of concern is limited to equipment located on and in the proximity of the launch pad, generally within a 300-meter (1,000-foot) radius of the launch pad.

3.3.6.2 Exclusions

Development of GSE shall consider other vibration environments that equipment may encounter and other specialized vibration tests that are recognized to ensure equipment reliability but are not covered by these specifications. The decision whether or not to require and perform these tests shall be based on past experience with similar items. The following are suggested procedures to be considered but are excluded from these specifications:

a. Vibration environments that occur during transportation and handling. Testing may be performed in accordance with requirements of MIL-STD-810.

b. Vibration screening tests using random vibration spectra. Screening tests are performed to disclose latent manufacturing defects, particularly in electronic components. Candidate items are usually subcomponents of a larger assembly, such as a chassis containing printed circuit cards housed inside a rack, which itself is a part of a system. These specifications may require a qualification test of the entire rack. Component acceptance during system development may require a screen test of a chassis. Screening may be performed in accordance with recommendations in NAVMAT P-9492 and/or by using a custom-tailored screening. For a screen to effectively precipitate latent flows, the screen level should exceed the expected service environment by at least two times. Duration of a screen test should not induce a cumulative damage (fatigue) effect that will reduce the normal life time of the test item.

c. Vibration tests designed to identify modal parameters (resonance frequencies, normal vibration modes, modal mass, and damping). These tests shall be performed early during development. The tests shall be designed for a specific item and may vary from a simple resonance search to a complete modal parameter identification.

A timely consideration of these tests during a system development may establish a need to incorporate a local vibration isolation of sensitive components and/or may govern a choice of components and design configuration. These tests ensure a better chance for the test item to pass the qualification tests required by these specifications.

3.3.6.3 Test Requirement Criteria

The vibration environments at the locations of the GSE are assumed to be known and defined in accordance with 3.3.6.4. All GSE, judged to be sensitive to vibration, may require a vibration test to ensure its expected service life. Nearly all equipment is prone to fail or malfunction if subjected to vibration of substantial severity. For most types of GSE, a record of performance histories exists upon which an initial judgment can be made as to whether or not an item is a candidate for vibration testing. A hardware item shall be vibration tested if it meets any one of the following conditions:

a. The hardware is defined as being critical to a launch and is functioning (operational) during a launch.
b. The hardware is operational either throughout or immediately after an FRF or a launch abort.
c. The hardware is related to personnel safety and must be operational immediately after a launch.
d. The hardware requires an acoustic test.

3.3.6.4 Guidelines for Establishing Environment and Test Specifications

3.3.6.4.1 General Considerations

The vibration environment that occurs during a launch or an FRF is caused by acoustics generated by rocket exhausts. Therefore, there are similarities between vibration and acoustic environments that are reflected in the duration and in the variation of intensities (measured by rms time histories) of both transients. The time of occurrence and the duration of peak rms pressures and accelerations correspond and are nearly the same. Consequently, procedures used to process measurements of an acceleration (vibration) transient are the same as those described in 3.3.5.4.1 for an acoustic transient. The description of a vibration environment from a group of multiple launch measurements is in terms of a mean and limit vibration PSD, in units of g^2/Hz, and in corresponding peak rms accelerations (peak g-rms). Two different sets of PSDs may be required if there is a need to distinguish between environments occurring during the hold down (Pre T-0) period and during the lift-off (Post T-0).

There are also differences between acoustic input and vibration response environments. Differences are further emphasized because they affect the definition of a vibration environment for a test specification.

The total frequency bandwidth of the vibration environment measured on the launch pad structures is generally less than that of the acoustic input. Structures act like filters, attenuating the high-frequency end of the acoustic spectrum more than at low frequencies. A notable exception to this occurs in structural components near the exhaust holes where apparent collisions between functionally different structural elements (heat shields and supporting structure) are generating high-frequency vibration components exceeding the frequency range of the acoustic input. This effect is local and may occur in other structures on the launch pad.

Acoustic spectra are broadband and smooth. Vibration spectra, while being broadband, contain many distinct narrowband peaks caused by local structural resonances. Multiple peaks appearing in a vibration PSD are impractical and perhaps impossible to simulate in a test specification. Another extreme of a specification would be to use a simplified envelope containing all measured PSD peaks. Such a specification would not be realistic, and its use would certainly result in over-testing and a possible rejection of the test item, often contradicting past experiences with similar items operating without failures. A test specification PSD derived from measurements in accordance with these guidelines shall cut off narrowband resonance peaks. If judged necessary, the effect of cutoff peaks may be simulated by a superimposed narrowband sweep with a random distribution of amplitudes within the sweeping narrow bandwidth. This option is often referred to as a random-on-random input. Implementation of a sweep option should be judicious.

The vibration environment varies within a structure and its components (a spatial variation) to a greater degree than does the acoustic field. Vibration also depends on the axis orientation of the measuring accelerometer. Standard vibration testing shall consist of at least three tests, one for each of the three orthogonal axes, sometimes requiring a different test specification PSD for each axis.

A variation of the vibration environment during a launch (a variation in time) may affect the testing requirements, depending on the following test item operational requirements:

a. The test item is operational during the launch. Three test specification PSDs (one for each axis) shall be derived for the peak launch environment. Three tests, one for each axis, shall be performed with the operational item.
b. The test item is operational during a part of the launch, such as the hold down period. Three test specification PSDs shall be derived for the operational period (one for each axis). For test articles that are required to perform Post T-0, the Pre T-0 environment should be evaluated for spectral content that may exceed the Post T-0 PSD values.
c. The test item is not operational during the launch. Testing requirements are the same as 3.3.6.4.1.a, except the test item is nonoperational.

Functional requirements for the test item during a test and test sequence shall be specified for each test item.

3.3.6.4.2 Measurement Selection

Vibration measurements on launch pad structures are usually taken on main and representative structural members (girders, floor beams, compartment walls, and shock-mounted floors) at selected locations judged to display a typical and perhaps the highest vibration level. The highest vibration level occurs at the midpoint between nodes. For example, the highest vibration level of the first mode occurs at the midpoint of the member. The definition of a test specification PSD requires a knowledge of the vibration environment at the interface between the test item and the supporting structure. Whenever available, even for a single direction, such measurements govern the definition of a vibration environment.

When interface measurements are not available, the definition of a vibration environment shall be made by a judgment, selecting available measurements that are not too distant from the intended location of the test item, and by considering the following:

a. Structural similarity. Only measurements on structurally similar members should enter into the definition of environment.
b. Distance from the prevailing acoustic input source. This may be the distance from the vehicle trajectory at lift-off or the distance from a compartment wall, ceiling, etc., known to have the highest vibration level. The distance effect of selected measurements may be weighted relative to the distance of the test item (see 3.3.6.4.2.d).
c. Vibration propagation characteristics of the structure supporting a test item. For example, a well-braced floor may be expected to exhibit a similar horizontal vibration throughout the floor plane, at least at the lower frequency end of the spectrum. A horizontal vibration in the plane of a vertical girder is expected to be nearly the same throughout the girder.
d. Weighting of selected measurements relative to the location of the interface with the test item. A weighting multiplier or a more general frequency-dependent correction (a "PSD window") based on the concept similar to that of a transfer function can be applied to PSDs of selected measurements in order to compensate for the difference in locations between selected measurements and the test item interface.

Another commonly encountered situation is that the same equipment may be intended for installation at many locations. Selection of measurements shall consider all such locations. Consequently, the definition of the vibration environment PSD becomes a composite curve defining a hypothetical worst case. An environment defined by a composite PSD is usually more severe than the measured vibration at a single location.

3.3.6.4.3 Procedure to Define the Environment and Test Specification

Derivation of a test specification PSD involves two steps. The first step is the definition of the vibration environment PSD from selected measurements. The second step is a derivation of the test specification PSD from a defined vibration environment. This process shall be performed for each of the three orthogonal test axes.

NOTE

The following subsections (3.3.6.4.3.1, 3.3.6.4.3.2, and 3.3.6.4.3.3) describing how to derive a vibration test specification are based on the assumption that pertinent vibration measurements are available and are selected in accordance with the guidelines in 3.3.6.4.2. If the launch vehicle or the structure is new, then measurements are not available. Definition of a vibration test specification shall involve a study of the expected vibration environment. As an example, many studies were made during the transition between the Saturn V and Shuttle programs; these methods generally involve a "scaling rationale" using existing vibration test specifications rather than measurements as a basis and are beyond the scope of these specifications. Periodic publications of launch environment measurement summaries constitute another data base upon which test specifications can be established.

3.3.6.4.3.1 Environmental Definition

The vibration environment is defined by a mean PSD and a two-sigma-limit PSD computed from all selected measurements. A corresponding rms acceleration is also computed from each curve: mean g-rms and limit g-rms.

A mean PSD is a computed average of all constituent PSDs. At each frequency where a mean PSD is defined, a standard deviation (sigma) of the sample is computed from all constituent PSDs. The limit PSD is equal to the mean PSD plus two standard deviations of the sample. An example of this basic procedure to define a vibration environment is shown in Figure 3.

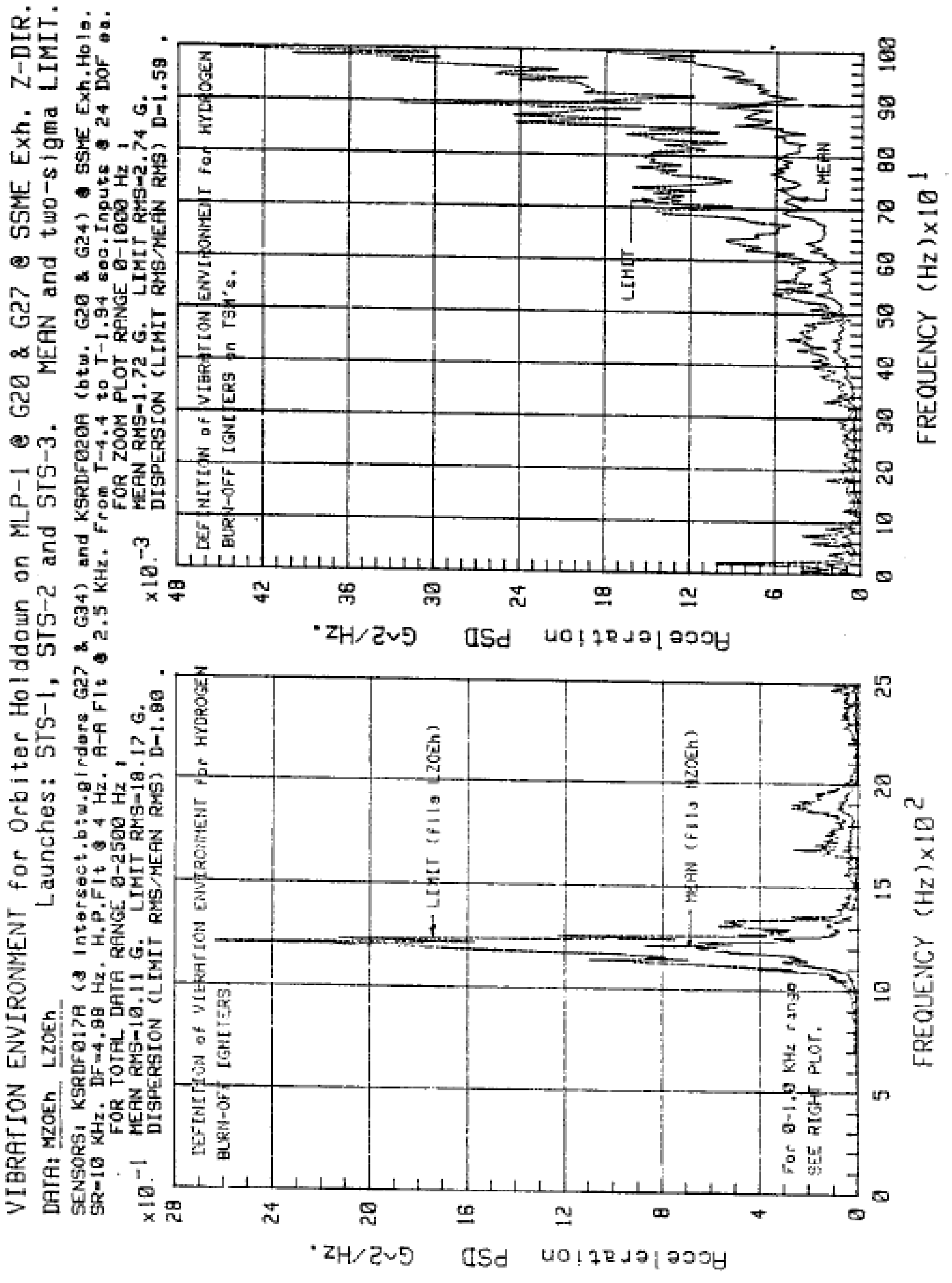

Figure 3. Example of a Vibration Environment

Figure 3. Example of a Vibration Environment

Because the sample of available and selected measurements is usually small in a statistical sense, the term "limit PSD" should not imply a statistical significance. The value and significance of a two-sigma-limit PSD is that this PSD is essentially equal to the upper envelope of all constituent PSDs. The approach to specify the limit rather than an envelope provides a consistent criterion for the entire frequency range, while the envelope may be affected by peculiarities or anomalies of a single measurement.

When the number of samples is small (less than four or five) and the sample consists of the same measurement that is not located at the test item/structure interface (the sample does not account for a spatial variation of the environment), the basic procedure to derive a limit PSD may require a correction. This correction always applies when there is a single available measurement and when there is a recognition of uncertainty in the choice of selected measurements.

The ratio, D = (limit g-rms) / (mean g-rms), defines a dispersion attributed to launch-to-launch and spatial variations of the vibration environment. These ratios are known at a number of locations on launch pad structures. The ratios may be found in existing (and future) publications of vibration/acoustic data summaries that constitute a data base at KSC.

The limit PSD can be computed from the mean PSD by: Limit PSD = (mean PSD)*D2

Corresponding limit g-rms = (mean g-rms)*D Commonly encountered values of D vary between 1.4 and 1.9.

3.3.6.4.3.2 Standard Test Specification

Derivation of a test specification PSD is based on the vibration environment defined by a limit PSD and by a corresponding limit g-rms, a total rms acceleration. Derivation involves a simplification of vibration environment to a form that can be easily reproduced and controlled in vibration test facilities. The jagged shape of a limit PSD is approximated by flat (constant PSD amplitude) sections connected by smooth sloping curves. In an often-used log/log scale, sloping sections consist of straight lines with slopes defined in units of (plus or minus) decibels per octave (dB/oct). The sign convention defines a positive slope when PSD amplitudes increase with the increase in frequency and a negative slope when the opposite occurs. In a linear scale, slopes are true curves, either parabolas when slopes are positive or hyperbolas when slopes are negative. The order (exponent) of either curve is equal to (dB/oct)/3.

Figure 4 is an example of a vibration test specification PSD derived from a defined vibration environment as shown in Figure 3.

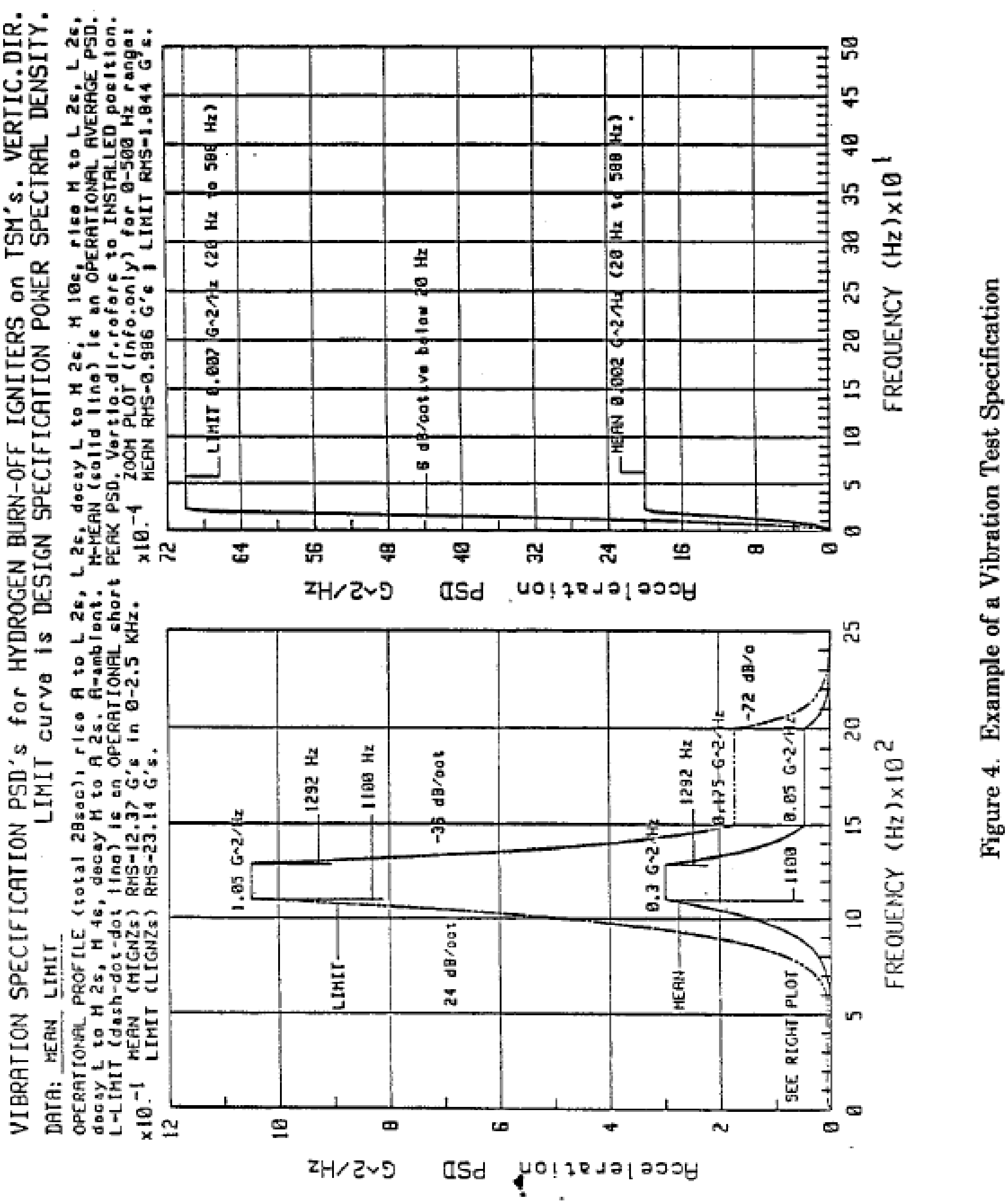

Figure 4. Example of a Vibration Test Schematic

The following rules and tolerances apply when deriving an approximation (a standard test specification PSD):

a. The total rms acceleration of a test specification shall remain within 1.0 to 1.3 of the limit g-rms. In adherence to this tolerance, the test specification PSD will cut off protruding peaks of the vibration environment PSD (see the rationale and a possible compensation in 3.3.6.4.1).

b. The number of flat sections should be limited to not more than three. The unusual case where two sloping curves with opposite signs may intersect at a common frequency is considered to contain a flat section of zero bandwidth. Test tolerances (see 3.3.6.5.5) always apply to flat sections.

c. Slope specification should not exceed 48 dB/oct. The difficulty of controlling shaker input and of satisfying specified tolerances within the sloping sections increases with the slope steepness. Preferably, slopes should remain between ±3 and ±36 dB/oct. Test tolerances (see 3.3.6.5.5) do not apply to sloping sections exceeding ±24 dB/oct.

d. The total frequency range of a test specification PSD should correspond to the range of significant amplitudes in the source vibration environment PSD. When testing is performed using electrodynamic shakers as drivers, the low-frequency end of the spectrum (below 5 Hz, and often below 10 Hz) is limited by the shaker excursion capability. The frequency range 1 to 10 Hz contains resonances of fundamental modes of large structures on the launch pad. Vibration at these frequencies usually is not critical to the qualification of test items. The total number of cycles at these frequencies that a test item is expected to experience during its service life time cannot induce fatigue. Therefore, a test specification may disregard peaks below 10 Hz that are abundant in measurements. The exception to this is when the test item contains vibration isolators (usually tuned to resonate below 20 Hz), and the purpose of the test includes testing of isolators. Such a case may require a specification of special hydraulic or hydrodynamic exciters capable of large low-frequency excursions but operating within a more limited frequency range than electrodynamic shakers. A satisfactory test may be made using electrodynamic shakers and by specifying a waiver to tolerances below 10 Hz. The upper frequency range of a test specification may end up in a flat section with a sharp roll off above the cutoff frequency left unspecified.

In conclusion, a test specification PSD describes a broadband random vibration with a distribution of instantaneous acceleration amplitudes approaching a normal (Gaussian) distribution within the amplitude range from -3.0 to +3.0 times the total rms value.

3.3.6.4.3.3 Additional Nonstandard Requirements

In unusual instances when it is judged that a compensation shall be made for not including narrowband PSD peaks from a defined vibration environment into the standard test specification PSD, a test specification may require a superposition of a narrowband sweep or of multiple dwells over the standard broadband specification PSD. Such a requirement involving nonstandard procedures of shaker input control shall concur with the existing capability of a selected testing facility. The following parameters shall be specified to define a superimposed narrowband random vibration:

a. Superimposed narrow bandwidths. For dwells, each bandwidth should not exceed 5 percent of its center frequency, except for center frequencies below 200 Hz where a 10-Hz bandwidth may be specified. For a sweep, the swept bandwidth should be kept constant within the total sweep range. The suggested value is 25 Hz.

b. The PSD amplitude or the rms acceleration within the narrow bands of dwells or a sweep. The sum of superimposed and broadband PSD amplitudes should be above the highest cutoff peak of the vibration environment PSD. The addition of dwells or a sweep should not increase the total rms acceleration of the composite input by more than 10 percent above that of the standard broadband specification.

c. Center frequencies of dwells and the frequency range of a sweep. The lowest center frequency of sweep depends on the sweep bandwidth and should not fall below 30 Hz.

d. Sweep rate or the number of sweeps required during a test. These parameters shall be coordinated with the total test duration in 3.3.6.4.4. The number of sweeps should not exceed two: the first one up and the second one down the frequency range. The sweep rate shall be logarithmic, specified in octaves per minute (oct/min). The rate should not exceed 4 oct/min. A faster sweep is judged to provide an insufficient compensation for the number of cycles with high amplitudes that the test item would encounter if a vibration environment PSD were used instead of the test specification PSD. A sweep shall not be specified whenever the total test duration is less than 2 minutes.

3.3.6.4.4 Test Duration

Duration of a vibration test depends on the expected operational and maintenance conditions of the test item and on its projected service life. For an item, the test duration is the same for each of the three orthogonal test axes. The test duration shall be specified for each test item using the following guidelines.

a. For single-use launch-operational items, test duration may be as short as 10 seconds. Test duration can in no case be shorter than 10 seconds. This item category may include a specification of an operational profile where the test level, defined by the total rms acceleration, is varied during the test while the test item remains operational. An example of such a specification is shown in Figure 4 where the terms mean and limit PSDs also designate two different test levels.

b. Multiuse items with scheduled maintenance involving disassembling, inspection of parts, and a functional test between launches can be considered as a single-use item. If inspection procedures are not expected to be performed between each launch, the minimum test duration (10 seconds) shall be increased by 5 seconds for each additional launch between inspections, not to exceed a total of 3 minutes. Short-duration tests do not compensate for the cumulative damage effect.

c. A test of 3 minutes is considered to be standard and sufficient to qualify an item for a service life of approximately 100 launches.

A specified test duration may deviate from these guidelines if it can be justified by the accumulated experience and a specific operational profile of the test item. Exceptional short-duration tests less than 30 seconds require special procedures to verify compliance of the test input with the specification PSD. The specified duration shall comply with the requirements in 3.3.6.5.3.

Whenever a vibration test specification contains a (nonstandard) requirement for a superimposed narrowband sweep, the specified test duration shall correlate with the guidelines in 3.3.6.4.3.3.d that are pertinent to the specification of the sweep rate and with the guidelines in 3.3.6.5.3.2 that are pertinent to the required sweep interruption.

3.3.6.5 Testing

Vibration testing is normally performed using electrodynamic exciters (shakers) as drivers. These machines are readily available as a basic excitation source in vibration testing laboratories. Testing requirements and test tolerances of these specifications assume that electrodynamic exciters will be used.

The use of a special hydraulic exciter must be specified when a test specification PSD requires adherence to tolerances below 5 Hz (seldom between 5 and 10 Hz) and when exciter excursions (required to meet specification and tolerances) exceed the capability of the electrodynamic exciters. Hydraulic exciters may not be readily available. Hydraulic exciters are capable of large excursions and large driving forces at low frequencies, extending the lower bound of the usable frequency range to below 1 Hz. Their control to adhere to tolerances is more difficult than electrodynamic types. Their upper frequency bound is limited, some to below 200 Hz. The requirement to use a hydraulic exciter shall consider tailoring the test specification PSD and tolerances to account for exciter limitations of a selected test facility.

Vibration control of electrodynamic exciters and data analysis are almost exclusively digital. Both provide a rapid and efficient definition of the driving signal to match the specification (process of equalization) with a tight adherence to tolerances and a continuous input control during test. If problems arise during equalization, they are probably a sign of an insufficient capability of the exciter driving force and/or exciter/fixture resonances rather than the complexity of a specification.

Because of a continuous proliferation of vibration control and analysis equipment, the user should expect changes in equipment capabilities that may prompt a revision of the following guidelines.

3.3.6.5.1 Test Setup

Unless otherwise specified, the test item shall include attachment brackets, isolators, and other hardware interfacing between the test item and the supporting structure where the vibration environment was defined. The direction of the vibration axes is normally referenced relative to the supporting structure and not to any prominent features or planes of the test item. Proper positioning of the test item in the fixture shall be accomplished by means of the supporting hardware simulating field installation.

3.3.6.5.2 Fixture Requirements

The fixture shall be designed to accommodate a test item installation and to transmit vibration from the exciter head or a slip table to the test item. Vibration transmission by the fixture should not alter the motion of the exciter to such a degree that the equalization becomes significantly impaired by fixture resonances and/or insufficient fixture stiffness. As a rule, control accelerometers will be located near or at the fixture/test item interfaces. While a very stiff fixture is always desirable, its design may not be practical, particularly for large test items in excess of 45 kilograms (100 pounds). The fixture design should take into consideration:

a. Frequency range of the vibration test specification. Generally, the broader the specification frequency range, the stiffer the fixture should be. The considered frequency range is that of significant amplitudes in accordance with 3.3.6.4.3.2.d.
b. Stiffness of the structure supporting the test item in the field. There is no requirement to design a fixture to be substantially stiffer than the supporting structure, except for flexible, acoustically driven panels that usually support light test items.
c. Type of attachment and the placement of the exciter. Whenever a test item is not directly attached to the exciter (a shaker head or a slip table) but requires separate suspension for its support, the fixture design can simulate a supporting structure.

As long as the output of the control accelerometer meets test tolerances (see 3.3.6.5.5) and the uniformity criteria (see 3.3.6.5.3), the fixture is considered to be satisfactory.

3.3.6.5.3 Control Measurements and Equalization

Measurements intended to define and verify test control signals shall be approved by the design agency requesting the test. For small test items and stiff fixtures, a single control accelerometer located on the fixture near its center is sufficient. However, a second accelerometer should be used to verify signal integrity.

Test items with multiple support points spaced in excess of 600 millimeter (24 inches) will generally require an accelerometer located near each interface between the, fixture and the test item. Unless otherwise specified, outputs (PSDs) from individual interface accelerometers shall remain within 3 dB of each other at all frequencies below the lower value of either 500 Hz or the maximum frequency of the last flat (constant PSD amplitude) section of the specification. The fixture design shall ensure a concurrence with this criterion for a uniform input. An average signal from all interface accelerometers shall be used as a vibration control signal.

Additional functions such as the cross-spectral density (magnitude and phase) and coherence are helpful to evaluate vibration transmission characteristics of large fixtures, specifically those simulating a supporting structure. For large fixtures, requirements and tolerances for interface accelerometers should be established on a case-by-case basis.

Digital analysis of an analog (from accelerometer output) control signal is assumed to have a constant resolution bandwidth that depends on the data block size (defining the averaging time interval) remaining after filtering and decimation, and on the cutoff frequency of the low-pass anti-aliasing filter (analog or digital) preceding the decimation. Whatever procedures and parameters are employed by the data analysis equipment, the resulting resolution bandwidth (the constant delta-f spacing of ‘PSD points) depends on only two parameters: the averaging interval (seconds) and either the maximum frequency of the specification or the anti-aliasing filter cutoff frequency. The constraints on the maximum resolution bandwidth, delta-f, may require multiple analyses (each using different parameters) of the control signal during equalization and testing.

The following constraints on delta-fare designed to ensure a minimum acceptable resolution at the low end of the spectrum:

Delta-f < 2 Hz below 250 Hz

Delta-f < 10 Hz between 250 Hz and 1,000 Hz

Delta-f < 20 Hz between 1,000 Hz and 2,000 Hz

The analysis (for each delta-f case if there are multiple analyses) should utilize the available capability of the equipment to remain below the minimum specified bandwidth limits. For a comparison with specification, the averaged PSD from the vibration control signal should have a minimum of 100 degrees of freedom (DOF), minimum 50 data blocks.

Requirements for the minimum of 100 DOF and requirements for the resolution bandwidth delta-f affect the specification of a test duration. For the exceptional short-duration test (3.3.6.4.4.a and often in 3.3.6.4.4.b), these requirements cannot be met. The specifications for exceptional short-duration tests shall specify requirements and tolerances for the analysis/verification of the control signal. Preparations for a short-duration (less than 30 seconds) test should be made using a dummy specimen and trial test runs of a sufficient duration that allows the verification of the input signal. Trial run records can be used to verify input compliance with the specification PSD and with the tolerances in 3.3.6.5.5.

3.3.6.5.3.1 Broadband Input Equalization

Equalization of the driving signal to comply with the broadband specification PSD can be performed either using a test item and a reduced signal level of 6 dB below specification or using a mass-simulating dummy specimen and no signal level reduction. A reduced driving signal level should not fall below the analysis equipment and control accelerometer noise level within any frequency range containing a flat PSD section.

Whenever the test tolerances (see 3.3.6.5.5) are satisfied for the broadband PSD curve that is 6 dB below the specification curve, the equalization is considered acceptable even when the increase of the driving signal to the specification level distorts the broadband PSD curve outside the specified tolerances. An exception to this may be test items containing nonlinear (amplitude/velocity dependent) elements, in which case the equalization method shall be specified.

The equalization and a short trial run for the specification of an operational profile containing variable test levels can be performed using the test item, which shall remain nonfunctional during the equalization procedure.

3.3.6.5.3.2 Narrowband Input Equalization

The equalization for nonstandard inputs, superimposed narrowband dwells or a sweep, may be performed using the test item and without the broadband input being present. The vibration control software shall have the capability to perform superposition of inputs at test levels.

For a sweep, equalization shall be performed at frequencies that are remote from distinct structural resonances where the driving force of the exciter is not affected by increased impedance due to a resonance. Notch tolerances do not apply to a sweep.

Sweep control shall have the on/off capability to interrupt and resume the sweep waveform at intervals required to obtain and record the output of the control accelerometer in order to verify the compliance of the broadband vibration and dwells if present with the specification PSD. The control of the logarithmic sweep rate shall account for these interruptions. The duration of an interruption depends on two requirements (see 3.3.6.5.3): (1) delta-f is less than 2 Hz and (2) the averaged PSD has a minimum of 100 DOF; the corresponding interruption is at least 26 seconds. The requirement for a delta-f less than 10 Hz and 100 DOF results in an interruption of approximately 6 seconds. The effective sweep rate shall be defined from the total specified test duration less the time required for sweep interruptions. This rate should not exceed 4 oct/min. If the available sweep time requires a rate higher than 4 oct/min and the total interruption times do not exceed 30 seconds, the total test duration shall be increased to allow a single sweep to be performed at the highest allowable rate.

The equalization should be performed at a zero sweep rate (using dwells) at center frequencies, within the sweep range, not exceeding either four sweep bandwidths or one-third active, whichever is greater.

3.3.6.5.4 Test Verification

The purpose of the following requirements is to provide a record and to ensure compliance of the test input with these specifications and tolerances. Whenever this record contains a deviation from the suggested tolerances, the test may be considered acceptable if the record analysis can, confirm that the principal objectives of the test were met.

The vibration control signal, which in accordance with 3.3.6.5.3 may be the output of a single accelerometer or an averaged output of a few accelerometers, shall be continuously monitored and recorded during the test. A real-time only data analysis is acceptable if the test is performed at a constant g-rms level, if the data analysis satisfies the resolution bandwidth requirements in 3.3.6.5.3, and if the test specification does not contain the requirement for a superimposed sweep.

The verification of the distribution of instantaneous amplitudes of the vibration control signal may be required for the broadband vibration and for superimposed dwells. Such verification may be presented in the format of histograms, probability densities, and/or probability densities in the standardized form. The last format is the most suitable for a comparison with a normal distribution. The analysis interval for these functions should be the same as that used for PSDs. There are no pertinent tolerances, except a judgement, to assess compliance with a desirable normal distribution.

3.3.6.5.4.1 Standard Test Documentation

For the broadband vibration (and dwells when present), data analysis output and documentation shall consist of the following items a and b. Item c is an additional requirement when applicable.

a. The total rms acceleration time history (g-rms level). The averaging time interval (a data block time) shall be the same or less than that used in the computation of the broadband PSD (for the widest delta-f bandwidth if there are multiple analyses). A plot of the recorded PSD from the controller at 1-second intervals will be provided. The purpose of this documentation is to ensure that the g-rms level was held constant (within the test tolerances of 3.3.6.5.5) during the test.

b. The broadband PSD plot, including superimposed dwells if these were specified. Documentation may require multiple analyses in order to satisfy the resolution bandwidth requirements in 3.3.6.5.3 whenever the capability of analysis equipment has limitations of the data block size or equivalent limitations of the number of PSD resolution lines. Each analysis shall extend to the maximum frequency where resolution bandwidth requirements are satisfied. A piece-wise composite PSD, where each component satisfies resolution bandwidth requirements only within a limited frequency range, may be used for a comparison with the test specification and shall satisfy tolerances in 3.3.6.5.5.

   The analysis of the test input, broadband PSD, and dwells shall be performed within a time interval that does not contain sweep input. If the sweep was specified, the drive signal controlling the sweep shall be turned off for a duration not to exceed 30 seconds for a single interruption.

c. Whenever the vibration control signal is an average output of accelerometers, the output of each accelerometer during equalization shall be documented in a manner similar to 3.3.6.5.4.1.b. This documentation is needed to evaluate the transmission of vibration by the fixture. The frequency range of the composite PSD computed from each accelerometer output shall be the same as that of the specification PSD. A single plot containing all composite PSDs is required to confirm the uniformity of transmitted vibration in accordance with 3.3.6.5.3. Documentation of additional functions, such as cross-power spectra and coherences, may be requested for large fixtures and for fixtures simulating a supporting structure.

Documentation requirements in 3.3.6.5.4.1.a, 3.3.6.5.4.1.b, and 3.3.6.5.4.1.c are sufficient to verify concurrence of vibration input with the specification for a standard test when the test duration is longer than 30 seconds and there are no requirements to add a sweep.

3.3.6.5.4.2 Nonstandard Test Documentation

The following guidelines for documentation pertain to short-duration tests, variable-level tests, and tests requiring a superimposed (random-on-random) sweep.

a. The records for the equalization of a short-duration test performed with a dummy specimen on trial runs in accordance with 3.3.6.5.3.1 may be used to satisfy test verification requirements of 3.3.6.5.4.1.b and 3.3.6.5.4.1.c. The test input shall be recorded and analyzed to provide a test PSD with a resolution that is within the capability of the test facility. Test tolerances do not apply whenever the test duration does not allow analysis to obtain a PSD with at least 100 DOF.

b. Variable level tests can use procedures3.3.6.5.4.1.a through 3.3.6.5.4.1.c applied separately to each time period when the input level was held constant. If any of these periods can be classified as a short-duration test, then documentation should comply with 3.3.6.5.4.2.a for each period.

c. Test requiring a superimposed sweep shall provide records and documentation required in 3.3.6.5.4.1.a through 3.3.6.5.4.1.c. Additionally, at least three time intervals of the test record (preferably near the start, half time, and test end) containing the sweep shall be analyzed to provide PSDs with the resolution bandwidth that is compatible with 3.3.6.5.3 and containing superimposed sweep amplitudes. The verification of sweep amplitudes may be obtained only approximately as the difference between the PSDs containing the sweep and those obtained in 3.3.6.5.4.1.b without the sweep. Because the sweep is present at the time of a measurement and the definition of the broadband PSD requires a minimum of 100 DOF (a long-time relative to a single averaging time interval), PSD amplitudes of the sweep component are lowered by the averaging and are "blurred" in direct proportion to the sweep rate and the range of frequencies being swept during the measurement. During the equalization procedure, actual sweep verification should be performed using dwells in accordance with 3.3.6.5.3.2. Sweep amplitude tolerances do not apply to measurements acquired during the test at non-zero sweep rates because they generally are not verifiable to the same degree of accuracy as the broadband vibration.

3.3.6.5.5 Test Tolerances

The following tolerances apply to test verification measurements defined in 3.3.6.5.4.1.a and 3.3.6.5.4.1.b for a standard vibration test with a duration exceeding 30 seconds. Tolerances are relative to a test specification defined in accordance with 3.3.6.4.3.2, including superimposed dwells in 3.3.6.4.3.3.

Item	Tolerance
Test duration	0 to 10 percent, not to exceed 10 seconds
Overall root mean square acceleration (g-rms level in 3.3.6.5.4.1.a)	±10 percent
Acceleration spectral density of the broadband waveform, within any frequency range	-2 dB (-37 percent) +2 dB (+59 percent)

Acceleration spectral density of the narrowband waveform (superimposed dwell) within its bandwidth	-3 dB (-50 percent) +3dB (+100 percent)
Notch and peak tolerance on acceleration spectral density (wideband and narrowband) within a single delta-f defined in 3.3.6.5.3, provided that other tolerances are met within adjacent delta-f bandwidths	-3 dB (50 percent) +4 dB(150 percent)
Total bandwidth of the narrowband waveform (superimposed dwell)	±25 percent (referenced to the specified bandwidth) or ±4 delta-f (referenced to 3.3.6.5.3), whichever is larger

Large test fixtures and test items in excess of 45 kilograms (100 pounds) may require an adjustment to notch and peak tolerances. Tolerances for nonstandard tests involving short-duration tests (less than 30 seconds), variable level tests, and tolerances for a superimposed narrowband sweep shall be determined on a case-by-case basis considering measurement verification methods 3.3.6.5.4.2.a through 3.3.6.5.4.2.c and in accordance with the capability of a specific testing facility selected to perform nonstandard tests.

3.3.6.5.6 Test Performance

All equipment undergoing a vibration qualification test shall be functionally tested before and after the test. Equipment that must be operational during a test shall be adequately instrumented to monitor its performance. This instrumentation shall be specified by the test requester. A test, once commenced, shall not be interrupted except when:

a. A failure occurs. The time of failure shall be recorded. Corrective action shall be initiated by the test requester.

b. At the discretion of the test engineer, whenever the continuation of the test under controlled conditions cannot proceed.

Immediately after the test, equipment shall be inspected for any damaged or loose parts. A functional test should be made as soon as practical.

3.3.7 Shock

3.3.7.1 General

The launch of a space vehicle generates pressure and acoustic environments that do not contain shocks. A pressure pulse generated by some engines at the time of ignition does not induce as a response a distinct vibration shock, rather it results in a transient vibration with peak amplitudes that are substantially lower than the peak vibration during a lift-off period. True vibration shocks occurring during a launch are anomalies caused by collisions between structural elements and by bottoming of vibration isolators. High shocks can be generated by a hard bottoming of vibration isolators that do not have snubbers and that involve metal-on-metal impacts.

Shocks generated by explosive devices, such as explosive bolts or nuts, were found to be significant only in the close proximity to such devices (an example is a hold down post). These shocks attenuate rapidly with the distance from the explosive device. Their effect at locations of electronic and other equipment on the Mobile Launcher Platform (MLP) is insignificant compared to the vibration environment during a launch.

Whenever possible, the cause of shocks should be corrected rather than trying to qualify equipment for an operation in the shock environment by testing. Exceptional shock occurrences covered by these specifications are those that cannot be corrected by a structure/isolator redesign or by moving equipment to another location free from shocks. Because there are exceptions, test specifications, testing procedures, and tolerances should be handled on a case-by-case basis. These specifications provide only general guidelines concerning shock definition and testing.

3.3.7.2 Exclusions

These specifications do not concern shock environments occurring during transportation and handling of equipment. Pertinent specifications and testing guidelines can be found in MIL-STD-810.

3.3.7.3 Shock Definition

A shock is defined by means of an acceleration response shock spectrum computed from selected sections of an acceleration measurement containing single or multiple shocks occurring during a launch. In an acceleration time history, a shock is characterized by a sudden rise of acceleration to a peak amplitude, followed by a decaying cycles. The duration of a shock is defined, somewhat arbitrarily, as the time required for the initial peak acceleration amplitude to decay to a certain lower value, often assumed to be one-third of the peak or less.

The decay of the peak shock acceleration amplitude and the shock duration depend on actual damping present in the structure. Computation of a shock spectrum requires a specification of an equivalent viscous damping [a damping coefficient (Z), a fraction of critical damping] which is often arbitrary and unrelated to actual structural damping governing shock decay. More often, a magnification factor Q = 1/ (2*Z) is specified instead of damping. The conventional value commonly specified is Q = 10 (Z = 0.05, or 5 percent). The higher the specified damping (and the lower Q is), the smoother the computed maximax shock spectra are. Normally a maximax spectrum, involving the absolute maximum of both positive and negative response amplitudes, is computed for a specified value of Q. A definite specification of Q is necessary so a shock spectrum can be reproduced in a testing laboratory by the synthesis procedure, which combines acceleration pulses (usually half-sine, and other shapes) in a sequence of a time history whose shock spectrum matches (or exceeds) that of the specification. The duration of the synthesized shock is adjusted to match or exceed previously defined actual shock duration. The actual time history from which the specification shock spectrum was derived is not reproduced by the shock synthesis, although some algorithms provide a reasonably close approximation.

The time history used to derive a shock spectrum shall be derived from launch measurements. When shocks occur often and periodically, the entire measurement time history may be used to derive a maximax shock spectrum. The corresponding shock duration is the time between the start of the first shock and the end of the last. In such a time history, a specification of a conventional Q (for example, Q = 10) results in a generally lower test shock spectrum than an actual environment because the high damping provides a substantial decay of response between frequent shocks. A more realistic specification of Q (or damping) should be based on the decay of measured amplitudes, assuming them to represent a free vibration (which they are not) and using a logarithmic decrement to estimate damping. Such an approach usually results in a Q between 15 and 25.

Another approach for defining a source time history for the computation of a shock spectrum is applicable in cases of separated and less frequent shocks, where multiple shocks are concatenated by omitting the background (usually low level) vibration between the shocks. In this instance, a specification of Q = 10 or lower is appropriate.

Shock spectra tend to increase with the frequency up to a certain frequency after which they level off. Generally, the upper frequency range of shock tests extends to 10,000 Hz. The amplitudes at the lower end of the shock spectrum may be) limited by the exciter excursion capability. Generally, a shock spectrum decays at a rate near 6 dB/oct below the frequency of the lowest wave component in the shock input. Unless explicitly requested, a compliance of the test input with the computed specification shock spectrum is not necessary at frequencies below 20 Hz.

3.3.7.4 Test Specification

An upper envelope of all maximax shock spectra derived from (or accounting for) multiple launch measurements constitutes a specification shock spectrum. For completeness, the specification shall contain the value of Q and the shock duration.

Specification shock spectrum represents a lower limit that a synthesized shock of the specified duration and Q will attain in the test facility. The upper limit of the shock spectrum from a synthesized shock is specified by a tolerance band above the specification. The tolerance band should take into account the capability (and the software used for shock synthesis) of the test facility; this is necessary to prevent an over-testing. The tolerance band may be variable and increase with the frequency.

The last parameter of a shock specification is the number of shocks to be induced into the test item during testing. Each synthesized shock is equivalent to or exceeds the shock environment of a single launch. The test requester shall specify the total number of shocks.

Different shock spectra specifications are generally required for each of the three test axes. Often, testing may be limited to a single axis in the direction of a prevailing shock.

3.3.7.5 Shock Testing

Shock testing is similar to vibration testing. It is performed almost exclusively using electrodynamic exciters. Because the shock environment is usually more severe than the vibration environment and the frequency range of shock spectra is usually equal to or greater than that of vibration specifications, the requirements for test fixtures are more stringent. Generally, stiffer fixtures and higher exciter driving forces are required for shock testing than are required for vibration testing.

3.3.8 Humidity

3.3.8.1 General

The humidity test is performed to determine the resistance of equipment to the effects of exposure to a warm, highly humid atmosphere such as that encountered in the KSC area. This is an accelerated environmental test, accomplished by the continuous exposure of the equipment to high relative humidity at an elevated temperature. These conditions create a vapor pressure, which is the force behind moisture migration and penetration. Corrosion is one of the principal effects of humidity. Hygroscopic materials are sensitive to moisture and deteriorate rapidly under humid conditions. Many materials lose their functional utility and physical strength and change their important mechanical properties. Insulating materials that absorb moisture may lose their insulating properties. Expected environmental conditions at KSC are documented in NASA/TM-2008-215633. These environmental conditions may be simulated for the purposes of this test, or the test procedures in MIL-STD-810 may be used. Alternately, the following procedure may be used if applicable.

3.3.8.2 Test Conditions

The chamber and accessories shall be constructed and arranged to avoid the dripping of condensate on the equipment under test. The chamber shall be vented to the atmosphere to prevent the buildup of vapor pressures. Relative humidity shall be determined from the dry-bulb/wet-bulb thermometer comparison method. The wet-bulb thermometer shall be installed at the internal mouth of the air inlet duct. The air velocity flowing across the wet bulb shall not be less than 275 meters (900 feet) per minute. Provisions shall be made for controlling the flow of air throughout the internal test chamber area where the velocity of air shall be maintained between 30 to 120 meters (98 to 394 feet) per minute. Distilled or deionized water having a pH value between 6.5 and 7.5 at 25 °C (77 °F) shall be used to obtain the specified humidity.

3.3.8.3 Procedure

a. The item shall be placed in the chamber as specified in 3.2.4.1. The chamber temperature shall be adjusted to 30 °C (86 °F); the relative humidity shall be adjusted to 95 percent.
b. The chamber conditions shall be adjusted to the high temperature specified (maintaining 95 percent relative humidity) within 2 hours as specified in Figure 5.
c. Conduct a functional test of the test item at any convenient time in the 24-hour cycle when the test conditions are constant and at maximum temperature and relative humidity levels. Tests should be accomplished at least once every five cycles.

d. After the 6-hour exposure period, the temperature shall be reduced to the initial level as specified in Figure 5 while maintaining relative humidity above 85 percent relative humidity. The temperature shall then be maintained for 8 hours at 95 percent relative humidity.

e. Completion of steps 3.3.8.3.b through 3.3.8.3.d constitutes one cycle. Ten complete cycles shall be conducted.

f. At the conclusion of the test, the test item shall be removed from the chamber and returned to room ambient conditions. Excess moisture can be removed by turning the test item upside down or by wiping the external surfaces only.

g. The item shall be inspected and functionally tested within 1 hour following exposure, and the results shall be recorded.

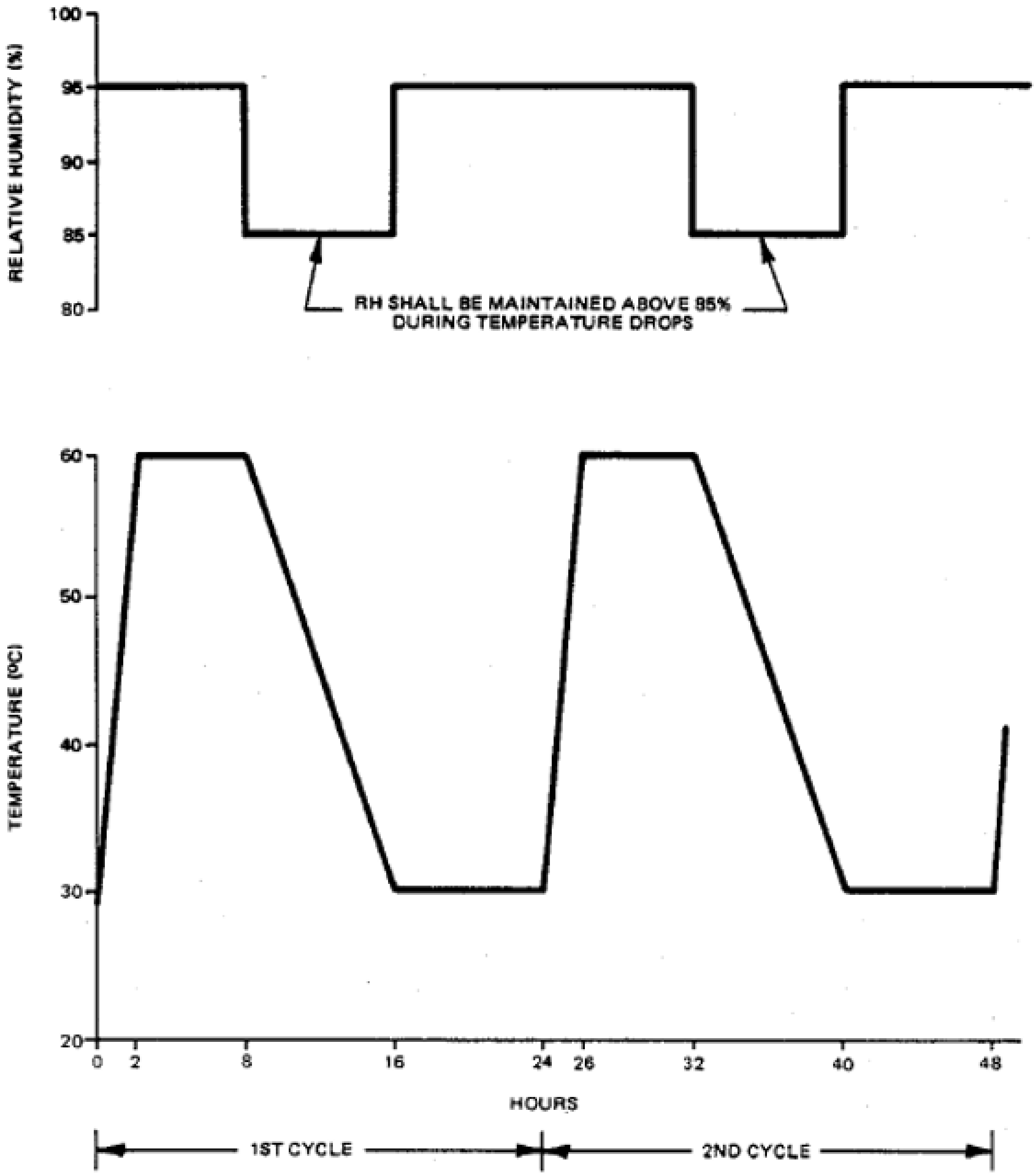

Figure 5. Temperature and Humidity Cycles

3.3.9 Rain

3.3.9.1 General

The rain test determines the resistance of GSE to the effects of exposure to rainfall rates that are encountered in the KSC area. The rain test determines the capability of equipment or component seals to resist water intrusion and determines the efficiency of protective covers or cases designed to shield the item from rain. The test object may be tested per the rain test procedures in MIL-STD-810 or the following procedure.

3.3.9.2 Test Conditions

The test item shall be exposed to a simulated rainfall utilizing the following rain cycle:

Period (min)	Rate (mm/hr)	Rate (in/hr)
10	13	0.5
3	221	8.7
5	89	3.5
42	13	0.51

Measurement of rainfall shall be by a U.S. Weather Bureau type gauge. Rain shall be simulated utilizing an average drop size of 2 millimeters with a maximum size of 5.9 millimeters. Air temperature shall be maintained as follows:

Summer Test		Winter Test	
Before	During	Before	During
3 °C (90 °F)	24 °C (75 °F)	13 °C (55 °F)	10 °C (50 °F)

The average rate of fall shall be 6.5 meters per second with a 12-meter minimum fall to reach the terminal velocity. In those cases where wind speed is to be included in the test, the following values shall be used: steady state of 5.1 meters per second (10 knots), and gusts to 15.4 meters per second (30 knots) lasting 2 minutes and applied every 15 minutes.

3.3.9.2.1 Test Equipment

The rain chamber shall be a self-contained unit with an insulated, well-lighted internal test space.

3.3.9.2.1.1 Observation Window

A large observation window with an area of at least one-third of the wall and equipped with a wiper shall be located in the upper half of the chamber wall.

3.3.9.2.1.2 Spray Nozzles

Spray nozzles, adequate in quantity and design to provide a simulated rainfall in accordance with requirements, shall be furnished. The nozzles shall be capable of satisfactory operation at the water supply pressure required to meet the test conditions.

3.3.9.2.2 Performance

Air velocity within the test space shall be capable of variation in order to assist in the simulation of wind-driven rain conditions. The angle between the vertical and the direction of all the simulated rain shall be controllable from 0 to 45 degrees. The rainfall shall be dispersed uniformly over the test area within the limits specified.

3.3.9.2.3 Procedure

a. The test item shall be placed in the chamber as specified in 3.2.4.1.
b. Each of the major sides of the test item shall be exposed to the simulated rainfall for not less than 60 minutes.
c. Total test time shall be not less than 2 hours.
d. The test item shall be functionally tested when the exposure period is completed, and the results shall be recorded.
e. Where possible, the protective cover or case shall be removed and the test item inspected with particular attention to evidence of water penetration, swelling, or other deterioration. The results shall be recorded.

3.3.10 Icing

3.3.10.1 General

The icing tests are conducted on GSE that is susceptible to the formation of ice on its external surface. This formation can occur during the normal operation of cryogenic systems and during the normal operation of pneumatic systems that require high flow rates and large pressure drops across individual components. Ice will also form on component surfaces that are physically located within the thermal gradient of these systems. For this reason, when selecting components for this test, the moisture and temperature conditions must be considered in relation to the proximity of the component to the system. Each component subjected to this test must be selected judiciously and its physical location must be adequately defined. Damage that can be expected from the accumulation of ice is mechanical binding or sticking, short circuiting of the electrical wiring, and sealing of the vent ports. The test object may be tested per the icing/freezing rain test procedures in MIL-STD-810 or the following procedure.

3.3.10.2 Test Conditions

The water supply, which will be used to form ice on the test specimen, shall be precooled to between 0 °C (32 °F) and 3 °C (37 °F). When chilled water cannot be obtained, unchilled water will produce acceptable rates but at a slower buildup rate. Suitable water spray nozzles shall be provided that will produce a fine spray of droplets having 8 minimum diameter of 1.0 to 1.5 millimeters. The water spray nozzles shall be located to achieve a uniform spray on the test specimen. The water droplets shall impinge on the test specimen in the same manner as it would during service operation.

3.3.10.3 Test Procedure

a. The test item shall be inspected and cleaned of all traces of oil or grease from areas that are not oily in the normal operating mode.

b. The test item shall be placed in a chamber as specified in 3.2.4.1 and temperature sensors installed on the item.

c. The chamber temperatures shall be reduced and the test item shall be temperature stabilized at approximately 2 ± l °C (36 ± 2 °F).

d. Deliver uniform spray of chilled water for 1 hour.

e. Lower the chamber air temperature to -10 °C (+14 °F) and maintain the water spray until 6 mm (1/4 inch) of ice has accumulated.

f. Adjust the chamber air temperature to -6 °C (+21 °F) for 2 to 6 hours, and functionally test the item. If a failure occurs and the test plan permits, remove the ice by simple, expedient, and obvious methods. Retest and document the results of ice removal.

g. Repeat steps 3.3.10.3.c through 3.3.10.3.f for a 13 mm (1/2-inch) coating of ice.

h. The chamber temperature shall be returned to ambient conditions.

i. The test item shall be visually inspected and functionally tested within 1 hour following establishment of ambient conditions. Particular attention shall be directed to physical changes caused by the formation of ice on moving surfaces, holes, and orifices and between mating surfaces. Document the results.

3.3.11 Solar Radiation (UV)

3.3.11.1 General

The solar radiation test is performed to determine the effect of solar radiant energy on equipment. Solar radiant energy causes heating of equipment, photo degradation (such as fading of fabric colors), and cracking of paints, natural rubber, and plastics. The solar radiation test is applicable to any item of equipment that may be exposed to solar radiation during service and that is constructed of materials that may be adversely affected by this environment. ASTM G155 can be used as a guide for the standard practice of operating a xenon arc light apparatus. The test object may be tested per the solar radiation procedures in MIL-STD-810.

3.3.11.2 Test Conditions

Test requirements and conditions may be tailored according to program and project requirements or the solar radiation procedures in MIL-STD-810.

3.3.11.3 Light Source

Tests conducted for degradation and deterioration of materials due to visible and ultraviolet light effects, as well as heat buildup within the test items, may be performed per MIL-STD-810.

3.3.12 Fungi

3.3.12.1 General

The fungus test is performed to determine the susceptibility of GSE to fungous attack and to ascertain the detrimental effects that are incurred when such equipment is subjected to the test environmental condition. During the normal growth of fungi, there is an enzymatic secretion that accelerates a chemical transformation of organic substances. Once attacked, most organic materials will be destroyed by the fungi. Many minerals are also destroyed by these spores. Fungi affect insulation, wood and wood derivatives (paper), some types of seals, lens coatings, as well as many other types of materials. This is an accelerated environmental test; therefore, the temperature and moisture conditions are specified to support rapid growth of fungi and accelerated deterioration of materials. The test object may be tested per the fungus procedures in MIL-STD-810.

3.3.12.1.1 Control Tests

Verify the viability of the spore suspension and its preparation and verify the suitability of the test chamber by conducting the control tests specified in the fungus procedures in MIL-STD-810.

3.3.12.2 Test Procedure

Conduct the test in accordance with the fungus procedures in MIL-STD-810, and record the information specified therein.

3.3.13 Salt Fog

3.3.13.1 General

The salt-fog test is performed to determine the resistance of equipment to the effects of a salt atmosphere. The expected damage from exposure to salt fog is primarily corrosion of metals, although in some instances salt deposits may result in clogging or binding of moving parts. This is an accelerated environmental test; therefore, the specified concentration of moisture and salt is greater than that found in normal service. The procedures in ASTM B117 can be used as a guide to operating a salt fog test apparatus. The test object may be tested per the salt fog procedures in MIL-STD-810. Note that KSC does not consider salt fog testing to be a substitute for actual exposure to the KSC environment.

3.3.14 Sand and Dust

3.3.14.1 General

The sand and dust test is performed to determine the resistance of equipment to blowing fine sand and dust particles. Because of their abrasive character, sand and dust can affect items into which sand may enter. Sand and dust can also cause parts to bind and can interfere with electrical contacts. Due to the high sand concentrations of the soils at KSC, dust will not be part of this test. The sand and dust test is applicable to those items that are exposed to wind-blown sand conditions common in the KSC area. This is an accelerated environmental test; therefore, the test conditions are more severe than those found in normal service. The test object may be tested per the sand and dust procedures in MIL-STD-810.

3.3.15 Explosion

3.3.15.1 General

Explosion tests are conducted to determine the explosion-producing or explosion-containment characteristics of hardware when operated in a hazardous location. Explosions may be initiated by mechanical or electrical sparking, flashes, temperature, or chemical reactions. Hardware can be placed into one of two categories: (1) intrinsically safe or (2) explosion proof. GSE and other facility hardware located near propellant storage or fueling areas may be considered in a hazardous location due to the possible exposure to high-atmospheric concentrations of hydrogen or hypergol propellants. Dust ignition requirements are not considered to be applicable to GSE or other facility hardware; therefore, dust ignition will not the part of explosion testing.

When hardware is exposed to a hazardous environment, KSC-STD-E-0002 establishes the policy for hardware design and qualification in accordance with ANSI/NFPA 70 and UL 913; this eliminates the need for a separate explosion test. In those applications where this is not possible, the hardware can be purged or pressurized in accordance with NFPA 496 as modified by KSC-STD-E-0002 or an explosion test can be conducted.

3.3.15.2 Test Conditions

The test conditions for an explosion test are determined by the type of hazardous atmosphere to which the hardware is exposed. Hazardous locations or atmospheres are categorized in accordance with ANSI/NFPA 70. Article 500 of ANSI/NFPA 70 defines and classifies hazardous locations by class, division, and group. The most common hazardous locations found at KSC are (1) Class I, Division 1, Group B; i.e., a hydrogen atmosphere and (2) Class I, Division 1, Group C or D; i.e., atmospheres containing hypergol propellants, rocket or jet propellants, oxygen (liquid and gaseous), petroleum, oil, and lubricants. The item shall be tested for the worst-case intended service-hazardous location.

Items tested successfully in a more hazardous atmosphere will automatically qualify for use in a less hazardous atmosphere. The more hazardous atmosphere mixtures are hydrogen-oxygen, hydrogen-air, and jet fuel vapors, in that order.

3.3.15.3 Test Procedure

3.3.15.3.1 Explosion proof Test Procedure

Explosion proof tests shall be conducted in accordance with ANSI/UL 1203, Part 1. All applicable tests, identified in Part 1 for the type of hardware and the class or group, shall be performed in a sequence compatible with the character and application of the hardware. The testing agency shall prepare a detailed test procedure for the performance of the following:

a. Inspect the item for the conformance to the construction requirements of ANSI/UL 1203, Part 1.
b. Perform the applicable tests of ANSI/UL 1203, Part 1, in the sequence suitable to the item.
c. Record the test results.

3.3.15.3.2 Intrinsically Safe Test Procedure

Intrinsically safe tests shall be conducted in accordance with ANSI/UL 913. All applicable tests identified for the type of hardware and the class or group shall be performed in a sequence compatible with the character and application of the hardware. The testing agency shall prepare a detailed test procedure for the performance of the following:

a. Inspect the item for conformance to the construction requirements of ANSI/UL 913.
b. Perform the applicable tests of ANSI/UL 913 in the sequence suitable to the item.
c. Record test results.

3.3.16 Lift-Off Blast

3.3.16.1 General

The lift-off blast test is performed to determine the effects of rocket engine exhaust on GSE and other facility hardware at the time of launch vehicle hold down and lift-off. The detrimental effects of a blast are due to extremely high temperatures and pressure and the erosion characteristics of the rocket engine exhaust plume. The extent of damage depends upon the exposure time, velocity of exhaust gases, type of propellants, and most importantly, the location of the item in relation to the rocket engine exhaust. Blast conditions may cause erosion of hardware surfaces, loss of protective coatings, permanent set or binding of parts, cracking or bulging of rubber and plastic due to high temperatures, and bent or deformed material due to the pressure load. The lift-off blast test should only be performed on those hardware items that cannot be shielded or protected from the lift-off environment.

3.3.16.2 Test Conditions

The lift-off blast test cannot be performed in a laboratory or test chamber. The lift-off blast environment can only be simulated at a launch pad during an actual launch or at a rocket engine test stand during a test firing. The test conditions for an item shall be estimated based on the proposed location of the hardware at the launch facility. The primary factor to be considered in determining the test conditions is whether the item will receive direct flame impingement or secondary flame impingement from the rocket engine and the orientation of the item in the exhaust flow. The test location should be selected, based on accumulated experience, to simulate the actual conditions the item would undergo in service during lift-off. The test location should replicate, as closely as possible, the flame impingement characteristics (i.e., impingement angle, water cooling, distance from the nozzle, exposure time, etc.) that would be encountered in service.

Special consideration should be given to securing the test item so the exhaust temperatures and pressures will not break loose or dislodge the item during exposure.

3.3.16.3 Test Procedure

a. The test item shall be bolted in place at its test location.
b. The test item shall be exposed to a launch or engine firing.
c. The test item shall be visually examined after exposure. Particular attention shall be directed to the physical changes caused by temperature, pressure, and erosion of surfaces.
d. The test item shall be removed from its test location and functionally tested, and the results shall be recorded.

4. QUALITY ASSURANCE

Quality assurance provisions shall be in accordance with the contract.

5. PREPARATION FOR DELIVERY

Not applicable.

6. NOTES

6.1 Intended Use

This standard is intended to establish uniform testing of ground support equipment and other facility components to assess the ability of the hardware to withstand the environmental stresses it will encounter during its life cycle and to ensure that plans and test results are adequately documented.

6.2 Definitions

For the purpose of this standard, the following definitions shall apply:

a. Component. The smallest assembled item identifiable as a complete, functioning, hardware entity that performs a distinctive function in the operation of an item of equipment or a system.

b. Explosion proof. Hardware that is designed and constructed in a case or enclosure so that gas- or vapor-air explosions occurring within the apparatus will not ignite the surrounding gas- or vapor-air atmosphere.

c. Failure. A deviation of a monitored functional parameter beyond established acceptable limits.

d. Functional Test. A test performed to demonstrate that the operation of the item meets or exceeds its performance requirements.

e. Ground Support Equipment (GSE). All equipment necessary to support the operations of receiving, handling, assembly, test, checkout, and launch of space vehicles.

f. Hazardous Location. An area where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

g. Intrinsically Safe. Hardware in which all the circuits are incapable of causing ignition of a gas- or vapor-air atmosphere in the most easily ignitable concentration.

h. Subsystem. A major functional subassembly or grouping of items or equipment that is essential to the operational completeness of a system.

i. System. Any combination of parts, assemblies, components, and sets joined together to perform a specific operational function or functions.

j. Test Item. A component, subsystem, or system that is subjected to a specific test program.

k. Test Requirements. A document listing the tests to be conducted and the parameters of those tests that are used as the basis for the preparation of a detailed test procedure. When in conflict, the test requirements shall take precedence over this standard.

Custodian:	Preparing activity:
NASA - John F. Kennedy Space Center	John F. Kennedy Space Center Laboratories, Development and Testing Division Engineering Directorate