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User Guide

Supplement to DO-160G

RTCA DO-357
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FOREWORD

This document was prepared by Special Committee 135 (SC-135) and was approved by the RTCA Program Management Committee (PMC) on December 16, 2014.

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- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;
- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
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TABLE OF CONTENTS

Purpose and Applicability.....	1
User Guide for Section 4 - Temperature & Altitude.....	3
User Guide for Section 5 - Temperature Variation.....	13
User Guide for Section 7 - Operational Shocks and Crash Safety.....	21
User Guide for Section 8 - Vibration.....	29
User Guide for Section 9 - Explosion Proofness.....	45
User Guide for Section 10 - Waterproofness.....	53
User Guide for Section 11 - Fluids Susceptibility.....	59
User Guide for Section 15 - Magnetic Effect.....	65
User Guide for Section 16 - Power Input.....	75
User Guide for Section 17 - Voltage Spike.....	87
User Guide for Section 18 - Audio Frequency Conducted Susceptibility – Power Inputs.....	95
User Guide for Section 20 - Radio Frequency Susceptibility.....	103
User Guide for Section 21 - Emission of Radio Frequency Energy.....	153
User Guide for Section 22 - Lightning Induced Transient Susceptibility.....	163
User Guide for Section 23 - Lightning Direct Effects.....	193
User Guide for Section 26 – Fire, Flammability.....	225
Appendix A Membership.....	241

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Purpose and Applicability

The purpose of this document is to provide users of DO-160G additional background information for the associated test procedures and requirements in DO-160G. This information includes rationale for requirements, guidance in applying the requirements, commentary, possible trouble shooting techniques, and lessons learned from laboratory experience. This User Guide is provided for guidance purposes and does not contain requirements. This information is intended to help users understand the objective and rationale behind the requirements, and to help users develop detailed test procedures based on the general test procedures in this document. It is highly recommended that detailed discussion will take place between the equipment manufacturer and the equipment installer during the development of the test plan.

Note that the User Guide subsections are numbered independently of the subsections in DO-160G.

DO-357 replaces the User Guides previously included in DO-160G.

DO-160G Change 1 has been published to remove all User Guides previously included in DO-160G.

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DO-160G

Environmental Conditions and Test Procedures for Airborne Equipment

User Guide for Section 4

Temperature & Altitude

**Based on
DO-160G Section 4**

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TABLE OF CONTENTS

4.UG.0	Temperature and Altitude	7
4.UG.1	Purpose of the Tests	7
4.UG.2	General	7
4.UG.3	Equipment Categories	7
4.UG.4	Definitions of Terms	7
4.UG.5	Temperature Tests.....	7
4.UG.5.1	Ground Survival Low Temperature Test and Short-Time Operating Low Temperature Test.....	7
4.UG.5.2	Operating Low Temperature Test	9
4.UG.5.3	Ground Survival High Temperature Test and Short-Time Operating High Temperature Test.....	9
4.UG.5.4	Operating High Temperature Test.....	10
4.UG.5.5	In-Flight Loss of Cooling Test	10
4.UG.6	Altitude, Decompression and Overpressure Tests.....	11
4.UG.6.1	Altitude Test.....	11
4.UG.6.2	Decompressions Test.....	11
4.UG.6.3	Overpressure Test.....	11

TABLE OF FIGURES

Figure 4.UG-1	- Combined Ground Survival Low Temp and Operating Low Temp Test.....	8
Figure 4.UG-2	- Combined Ground Survival High Temp and Operating High Temp Test.....	9

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4.UG.0 Temperature and Altitude

4.UG.1 Purpose of the Tests

4.UG.2 General

1. The measurement of the “EUT temperature stabilization time” can be performed by one of two methods:
2. A preliminary “engineering test” can be performed using the DO-160G test conditions on the EUT. The maximum value of the “EUT temperature stabilization time” measured should be then included in the determination of temperature cycles and used during the “qualification test”.
3. Instrumented EUT temperature measurement is allowed during the test as long as there is no impact on EUT and test integrity. Use of embedded internal temperature measurement function’ when available’ is also permitted. Prior to start of test user should validate the temperature sensor planned to be used for verification of temperature stabilization.

Note: This test applies to equipment that requires cooling for proper operation during the operating high temperature test, paragraph 4.5.4, has functions whose failure following in-flight loss of cooling would contribute to or cause a failure condition that would prevent the continued safe flight and landing of the airplane, and in which the cooling is externally supplied or powered.

4.UG.3 Equipment Categories

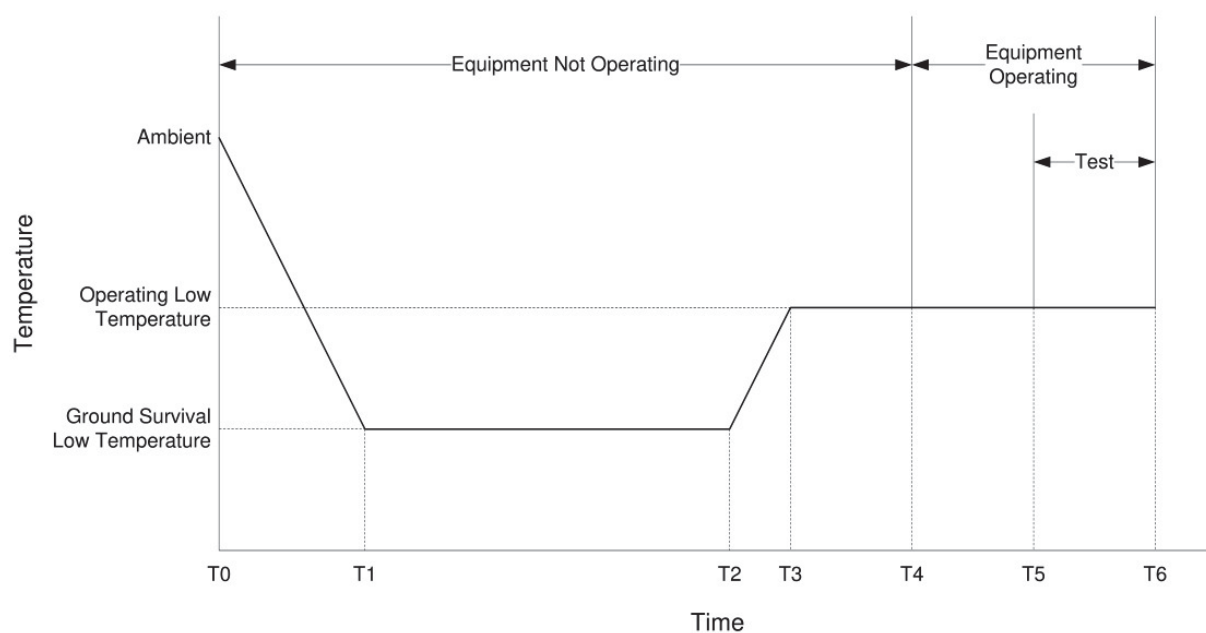
4.UG.4 Definitions of Terms

4.UG.5 Temperature Tests

4.UG.5.1 Ground Survival Low Temperature Test and Short-Time Operating Low Temperature Test

User guide information applicable to Section 4.5.1, Note 2:

When the Short-Time Operating Low Temperature test is deleted, the intent is that the Ground Survival Low Temperature Test (Section 4.5.1) be combined with the Operating Low Temperature Test (Section 4.5.2); to ensure appropriate cold start conditions are simulated. The combined test is described in Figure 4-UG-1.



- Note:*
- 1) *Temperature change rate from T0 to T1 is not specified.*
 - 2) *T1 to T2 is time for equipment temperature stabilization time, plus a minimum of three hours.*
 - 3) *T2 to T3 is at a minimum rate of 2°C/minute.*
 - 4) *T3 to T4 is 30 +5/-0 minutes or the time for internal stabilization.*
 - 5) *T4 to T5 is time for equipment temperature to stabilize.*

Note: Equipment performance at T4 should be per Note 1 on Paragraph 4.5.1

- 6) *T5 to T6 is 2.0 hours, minimum.*

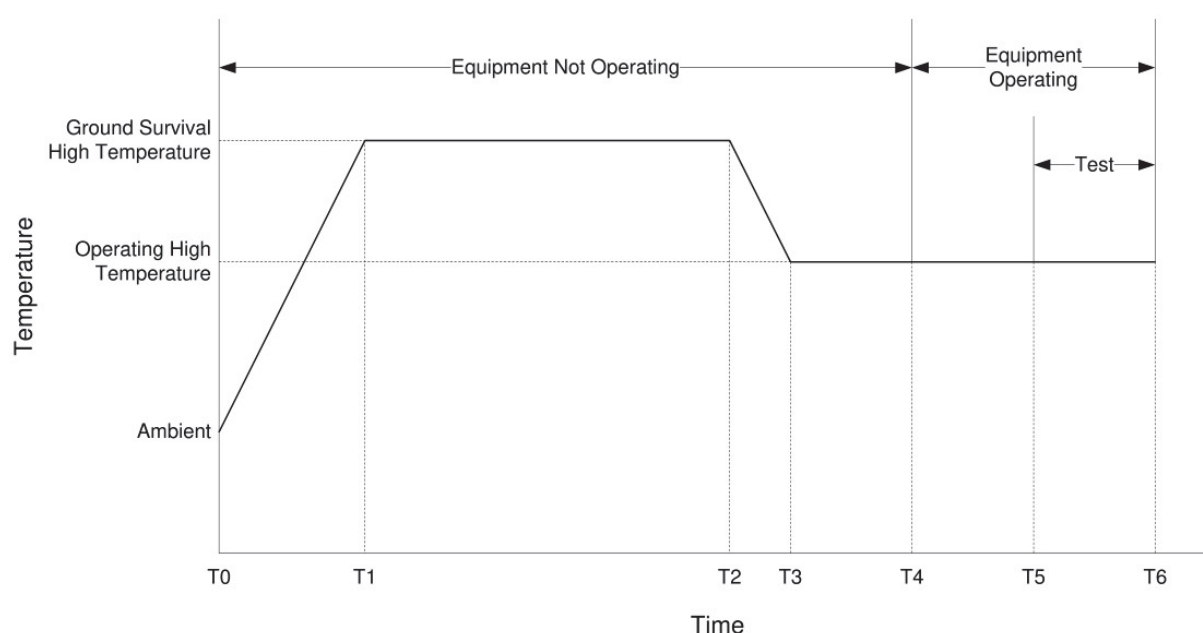
Figure 4.UG-1 Combined Ground Survival Low Temperature and Operating Low Temperature Test

4.UG.5.2 Operating Low Temperature Test

4.UG.5.3 Ground Survival High Temperature Test and Short-Time Operating High Temperature Test

User guide information applicable to Section 4.5.3, Note 2:

When the Short-Time Operating High Temperature test is deleted, the intent is that the Ground Survival High Temperature Test (Section 4.5.3) be combined with the Operating High Temperature Test (Section 4.5.4); to ensure appropriate hot start conditions are simulated. The combined test is described in [Figure 4-UG-2](#)



- Note:*
- 1) Temperature change rate from T0 to T1 is not specified.
 - 2) T1 to T2 is time for equipment temperature stabilization time, plus a minimum of three hours.
 - 3) T2 to T3 is at a minimum rate of 2°C/minute.
 - 4) T3 to T4 is 30 +5/-0 minutes or the time for internal stabilization.
 - 5) T4 to T5 is time for equipment temperature to stabilize.
- Note: Equipment performance at T4 should be per Note 1 on Paragraph 4.5.3
- 6) T5 to T6 is 2.0 hours, minimum.

Figure 4.UG-2 Combined Ground Survival High Temperature and Operating High Temperature Test

4.UG.5.4 Operating High Temperature Test

4.UG.5.5 In-Flight Loss of Cooling Test

1. Draft protection to prevent unintended cooling of the UUT through chamber air movement
2. Document the allowance of baffles and or an enclosure. Warning of creating an anti-chamber.

NOTE: To avoid artificial cooling of the EUT, the air in the chamber may be shielded to ensure the air is not being directed onto the EUT. This can be accomplished by use of baffles or vented enclosures inside the temperature chamber. As different chambers use various delivery/return paths, the air delivery system should be reviewed to determine the best method of shielding. If an enclosure is used, it is recommended that a T/C be placed inside the enclosure to monitor the test temperature. The chamber should not be controlled from this thermocouple as the temperature lag between the chamber air, and the enclosure air could put the chamber in thermal runaway.

3. Historically very early versions of DO-160, Section 4 Loss of Cooling, were written for large aircraft installations with centralized avionics cooling systems. The cooling air was delivered by hoses and plenums on the equipment trays. Because equipment manufacturers did not have control of the cooling system, Loss of Cooling tests were required.
4. In the business jet world, OEM's did not want the weight and space of avionics cooling systems and fans were often mounted on the equipment trays. In this case fans were usually powered separately from the avionics equipment and often with 115V/400Hz power.
5. There has also been equipment in use for many years where cooling fans are mounted directly on the equipment and connected to power either through the equipment connector or with converted power in the equipment power supply. The fans mounted in or on the equipment are more likely to be lower voltage and more recently may be quite compact and even board mounted.
6. In Rev. F, the committee added clarification to the application of the Loss of Cooling test and distinguishing were the equipment manufacturer may not have direct control of cooling air or cooling fan power. For equipment with internally powered cooling, we were implying that the fan reliability should, or may, be included in the equipment reliability prediction. Ultimately, the manufacturer is responsible for the equipment reliability and an internally powered fan is assumed to be integral to the equipment.
7. The note in paragraph 4.5.5 makes it clear that the cooling is supposed to be externally supplied or powered, such as dedicated cooling in a cockpit in which the EUT has no direct control over and no way to determine if the external cooling or supply is stopped or shut off.

8. This test does not apply to a EUT which has an internal fan in which the fan power is internally generated or supplied from the EUTs internal power source. The internal fan should be included in the EUT reliability predictions, failure analysis and/or stress analysis and thus its failure should already accounted for in the equipment performance.
9. The definition in Paragraph 4.4:

“This condition represents the failure of the external or internal system that normally provides dedicated cooling for the equipment. Certain equipment must survive for a limited time in the absence of cooling. Test requirements for this type of equipment shall be specified in the equipment performance specification.”

The intent of the definition of paragraph 4.4 is:

“This condition represents the failure of the external system or internal cooling devices, e.g. fans, that normally provide dedicated cooling for the equipment and the cooling supply is externally supplied, powered and/or controlled separate from the EUTs internal power source.
10. DO-160G tests are intended to operate the EUT in its normal operating mode in its operating environment. In this case, the EUT would be operated in a normal operating mode and then a fault is purposely induced to determine its effect and is outside the scope of environmental testing in the normal operating mode. To somehow stop an internal fan is a change to the hardware configuration and may not be consistent with a real failure mode. This additional thermal testing may be part of engineering design evaluations and/or fault or temperature analysis.

4.UG.6 Altitude, Decompression and Overpressure Tests

4.UG.6.1 Altitude Test

There are multiple ways to seal the chamber opening when performing altitude, molded plug, tapered rubber plug, plate compression. Whichever method is implemented, care should be taken to ensure that the seal will not damage any fragile cables. i.e. if a flat plate is used over the chamber opening, do not exceed the bend radius of the cables, do not crush matched impedance cables.

4.UG.6.2 Decompressions Test

It is a good practice to perform the decompression event using a load with a representative volume of the EUT. This will ensure there is not an overshoot condition that could increase the probability of damaging the EUT. Cable harness should be installed during this process to ensure any seal leak is accounted for.

4.UG.6.3 Overpressure Test

1. WARNING: Consult ASME for safety guidance.

2. The overpressure test is specified in absolute pressure. If you are monitoring your environment with a relative pressure device, the specific site pressure needs to be accounted for to perform an accurate test.

DO-160G

Environmental Conditions and Test Procedures for Airborne Equipment

User Guide for Section 5

Temperature Variation

**Based on
DO-160G Section 5**

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TABLE OF CONTENTS

5.UG.0	Temperature Variation	17
5.UG.1	Purpose of the Test.....	17
5.UG.2	Temperature Change Rates	17
5.UG.3	Test Procedure.....	17
5.UG.3.1	Test Procedure Categories A, B, and C.....	17
5.UG.3.2	Test Procedure Category S1	19
5.UG.3.3	Test Procedure Category S2.....	19

TABLE OF FIGURES

Figure 5.UG-1	- Temp Variation without Short Time Operating conditions.....	18
Figure 5.UG-2	- Temp Variation with Short Time Operating conditions.....	19

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5.UG.0 Temperature Variation**5.UG.1 Purpose of the Test****5.UG.2 Temperature Change Rates****5.UG.3 Test Procedure****5.UG.3.1 Test Procedure Categories A, B, and C**

1. When considering combining Temperature Tests with Temperature Variation, the Pros and Cons should be considered. There is a time advantage to combining this testing, but it may present increased risk.
2. If events occur during a combined test, it can be difficult to determine what testing you are able to take credit for. At the worst case, you could have to re-accomplish the entire profile with significant increase in total test time. Also, from a documentation standpoint, it could be difficult to clearly define the test results. If you are testing a product that carries a potential risk of failure, due to redesign, or incorporation of untested components or parts, it may be better to perform temperature and temperature variation testing separately.
3. Below is a Graphical Representation of Combined Temp/Temp variation profiles, with and without Short Time Operating conditions.

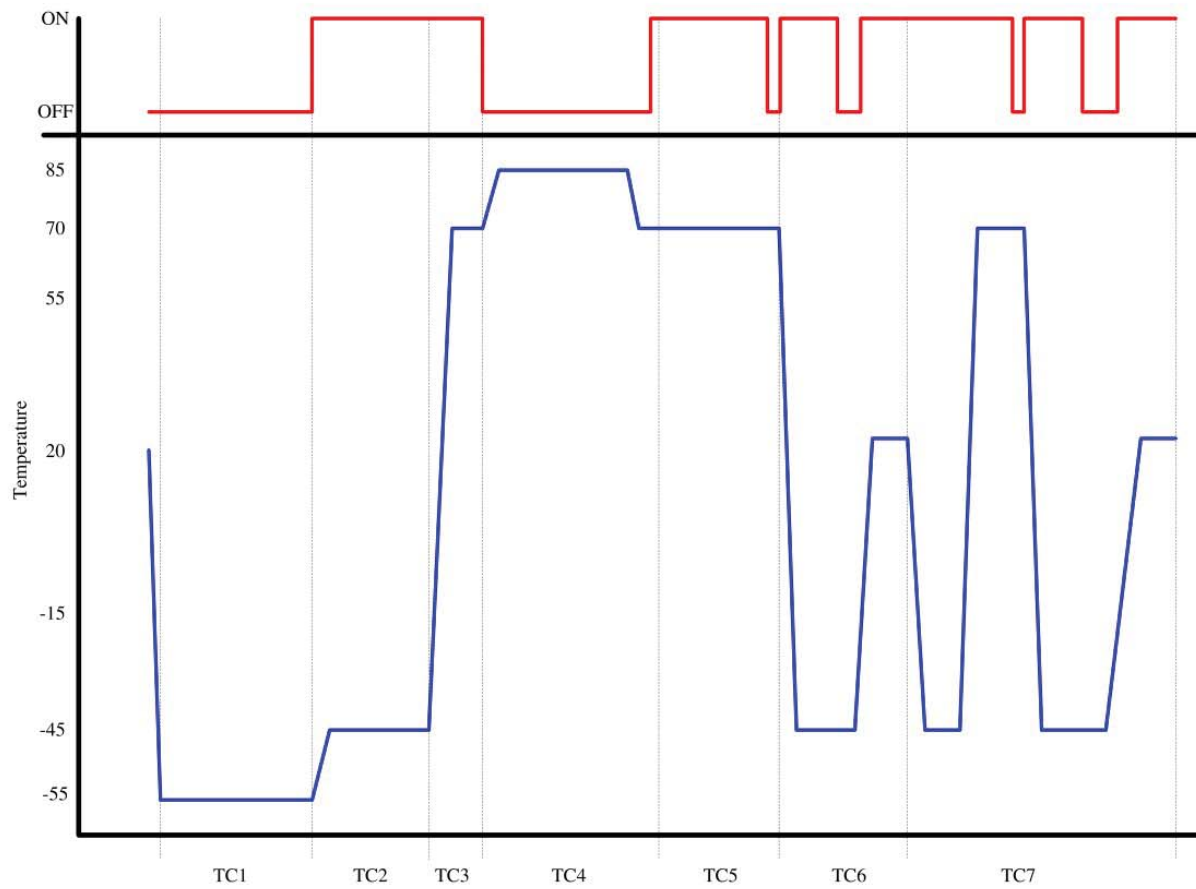


Figure 5.UG-1 - Temp Variation without Short Time Operating conditions

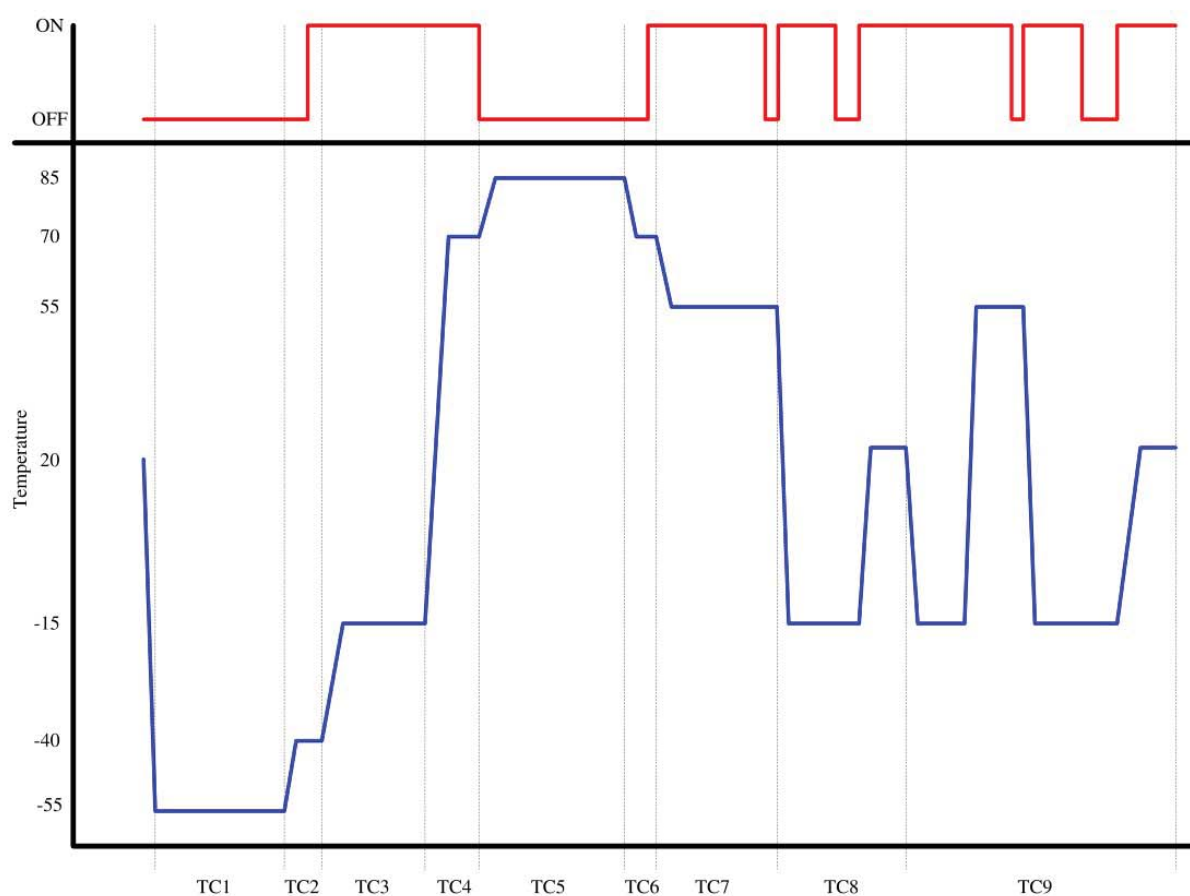


Figure 5.UG-2 - Temp Variation with Short Time Operating conditions

5.UG.3.2 Test Procedure Category S1

5.UG.3.3 Test Procedure Category S2

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DO-160G

Environmental Conditions and Test Procedures for Airborne Equipment

User Guide for Section 7

Operational Shocks and Crash Safety

**Based on
DO-160G Section 7**

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TABLE OF CONTENTS

7.UG.0	Operational Shocks and Crash Safety	25
7.UG.1	Purpose of the Tests	25
7.UG.2	Equipment Categories	26
7.UG.3	Operational Shocks	26
7.UG.3.1	Test Procedure.....	26
7.UG.3.2	Alternate Test Procedure.....	27
7.UG.4	Crash Safety	27
7.UG.4.1	Test Procedure 1 (Impulse)	27
7.UG.4.2	Alternate Test Procedure (Impulse)	27
7.UG.4.3	Test Procedure 2 (Sustained).....	27

TABLE OF TABLES

Table 7.UG-1 - Comparison of velocity and displacement changes during shock.....	25
--	----

TABLE OF FIGURES

Figure 7.UG-1 - Shock Response Spectra for the 6 g shock impulses.....	27
--	----

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7.UG.0 Operational Shocks and Crash Safety

7.UG.1 Purpose of the Tests

This section contains some tests that are transient shock pulses or “impulse” tests, and some tests that are static acceleration tests or “sustained” tests. Although both tests are specified with inertial load factors in “g’s”, the two types of tests cannot be directly compared. For example, an impulse test alone should not be used to cover a sustained acceleration requirement. The Section 8 vibration tests are also different types of tests and generally should not be used to demonstrate compliance to Section 7 tests or vice versa without additional analysis.

Another type of shock testing that is not included in DO-160G is repetitive shock typically associated with HALT testing. The repetitive shock testing typically includes repeating shocks with very high frequency content generated by pneumatic hammers. This is also a different kind of test that is not directly comparable to DO-160G shock testing and should not be used to demonstrate compliance to DO-160G shock requirements.

Three different terminal saw-tooth impulse shock durations are listed in Section 7.1, with different peak accelerations for the operational impulse shock and the crash safety impulse shock. [Table 7.UG-1](#) compares the velocity change and displacement change that occurs during the saw-tooth impulse.

Table 7.UG-1: Comparison of velocity and displacement changes during shock

Impulse Shock Test	Duration (ms)	Peak Acceleration (g)	Velocity Change (in/s)	Displacement Change (in)
Standard Operational Impulse Shock	11	6	12.7	0.05
Low Frequency Operational Impulse Shock	20	6	23.2	0.15
Very Low Frequency Operational Impulse Shock	100	6	115.8	3.86
Standard Crash Safety Impulse Shock	11	20	42.5	0.16
Low Frequency Crash Safety Impulse Shock	20	20	77.2	0.51
Very Low Frequency Crash Safety Impulse Shock	100	20	386.1	12.87

The NOTE in Section 7.1 indicates that aircraft acceleration loads may be demonstrated by testing to the “Unknown or Random” orientations for the “sustained” test procedure. Aircraft acceleration loads are typically broken into 2 sets of acceleration loads: limit loads and ultimate loads. Limit loads are typically lower than ultimate loads but have stricter pass/fail criteria where no permanent detrimental deformation is allowed, and equipment may need to demonstrate compliance with applicable performance standards after testing to limit loads. Ultimate loads are typically higher than limit loads but have the same pass/fail criteria as the sustained crash safety loads: bending and distortion are permitted as long as there is no failure of the mounting attachment and the equipment remains in place. Demonstrating compliance to aircraft acceleration loads may require testing to the “Unknown or Random” orientations for the “sustained” test procedure and also using the more conservative pass/fail criteria associated with limit loads so that both limit and ultimate acceleration loads are covered.

The use of the “Unknown or Random” orientation static acceleration load factors in Table 7-1 may cover the aircraft ultimate acceleration loads for many locations on the aircraft, but some installation locations on the aircraft may not be covered. For example, for aircraft type 2, the “Unknown or Random” orientation test is 9g in each of 6 directions, but the up and down ultimate acceleration load factors for equipment mounted on the wingtip may be higher than 9g. This is the reason why Table 7-1 has a “CAUTION” note stating that the test levels may not satisfy the installation requirement in the FARs.

7.UG.2 Equipment Categories

7.UG.3 Operational Shocks

7.UG.3.1 Test Procedure

Section 7.2.1 allows the use of an equivalent shock response spectrum in place of the terminal saw-tooth time history. For reference, the $Q=10$ (5% damping) shock response spectra for the 6 g operational impulse shock is shown in [Figure 7.UG-1](#).

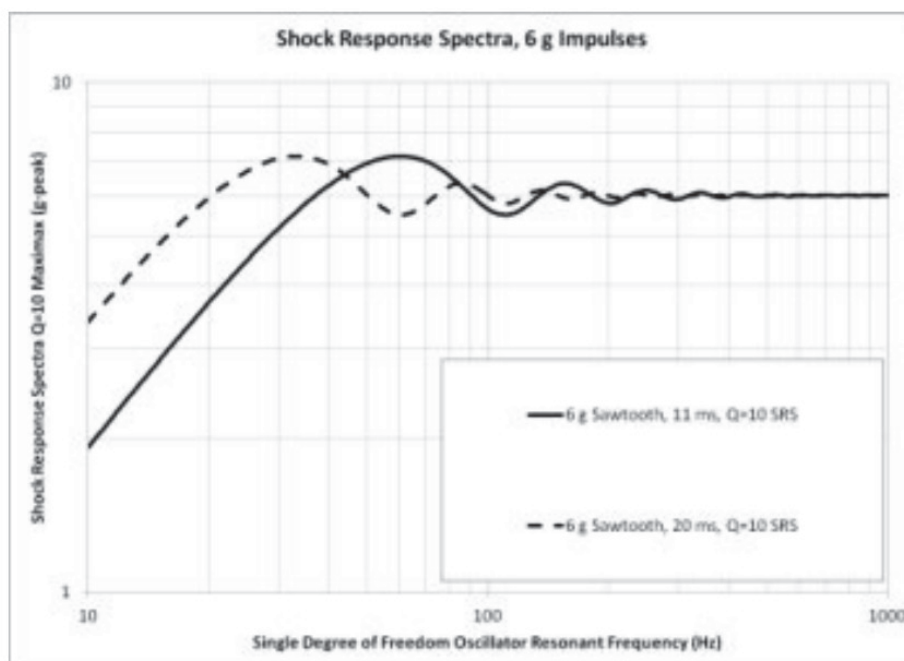


Figure 7.UG-1: Shock Response Spectra for the 6 g shock impulses.

7.UG.3.2 Alternate Test Procedure

7.UG.4 Crash Safety

If the crash safety test is applicable, both the impulse and sustained test procedures shall be performed.

7.UG.4.1 Test Procedure 1 (Impulse)

7.UG.4.2 Alternate Test Procedure (Impulse)

7.UG.4.3 Test Procedure 2 (Sustained)

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DO-160G

Environmental Conditions and Test Procedures for Airborne Equipment

User Guide for Section 8

Vibration

**Based on
DO-160G Section 8**

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TABLE OF CONTENTS

8.UG.0	Vibration.....	33
8.UG.1	Purpose of the Tests	33
8.UG.2	Applicability.....	33
8.UG.3	Vibration Test Category Definitions	34
8.UG.3.1	Standard Vibration Test (Category S).....	34
8.UG.3.2	Robust Vibration Test (Categories R, U, U2).....	34
8.UG.3.3	High-Level, Short Duration Vibration Test (Categories H, Z)	34
8.UG.4	Test Curve / Test Level Selection	35
8.UG.4.1	Test Description	35
8.UG.4.2	Test Curves.....	35
8.UG.5	Vibration Test Requirements.....	36
8.UG.6	Vibration Test Level Requirements.....	41
8.UG.6.1	Control Level Tolerance Requirements	41
8.UG.6.1.1	Sinusoidal Control Input	41
8.UG.6.1.2	Random Control Input.....	41
8.UG.6.2	Measurement of Acceleration Power Spectral Density	42
8.UG.6.2.1	Analog Analyzer Requirements	42
8.UG.6.2.2	Digital Analyzer Requirements	42
8.UG.7	Standard Vibration Test Procedure-Fixed Wing Aircraft	42
8.UG.7.1	Sinusoidal Test Procedure	42
8.UG.7.2	Random Test Procedure.....	42
8.UG.8	High-Level, Short Duration Vibration Test Procedure	42
8.UG.9	Robust Vibration Test Procedure-Fixed-Wing Aircraft.....	42
8.UG.9.1	Sinusoidal Test Procedure	42
8.UG.9.2	Random Test Procedure.....	42
8.UG.10	Vibration Test for Helicopters	42
8.UG.10.1	Sine-on-Random Test Procedure – Known Helicopter Frequencies	42
8.UG.10.1.1	Test Frequencies.....	42
8.UG.10.1.2	Sine and Random Test Levels	43
8.UG.10.1.3	Procedure	43
8.UG.10.2	Sine-on-Random Test Procedure for Category U – Unknown Helicopter Frequencies	43
8.UG.10.3	Random Test Procedure for Category U2 – Unknown Helicopter Frequencies	43

TABLE OF TABLES

Table 8.UG-1 - Reduction Factors for Heavy Equipment	36
Table 8.UG-2 - Summary of Vibration EQF reporting requirements	40
Table 8.UG-3 - Example EQF Reporting of Critical and/or Resonant Frequency Changes.....	41

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8.UG.0 Vibration

8.UG.1 Purpose of the Tests

The vibration tests in section 8.0 are a standardized method used to determine whether installed equipment is able to function as intended during aircraft operation and maintain structural integrity under vibration. The standardization of the test methods reduces the need to define unique vibration requirements for each installation and allow equipment compatibility across aircraft platforms.

While the tests defined in section 8.0 may or may not fully envelope the vibration environment that could be measured for each installation, the tests have been shown to be a useful criterion to identify inadequate equipment designs. Airframe manufacturers, engine manufacturers, and equipment installers may require testing to installation unique vibration environments, which may or may not be more severe than DO-160G.

8.UG.2 Applicability

The aircraft types, as listed in Table 8-1, are the following:

1. Helicopters (Reciprocating & Turbojet Engines).
2. Fixed Wing Turbojet or Turbofan Engines (Subsonic & Supersonic).
3. Fixed Wing Reciprocating & Turboprop Engines, Multi-Engine over 5,700 kg.
4. Fixed Wing Reciprocating & Turboprop Engines, Multi-Engine less than 5,700 kg.
5. Fixed Wing Reciprocating & Turboprop Engines, Single-Engine less than 5,700 kg.
6. Fixed Wing Unducted Turbofan Engines (Propfan).

The test categories are discussed in more detail in section 8.2.1, 8.A.2.1 and their subsections. The three test categories are the following:

- Category S: Standard Vibration.
- Category R, U, or U2: Robust Vibration.
- Category H or Z: High-Level Short Duration Vibration.

The aircraft zones, as listed in Table 8-1, are the following:

1. Fuselage.
2. Instrument Panel, Console & Equipment Rack.
3. Nacelle & Pylon.
4. Engine & Gear Box.
5. Wing & Wheel Well.

6. Landing Gear.
7. Empennage & Fin Tip.

The vibration test curves, as listed in Table 8-1, are the following:

- Standard Random Vibration: B, B2, B3, C, D, and E
- Standard Sinusoidal Vibration: L, M, T, and U
- Standard or Robust Sinusoidal Vibration: W, Y, and Z
- Robust Random Vibration: B & B1, B2 & B12, B3 & B4, C & C1, D & D1, and E & E1
- High-Level Short Duration Sinusoidal Vibration: P and R
- Helicopter Sine-On-Random Vibration: G, H, I, and J
- Helicopter Random Vibration: F & F1

8.UG.3 Vibration Test Category Definitions

The standard and robust test categories are both related to the aircraft vibration environment during normal operating conditions. The robust test is more severe than the standard test. The high-level short duration test is related to sustained engine imbalance conditions and thus is unrelated to the standard and robust test categories.

8.UG.3.1 Standard Vibration Test (Category S)

The standard vibration test demonstrates that equipment will meet its functional performance requirements in the vibration environment experienced during normal operating conditions of the aircraft. It is not intended to represent a service life endurance vibration test.

The use of the word “standard” does not imply that this is the preferred test category. “Standard” is simply the name for this test category.

The standard vibration test is not available for helicopters.

8.UG.3.2 Robust Vibration Test (Categories R, U, U2)

The test requirements of the robust vibration test are of longer duration and sometimes higher level than the standard vibration test. The robust test demonstrates functionality during a performance level vibration test and also demonstrates some degree of physical endurance that can be expected with extended vibration exposure during an endurance level vibration test. However, the robust test may or may not represent a service life test.

8.UG.3.3 High-Level, Short Duration Vibration Test (Categories H, Z)

The High-Level Short Duration (HLSD) vibration test is only applicable to Aircraft Type 2) Fixed Wing Turbojet or Turbofan Engines (Subsonic & Supersonic) and Aircraft Type 6) Fixed Wing Unducted Turbofan Engines (Propfan). See the Aircraft Types listed in DO-160G Table 8-1.

The HLSD vibration test is intended to demonstrate equipment functionality during sustained engine imbalance conditions that result from blade loss or shaft support failure. This test typically is applicable only to equipment with functionality required for continued safe flight and landing after a blade-out event.

FAA Advisory Circular 25-24, “Sustained Engine Imbalance,” dated 8/2/2000, provides additional detail about sustained engine imbalance. More specifically, AC 25-24 defines two imbalance conditions that may affect safe flight: the windmilling condition and a separate high power condition. Reference this Advisory Circular for further details regarding these conditions.

This test alone may or may not be sufficient to demonstrate equipment functionality and/or structural integrity during windmilling and high power conditions since the test amplitudes may not envelope the high power and windmilling environments for the applicable aircraft.

8.UG.4 Test Curve / Test Level Selection

8.UG.4.1 Test Description

8.UG.4.2 Test Curves

Small equipment racks where the shelf is attached to frames, stringers, skin or other fuselage structure should utilize Zone 1: fuselage.

The test curves may not be adequate for an externally mounted item with significant surface area, like a blade antenna.

Equipment that is attached directly to fuselage structure and contained within the wing-to-body fairing is considered part of Zone 1: fuselage.

Zone 2 “Instrument Panel Console and Equipment Rack” also includes interior items attached to the galley interior partitions and cabin main deck floor and is separate from the “fuselage” zone.

See Table 8.A.2.2.2-1 below for the reduction factors for the “Weight Allowance” for a EUT weighing greater than 22.68 kg (50 lbs.). The weight of the test fixture should not be included when evaluating whether a EUT is heavy enough for a weight allowance. The “APSD Factor” in the table would be applied to the g^2/Hz APSD levels for the random tests. The “Sinusoidal Factor” would be applied to the overall g_{rms} levels for the random tests or to the Displacement Double Amplitude (DDA) and g levels for the sinusoidal tests. The factors in the tables are displayed in 5 lb. increments, but the factors can be computed in smaller increments with the following equations:

$$\text{APSD factor:} \quad 10^{(0.1 * [50 - w] / 10)}$$

$$\text{Sinusoidal factor:} \quad 10^{(0.1 * [50 - w] / 20)}$$

Where “w” is the equipment weight in pounds for equipment weighing between 50 lb. (22.68 kg) and 110 lb. (49.90 kg). The reduction factors for heavy equipment should not be used for equipment weighing less than 50 lb. (22.68 kg). For equipment weighing more than 110 lb. (49.90 kg) the maximum reduction of 6 dB should be used. The reduction factors can only be applied to frequencies above 60 Hz.

The weight allowance can be applied to all test curves in Section 8, including the Standard, Robust, and High Level Short Duration categories (categories S, R, U, U2, H, and Z) for a EUT weighing more than 22.68 kg. While a reduction in amplitude is typically appropriate for a heavy weight EUT, for some installations, in particular on helicopters, it may be inappropriate to reduce the test level.

Table 8.UG-1 - Reduction Factors for Heavy Equipment

Reduction Factors for Heavy Equipment Applicable Only Above 60 Hz Applicable to Standard and Robust Test Levels				
Equipment Mass (kg)	Equipment Weight (lb.)	dB Change	APSD Factor	Sinusoidal Factor
22.68 or less	50 or less	0.0	1.00	1.00
24.95	55	-0.5	0.89	0.94
27.22	60	-1.0	0.79	0.89
29.48	65	-1.5	0.71	0.84
31.75	70	-2.0	0.63	0.79
34.02	75	-2.5	0.56	0.75
36.29	80	-3.0	0.50	0.71
38.56	85	-3.5	0.45	0.67
40.82	90	-4.0	0.40	0.63
43.09	95	-4.5	0.35	0.60
45.36	100	-5.0	0.32	0.56
47.63	105	-5.5	0.28	0.53
49.90 or more	110 or more	-6.0	0.25	0.50

8.UG.5 Vibration Test Requirements

- a. The test axes should be defined with respect to the equipment's primary orthogonal axes, without regard to the aircraft installation orientation.

The purpose of a vibration test fixture is to transmit energy from the shaker into the test item without affecting its transmission in any way. In reality, a test fixture affects the frequency, phase and amplitude of the energy it transmits. Although perfect fixtures may not be possible, proper design and preparation early in a test program will help achieve an optimum result.

Vibration fixtures should be as rigid and non-compliant as possible. The ideal fixture will not have modes below 2.5 kHz to ensure the controllability of the test. In some situations test fixtures will have resonances in the test frequency range. This is especially true for large test items. For this reason it is recommended that the fixture-specimen system be experimentally evaluated prior to formal vibration testing. The goal of this pre-test evaluation is to characterize any in-axis or out-of-axis fixture dynamic responses that will affect the actual test. The test plan should allow

modification of vibration test levels and control strategies to mitigate any undesirable fixture effects – both resonance and anti-resonance.

Non-rigid fixtures should not be used because they make controlling vibration input levels extremely difficult or impossible. The difference in stiffness between vibration fixtures and real world installation has been thoroughly documented in the technical literature and is typically referred to as vibration test fixture impedance mismatch.

Equipment that is mounted on external vibration/shock isolators shall be tested with the isolators. If the isolators are not part of the EUT, then they may be changed during the test as they show wear and/or affect the results of the test.

- b. The response accelerometer locations should be carefully considered to ensure that critical responses are recorded. Consider locations that will capture the EUT resonances that contribute most to mechanical fatigue of critical details or resonances that may affect performance. For example, placing an accelerometer on a EUT cover may show multiple resonances of the cover, but the cover resonances may have little influence on mechanical fatigue of critical mechanical components or EUT performance. Response accelerometer locations could affect conformity, especially for locations internal to the EUT. The degree of conformity impact should be considered when selecting EUT accelerometer locations. Response accelerometer locations should be documented.
- c. Control accelerometers should be placed on the fixture as close as possible to the equipment mounting location. A fixture survey is recommended to determine the number of control accelerometers and locations required for the vibration test. The fixture should have a representative mass loading during the fixture survey. Control accelerometer locations should be documented.
- d. [This section is intentionally left blank]
- e. The accuracy of the instrumentation system for measuring sinusoidal acceleration shall be ± 10 percent for acceleration and ± 2 percent for frequency. The values noted here are with respect to the instrumentation accuracy. That is, the accelerometers and other associated instrumentation should be accurate within $\pm 10\%$ for sinusoidal amplitude, and accurate within $\pm 2\%$ for sinusoidal frequency. This instrumentation accuracy requirement is separate from the test control tolerances noted in sections 8.4.1.1 and 8.4.1.2.
- f. CAUTION: While splitting the spectrum into separate frequency bands of 10 Hz to 600 Hz and 600 Hz to 2000 Hz is permissible, it is not recommended due to the complicated dynamics that occur during a random vibration test. The full frequency band is expected to be tested together and the EUT vibration dynamics are extremely difficult, if not impossible, to predict if the band is split. This practice should be avoided if a critical natural frequency is found to be within 600Hz ± 100 Hz.

Other General Guidance

If a condition is present that requires a stoppage of the test, the test may be interrupted and resumed after the condition is resolved.

Guidance for Critical and Resonant Frequencies

The terms “Resonant Frequencies” and “Critical Frequencies” are used and defined in several locations throughout the vibration test procedure. These terms are summarized below along with additional guidance.

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Resonant frequencies

Resonant frequencies are defined as response peaks that are greater than twice the input acceleration amplitude.

Resonant frequencies are referenced for Standard Random, Robust Random, and Sine-On-Random test procedures. While the resonant frequencies do not have a direct effect on the test procedure, these frequencies should be clearly identifiable in the APSD plots. These same tests also include a statement regarding recording changes in resonant frequencies in the EQF.

Critical frequencies

Critical frequencies are defined as: (1) resonant frequencies, or (2) frequencies where a change in performance or behavior is noticeable whether or not performance standards are exceeded.

Critical frequencies are referenced for both Standard Sinusoidal and Robust Sinusoidal test procedures. These frequencies are used as special 30 minute dwell frequencies during the Robust Sinusoidal test procedure. These same tests also include a statement regarding recording changes in critical frequencies in the EQF.

Identifying Changes in Critical or Resonant frequencies

The test procedure contains no limits to determine what constitutes a change in Critical or Resonant Frequency. However, the measurement accuracy specifications are $\pm 10\%$ for acceleration/amplitude and $\pm 2\%$ for frequency. Therefore, typically changes within these specified accuracy limits should not be reported as changes.

Generally, resonant frequencies are considered as the frequencies where there is a response peak that is greater than twice the input acceleration amplitude. However, strictly speaking, this could result in a large number of small peaks that still exceed twice the value of the input acceleration amplitude but are all generally part of the same larger resonance. For the purpose of EQF reporting it may not be practical to include literally every peak in the resonant frequency comparison. However, complete detailed plots should be available in the test report for future review.

Resonant frequency changes due to equipment settling

It is useful to monitor EUT resonant frequencies for changes because significant changes in resonant frequencies are sometimes indicative of structural degradation of the EUT or test fixture. However, significant changes in resonant frequency may occur without any associated structural degradation. When testing a recently built EUT and built-up test fixture it is not uncommon to experience fixture or equipment settling. This settling may result in changes in the measured resonant frequencies, even though the settling does not cause structural degradation or performance degradation. Changes in resonant frequency are not part of the pass/fail criteria.

Applying some informal vibration testing prior to formal testing may allow settling to occur such that resonance changes are minimized during the formal test. Reducing the number of nuisance variations due to settling would allow the equipment manufacturer to focus on resonance changes resulting from causes other than settling.

Sinusoidal General Notes

All Sine curves are specified with Acceleration g-level, Displacement Double-Amplitude (DDA), and Frequency. However, only two parameters can be used to set the crossover points. The resulting value of the third parameter will not be exactly equal to the value in the figure. It is recommended to use Acceleration g-level and Displacement Double-Amplitude to set the crossover points. In this case frequency may vary slightly from that specified in the chart.

For example, Figure 8-2 has a breakpoint at 24 Hz, 1.0 g, and 0.036 inches displacement double-amplitude. The crossover frequency is actually closer to 23.31 Hz using a conversion of $1.0 \text{ g} = 386.1 \text{ in/s}^2$. It is acceptable to run the test with the breakpoint at the calculated crossover frequency. Alternately, it is also acceptable to run the test with a constant 1 g input up to 24 Hz, then have a slight discontinuity at 24 Hz to transition up to 0.036 inches DDA.

Random Vibration General Notes

It is generally not accepted to combine random vibration test curves. However, if combining is desired, then it is permissible if the maximum APSD and maximum frequency bandwidths of the curves to be combined are used for the resulting curve. It should also be noted, that the combination of two curves is a more severe test than testing each curve separately on two different EUTs. This would typically be used for a EUT that is qualified for multiple applications or locations.

Acceleration Power Spectral Density (APSD) plots of the control accelerometer(s) should be included in the test report to document that the EUT was tested within tolerances. Since an APSD plot represents just a brief duration, control APSD plots from at least the start and end of a random test should be included in the test report.

The random vibration tests also include a requirement to perform APSD analysis of the response accelerometer(s). The response accelerometer APSD plots include useful data about the EUT response to random vibration excitation and should be included in the test report for reference. The EUT response APSD may be monitored for changes, where significant changes may be indicative of response accelerometer instrumentation problems, EUT settling, or EUT degradation.

Guidelines for EQF reporting requirements

The vibration test procedure includes several Environmental Qualification Form (EQF) reporting requirements. A summary of all such reporting requirements is provided in the table below.

The intent of these requirements was not to include detailed measurement plots in the EQF. Any applicable detailed plots should be available in the test report for future reference.

Generally, references to listing changes in performance were intended to be a reference to listing critical and/or resonant frequency changes. EUT performance requirements are already dictated by the applicable TSO and/or aircraft manufacturer requirements.

Examples for how to sufficiently meet the EQF reporting requirements are provided below. Note that depending on the number of resonances it may not be practical to report literally every peak. See the guidance on critical and resonant frequencies for further guidelines on what differences to report.

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In the event that there are no reportable critical and/or resonant frequency changes, then it is acceptable to simply provide a statement similar to the following: “No notable changes to critical and/or resonant frequencies occurred as a result of the applicable vibration testing”.

Table 8.UG-2: Summary of Vibration EQF reporting requirements

<u>Section</u>	<u>Section Description</u>	<u>EQF reporting requirements</u>
8.5.1	Sinusoidal Test Procedure	Any changes in the critical frequencies that occur during the test.
8.5.2c	Random Test Procedure	Any changes in vibration resonance frequencies.
8.6	High-Level Short Duration Vibration Test Procedure	For Category Z, the maximum frequency tested.
8.7.1c	Robust Sinusoidal Test Procedure	Any changes in the critical frequencies that occur during the test. If no change occurs, then note that no changes occurred.
8.7.2d	Robust Random Test Procedure	Any changes in the vibration resonant frequencies.
8.8.1.3 d	Sine-On-Random Test Procedure	Any change in performance
8.8.1.3e	Sine-On-Random Test Procedure	Any changes in vibration resonant frequencies. If no change occurs, then note that no changes occurred.
8.8.3c	Random Test Procedure for Category U2	Any change in the performance or the vibration resonances.

Table 8.UG.3: Example EQF Reporting of Critical and/or Resonant Frequency changes.

Resonant frequency changes are noted below per RTCA DO-160G section 8.5.2.c Random Test Procedure. Standard Vibration – Category S, Curve B. Detailed measurements are available in the test report.

	<u><i>Initial Sine Sweep before Random Test</i></u>		<u><i>Final Sine Sweep after Random Test</i></u>	
<u><i>Axis</i></u>	<u><i>Frequency (Hz)</i></u>	<u><i>Acceleration (g)</i></u>	<u><i>Frequency (Hz)</i></u>	<u><i>Acceleration (g)</i></u>
X	161	1.3	152	1.1
Y	464	1.4	469	1.5
Y	1609	1.7	1609	1.1
Z	111	6.9	108	8.5
Z	159	1.5	159	1.3
Z	288	1.5	289	1.7
Z	319	1.4	308	1.7
Z	431	1.2	429	1.3
Z	1063	1.8	1057	2.0

8.UG.6 Vibration Test Level Requirements

8.UG.6.1 Control Level Tolerance Requirements

8.UG.6.1.1 Sinusoidal Control Input

The +/- 10% tolerance on the sinusoidal control input may be applied to a bandpass-filtered control signal, rather than a broadband control signal. A bandpass-filtered signal will be representative of the amplitude at the input frequency and filters out content at other frequencies.

8.UG.6.1.2 Random Control Input

For items of large mass that can be difficult to control, a typical practice is to allow a small percentage of the cumulative bandwidth to be out of tolerance. The out of tolerance bandwidth should be limited to a maximum of 5 percent of the test frequency range.

If out of axis input motions are measured, it is recommended that these out of axis inputs be limited to 100% of the in axis input.

8.UG.6.2 Measurement of Acceleration Power Spectral Density**8.UG.6.2.1 Analog Analyzer Requirements****8.UG.6.2.2 Digital Analyzer Requirements**

The requirement stated in DO-160G Section 8.4.2.2 is that analysis and control systems shall use a bandwidth-time (BT) product greater than or equal to 50. The bandwidth “B” is the frequency resolution of the APSD, and the time “T” is the full duration of time used for averaging the APSD. The bandwidth-time product is related to the number of ensemble averages or degrees of freedom (DOF) used to calculate the APSD. A bandwidth-time product greater than or equal to 50 corresponds to a minimum of 50 linear averages or 100 DOF. As an example, with a bandwidth $B=5$ Hz, the minimum time used for APSD calculations would be $50/5 = 10$ seconds.

8.UG.7 Standard Vibration Test Procedure-Fixed Wing Aircraft**8.UG.7.1 Sinusoidal Test Procedure****8.UG.7.2 Random Test Procedure****8.UG.8 High-Level, Short Duration Vibration Test Procedure****8.UG.9 Robust Vibration Test Procedure-Fixed-Wing Aircraft****8.UG.9.1 Sinusoidal Test Procedure****8.UG.9.2 Random Test Procedure**

The existence of EUT performance monitoring during testing at the endurance test levels is intended to provide a means to eliminate the need to perform a second performance level vibration test after completion of the endurance level vibration test. If EUT performance monitoring does not occur during testing at the endurance test levels, then repeat the performance level test as directed.

8.UG.10 Vibration Test for Helicopters**8.UG.10.1 Sine-on-Random Test Procedure – Known Helicopter Frequencies****8.UG.10.1.1 Test Frequencies**

The intent of this section is to help to define the significant disturbance frequencies. The helicopter manufacturer may define the significant disturbance frequencies. The list of test frequencies from DO-160G may not cover all the significant disturbance frequencies. Some helicopter manufacturers have considered FG to be the Tail Drive shaft one rev frequency.

8.UG.10.1.2 Sine and Random Test Levels**8.UG.10.1.3 Procedure****8.UG.10.2 Sine-on-Random Test Procedure for Category U– Unknown Helicopter Frequencies**

Category U may be applied to Zone 1a (fuselage) and Zone 2 (instrument panel, console, & equipment rack). Category U should not be applied to zone 1b (tail boom).

8.UG.10.3 Random Test Procedure for Category U2 – Unknown Helicopter Frequencies

The purpose of Category U2 is to provide an alternative procedure for labs that don't have sine-on-random test capability.

Category U2 is applicable to Zone 1a, Zone 1b, and Zone 2. Note that Category U2 is applicable to Zone 1b (tail boom) and Category U is not applicable to Zone 1b.

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