EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

29 July 1997

Supersedes ED-14C/DO-160C

FOREWORD

1. This document prepared jointly by EUROCAE Working Group 14 and RTCA Special Committee 135, with the participation of EUROCAE Working Groups, 31 and 33, was accepted by the Council of EUROCAE on July 1997.

2. EUROCAE is an international non-profit making organisation in Europe. Membership is open to manufacturers and users of equipment for aeronautics, trade associations, national civil aviation administrations, and, under certain conditions, non-European organisations. Its work programme is principally directed to the preparation of performance specifications and guidance documents for civil aviation equipment, for adoption and use at European and world-wide levels.

3. This document supersedes document EUROCAE ED-14C/RTCA DO-160C of December 1989 with its changes 1, 2, and 3 of September 1990, June 1992 and May 1993.

4. The findings of EUROCAE are resolved after discussion amongst Members of EUROCAE and interested Administrations, and in collaboration with RTCA Inc, Washington D.C., and/or the Society of Automotive Engineers (SAE), Warrendale PA, U.S.A., through their appropriate committees.

5. EUROCAE performance specifications are recommendations only. EUROCAE is not an official body of the European Governments. Its recommendations are valid as statements of official policy only when adopted by a particular government or conference of governments.

6. Copies of this document may be obtained from:

EUROCAE
11, rue Hamelin
75783 PARIS CEDEX 16
France

Telephone: 33 1 45 05 71 88
Fax: 33 1 45 05 72 30
Email: Eurocae@CompuServe.Com

TABLE OF CONTENTS

Detailed Tables of Contents appear on the inside covers of most sections

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 1

Purpose and Applicability

Section 2

Definitions of Terms - General

Section 3

Conditions of Tests

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

1.0 PURPOSE AND APPLICABILITY

This document defines a series of minimum standard environmental test conditions (categories) and applicable test procedures for airborne equipment. The purpose of these tests is to provide a laboratory means of determining the performance characteristics of airborne equipment in environmental conditions representative of those which may be encountered in airborne operation of the equipment.

The standard environmental test conditions and test procedures contained herein may be used in conjunction with applicable equipment performance standards as a minimum specification under environmental conditions, which can ensure a sufficient degree of confidence in performance during operations.

NOTE: *In each of the test procedures contained herein, the following phrase will be seen several times:*

"DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS".

The "applicable equipment performance standards" referred to are either:

a. EUROCAE Minimum Operational Performance Specifications (formerly Requirements) (MOPS/MOPR).

b. RTCA Minimum Performance Standards (MPS) and/or RTCA Minimum Operational Performance Standards (MOPS).

c. The manufacturer's equipment specification(s), where applicable.

Some of the environmental conditions and test procedures contained in this document are not necessarily applicable to all airborne equipment. The selection of the appropriate and/or additional environmental conditions and test procedures is the responsibility of the writers (authors) of the performance standards for the specific airborne equipment.

NOTES:

1. *There are several additional environmental conditions (categories), that specific airborne equipment may be subjected to, that have not been included in this document. These include, but are not limited to: hail, acceleration and acoustic vibration.*

2. *The procedures for testing airborne equipment for special environmental conditions that are usually uniquely related to that specific type of airborne equipment, should be the responsibility of the writer (author) of the performance standard for that specific equipment.*

3. *The International System of Units (SI) is usually used throughout this document as the primary values. In certain instances, however, when the primary values were derived in English units, these units are used as the primary values.*

4. *Subject to the provisions of Subsection 3.2, it is permissible to use more than one test article.*

The words "airborne equipment," as used within this document, have direct applicability to most airborne equipment. It is the responsibility of those who wish to apply the test conditions and procedures contained in this document to determine the applicability of these test conditions and procedures to a specific equipment intended for installation on, or within, a specific or general class or type of aircraft.

The environmental conditions and test procedures defined herein are intended to determine only the performance of the airborne equipment under these environmental conditions and are not intended to be used as a measure of service life of the airborne equipment subjected to these tests.

Any regulatory application of this document is the sole responsibility of appropriate governmental (regulatory) agencies.

2.0 DEFINITIONS OF TERMS - GENERAL

This section contains the definitions of general terms that are utilized throughout this document. The definition of terms specific to a particular section may be found in the appropriate section.

2.1 Equipment Temperature Stabilization

a. Not Operating

The equipment is considered temperature stabilized when the temperature of the functioning parts of the test item considered to have the longest thermal lag are within three degrees Celsius of the specified test temperature. When temperature measurement of the largest internal mass is not practical, the minimum time considered applicable for temperature stabilization shall be three hours.

b. Operating

The equipment is considered temperature stabilized when the functioning parts of the test item considered to have the longest thermal lag do not vary by more than two degrees Celsius per hour. When temperature measurement of the largest internal mass is not practical, the minimum time considered applicable for temperature stabilization shall be two hours.

2.2 Maximum Duty Cycle

When operation of an equipment is periodic, the maximum duty cycle is the relationship between the maximum length of time for which the equipment is designed to operate at its rated capacity and the length of time during which the equipment is not operating; or when the operating capacity is at a defined minimum. The maximum duty cycle shall be established by the equipment specification.

2.3 Not Operating

Not operating is that condition wherein no power is applied to the equipment unless otherwise defined in the individual equipment specification.

2.4 Controlled or Partially Controlled Temperature Location

Controlled or partially controlled temperature location is a space within an aircraft in which the temperature of the air is maintained by an environmental control system (see Table 4-1 of applicable category).

2.5 Total Excursion

Total excursion means the total displacement from positive maximum to negative maximum.

2.6 Equipment

The term "equipment" includes the test items and all of the components or units necessary (as determined by the equipment manufacturer) for the equipment to properly perform its intended function(s). The equipment shall be representative of the production standard that will be utilized in service.

2.7 Altitude

Altitude represents the environmental pressure relative to sea level to which the equipment is exposed during the tests.

2.8 Category of Tests and Declarations

For each environmental condition addressed in this document, the equipment supplier shall select from categories defined within the particular sections that category which best represents the most severe environment to which the equipment is expected to be regularly exposed during its service life. The category selections thus determined are to be tabulated on the Environmental Qualification Form and/or the equipment nameplate in accordance with the guidelines presented in Appendix A.

Use of Category X on the environmental qualification form and/or equipment nameplate in association with any environmental test procedure of this document is reserved for the case where the equipment supplier wishes to indicate that compliance with equipment performance standards has not been demonstrated under the environmental conditions addressed by that particular procedure.

When the Statement "DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS" is found at the end of or during the test procedures, it should be understood that performance compliance and verification is considered to be the requirement that allows the equipment to be certified as to its ability to perform its intended function(s) during and/or after a specific test category.

3.0 CONDITIONS OF TESTS

3.1 Connection and Orientation of Equipment

Unless otherwise stated, connect and orient the equipment (e.g. mechanically and electrically) as recommended by the equipment manufacturer for normal service installation, including any cooling provisions, as necessary to perform the tests and to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. Interconnecting cable lengths, where not specified, shall be at least 1.50 m long and shall be configured so as to allow one common bundle of 1.20 m. Any inputs or outputs to or from other equipment(s) normally associated with the equipment(s) under test shall be connected or adequately simulated.

NOTE: Paragraphs 19.3, 20.3 and 21.5, if applicable, will require an interconnecting cable longer than these minimums.

3.2 Order of Tests

Unless otherwise required by the equipment specification, the tests may be conducted in any desired order; however, the following provisions always apply:

a. The humidity test shall not be conducted prior to the temperature, temperature variation, altitude tests and the vibration tests. The purpose of this exception is to determine whether materials used to protect equipment components from moisture have lost their protective function due to deterioration from exposure to either extreme temperature or to vibration.

b. The salt spray test and/or sand and dust test shall not be conducted prior to the fungus resistance test.

c. The explosion proofness tests should normally be conducted after the article being tested has been subjected to the other environmental tests of this document, except as noted in paragraph 4.6.1, "Altitude Test".

d. The sand and dust test shall not be conducted prior to the humidity or salt spray test.

3.3 Combining Tests Tests

It is acceptable to employ alternate procedures developed as combinations of the procedures described herein, provided it can be demonstrated that all applicable environmental conditions specified in the original procedures are duplicated or exceeded in the combined procedure. If alternate procedures are used, appropriate information should be provided along with the Environmental Qualification Form, (see Appendix A).

3.4 Measurement of Air Temperature in the Test Chamber

The temperature of the air in the test chamber shall be measured at a location where the air conditions are representative of that immediately surrounding the equipment. Measurement of chamber wall temperature is not suitable, due to temperature lag and heat transfer through the chamber wall.

A means of circulating air in the test chamber should be employed to assure an approximate uniform air temperature condition throughout the chamber. When such means are employed, the air movement shall not be directed on the equipment under test, and the equipment shall be tested at the minimum flow rate consistent with the purpose of maintaining a uniform temperature distribution in the chamber. The ambient air velocities surrounding equipment not requiring auxiliary cooling shall remain comparable to those air velocities that occur from natural convection.

For equipment that requires auxiliary cooling to assure proper operation, as defined in the equipment installation instructions, the following applies:

a. If air is the cooling medium, the supplied cooling air characteristics shall be the same as the specified chamber air characteristics, unless otherwise specified by the equipment manufacturer.

b. If the cooling medium is not air, the medium and its supply temperature shall be as specified by the equipment manufacturer.

NOTE: For equipment whose installation location is known and defined relative to other equipment, sources of radiated heat and/or impediments to normal convection should be simulated in the test.

3.5 Ambient Conditions

Unless otherwise specified, all tests shall be made within the following ambient conditions:

a. Temperature: +15 to +35 degrees Celsius.

b. Relative Humidity: Not greater than 85 percent.

c. Ambient Pressure: 84 to 107 kPa (equivalent to +5,000 to -1,500 ft) (+1525 to -460 m).

When tests are conducted at ambient conditions that differ from the above values, the actual conditions shall be recorded.

3.6 Environmental Test Condition Tolerances

Unless otherwise specified, tests made at environmental conditions other than ambient, as defined above, shall be conducted subject to the following tolerances:

a. Temperature: ±3 degrees Celsius.

b. Altitude: ±5 percent of specified pressure.

3.7 Test Equipment

All stimulus and measurement equipment used in the performance of the tests should be identified by make, model, serial number and the calibration expiration date and/or the valid period of calibration where appropriate. When appropriate, all test equipment calibration standards should be traceable to national and/or international standards.

3.8 Multiple Unit Equipment

If the equipment to be tested consists of several separate units, these units may be tested separately, provided the functional aspects are maintained as defined in the relevant equipment specification.

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 4

Temperature and Altitude

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

4.0 TEMPERATURE AND ALTITUDE

4.1 Purpose of the Tests

These tests determine the performance characteristics of equipment at the applicable categories for the temperatures and altitudes specified in Table 4-1 and at the pressures defined in Table 4-2.

4.2 General

Several temperature and altitude test procedures are defined, each to be selected according to the category for which the equipment is designed to be used when installed in an aircraft (see Subsection 4.3 and Table 4-1).

NOTE: *The selection of a temperature/altitude category depends on the location in (or on) the aircraft, the maximum operating altitude of the aircraft and whether the equipment is located within a temperature and/or pressure controlled area. The above conditions must be taken into consideration by the equipment designer in evaluating these requirements, which are determined by the end application and use of the equipment.*

4.3 Equipment Categories

The following categories cover the wide range of environments known to exist in the majority of aircraft types and installation locations. It should be recognized that not all possible combinations of temperatures and altitude limits are covered in these equipment categories. Categories for in-flight loss of cooling are defined in paragraph 4.5.4.

Category A1

Equipment intended for installation in a controlled temperature and pressurized location, on an aircraft within which pressures are normally no lower than the altitude equivalent of l5,000 ft (4,600 m) Mean Sea Level (MSL), is identified as Category A1. This category may also be applicable to equipment installed in temperature controlled but unpressurized locations on an aircraft that operates at altitudes no higher than 15,000 ft (4,600 m) MSL.

Category A2

Equipment intended for installation in a partially controlled temperature but pressurized location on an aircraft within which the pressures are normally no lower than the altitude equivalent of 15,000 ft (4,600 m) MSL is identified as Category A2. This category may also be applicable to equipment installed in partially controlled temperature but unpressurized locations on an aircraft that operates at altitudes no higher than 15,000 ft (4,600 m) MSL.

Category A3

Equipment intended for installation in a controlled or partially controlled temperature but pressurized location within an aircraft within which the pressures are normally no lower than the altitude equivalent of 15,000 ft (4,600 m) MSL, where the temperatures will be more severe than those for categories A1 and A2, is identified as Category A3.

Category A4

Equipment intended for installation in a controlled temperature and pressurized location, on an aircraft within which pressures are normally no lower than the altitude equivalent of 15,000 ft. (4,600m) Mean Sea Level (MSL), for which temperature requirements differ from category A1 as declared by the equipment manufacturer. This category may also be applicable to equipment installed in a temperature controlled but unpressurized locations on an aircraft that operates at altitudes no higher than 15,000ft. (4,600m) MSL, for which temperature requirements differ from category A1 as declared by the equipment manufacturer.

Category B1

Equipment intended for installation in a non-pressurized but controlled temperature location in an aircraft that is operated at altitudes up to 25,000 ft (7,620 m) MSL is identified as Category B1.

Category B2

Equipment intended for installation in non-pressurized and non-controlled temperature locations on an aircraft that is operated at altitudes up to 25,000 ft (7,620 m) MSL is identified as Category B2.

Category B3

Equipment intended for installation in the power plant compartment of an aircraft that is operated at altitudes up to 25,000 ft (7,620 m) MSL is identified as Category B3.

Category B4

Equipment intended for installation in a non-pressurized location on an aircraft that is operated at altitudes up to 25,000 ft (7,620 m) MSL, for which temperature requirements differ from B1, B2 and B3, is identified as Category B4.

Category C1

Equipment intended for installation in a non-pressurized but controlled temperature location in an aircraft that is operated at altitudes up to 35,000 ft (10,700 m) MSL is identified as Category C1.
Category C2

Equipment intended for installation in non-pressurized and non-controlled temperature locations within an aircraft that is operated at altitudes up to 35,000 ft (10,700 m) MSL is identified as Category C2.

Category C3

Equipment intended for installation in the power plant compartment of an aircraft that is operated at altitudes up to 35,000 ft (10,700 m) MSL is identified as Category C3.

Category C4

Equipment intended for installation on a non-pressurized aircraft that is operated at altitudes up to 35,000 ft (10,700 m) MSL, for which temperature requirements differ from C1, C2 and C3, is identified as Category C4.

Category D1

Equipment intended for installation in a non-pressurized but controlled temperature location on an aircraft that is operated at altitudes up to 50,000 ft (15,200 m) MSL is identified as Category D1.

Category D2

Equipment intended for installation in non-pressurized and non-controlled temperature locations on an aircraft that is operated at altitudes up to 50,000 ft (15,200 m) MSL is identified as Category D2.

Category D3

Equipment intended for installation in the power plant compartment of an aircraft that is operated at altitudes up to 50,000 ft (15,200 m) MSL is identified as Category D3.

Category E1

Equipment intended for installation in non-pressurized and non-controlled temperature locations on an aircraft that is operated at altitudes up to 70,000 ft (21,300 m) MSL is identified as Category E1.

Category E2

Equipment intended for installation in the power plant compartment of an aircraft that is operated at altitudes up to 70,000 ft (21,300 m) MSL is identified as Category E2.

Category F1

Equipment intended for installation in non-pressurized but controlled temperature locations on an aircraft that is operated at altitudes up to 55,000 ft (16,800 m) MSL is identified as Category F1.

Category F2

Equipment intended for installation in non-pressurized and non-controlled temperature locations on an aircraft that is operated at altitudes up to 55,000 ft (16,800 m) MSL is identified as Category F2.

Category F3

Equipment intended for installation in the power plant compartment of an aircraft that is operated at altitudes up to 55,000 ft (16,800 m) MSL is identified as Category F3.

4.4 Definitions of Terms

Operating Low Temperature

Operating low temperature is the lowest temperature at which equipment will normally be exposed and be required to operate.

Operating High Temperature

The operating high temperature values given in Table 4-1 are the maximum levels that the equipment will be exposed to within the particular installation area, e.g. in an enclosed space behind an instrument panel, equipment racks, power plant areas, etc., under normal operating conditions.

Short-Time Operating High Temperature

These are the maximum temperature conditions to which equipment can be exposed. It is expected that these temperature conditions will occur infrequently and be of short duration, since the temperatures within the installation area will be reduced by the opening of doors, the circulation of moving air, etc.

Ground Survival Temperatures

These are the lowest and highest ground temperatures that the equipment is normally expected to be exposed to during aircraft storage or exposure to climatic extremes. The equipment is not expected to operate within specification limits at these temperatures but is expected to survive without damage.

In-Flight Loss of Cooling

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.

4.5 Temperature Tests

4.5.1 Ground Survival Low Temperature Test and Operating Low Temperature Test

With the equipment not operating, stabilize the equipment temperature at the appropriate ground survival low temperature specified in Table 4-1 at ambient atmospheric pressure. Maintain this temperature for at least three hours. Place the equipment into the operating state, then adjust and maintain the test chamber air temperature at the appropriate operating low temperature specified in Table 4-1 at ambient pressure. After the equipment temperature has stabilized, operate the equipment at maximum duty cycle for at least 30 minutes, beginning with the «ON» condition in the case of equipment designed for intermittent duty service. Maintain the temperature of the air in the test chamber at the operating low temperature of Table 4-1. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during the equipment operating period. The test profile is shown graphically in Figure 4-1.

NOTES:

1. *This test is not intended to be a temperature shock test. The rate at which the temperature of the equipment under test is reduced from ambient to the appropriate ground survival low temperature specified in Table 4-1 is optional and commensurate with the rate of temperature change applicable to the test chamber being used.*

2. *There is no requirement for the equipment to meet applicable equipment performance standards below the operating low temperature unless so specified by the equipment specification.*

4.5.2 Ground Survival High Temperature Test and Short-Time Operating High Temperature Test

At ambient pressure and with the equipment not operating, stabilize the equipment at the appropriate ground survival high temperature of Table 4-1. Maintain this temperature for at least three hours. Then with the equipment not operating, subject it to the short-time operating high temperature specified in Table 4-1 for a period of not less than 30 minutes. Place the equipment into the operating state and maintain the test chamber air temperature at the appropriate short-time operating high temperature specified in Table 4-1. Operate the equipment for at least 30 minutes. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this operating period. The test profile is shown graphically in Figure 4-2.

NOTE 1: *This test simulates temperature conditions that may be encountered by equipment while the aircraft is on the ground. In determining the level of performance required during the period of this test, the operational requirements of the particular equipment or systems must be considered.*

NOTE 2: *If the short-time operating high temperature and operating high temperature are the same, the short-time operating high temperature test need not be conducted. The ground survival high temperature test may not be deleted, even if the short-time high temperature is identical to the operating high temperature.*

4.5.3 Operating High Temperature Test

With the equipment operating, adjust the test chamber air temperature to the appropriate operating high temperature specified in Table 4-1 at ambient pressure. After the equipment temperature has become stabilized, operate the equipment for a minimum of two hours while maintaining the temperature of the air in the test chamber at the operating high temperature. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during the operating period. The test profile is shown graphically in Figure 4-3.

4.5.4 In-Flight Loss of Cooling Test

Categories of In-Flight Loss of Cooling Test Periods are defined by periods during which cooling is removed.

Category V - 30 minutes minimum
Category W - 90 minutes minimum
Category P - 180 minutes minimum
Category Y - 300 minutes minimum
Category Z - As defined in the equipment specification

With the equipment operating at ambient room pressure, and with cooling air supplied in accordance with the conditions specified in Subsection 3.3, adjust the test chamber air temperature to the value specified in Table 4-1 for the loss of cooling test, and allow the equipment temperature to stabilize. Turn off the equipment cooling air supply, and operate the equipment for the period of time specified for the applicable category while maintaining the temperature of the air in the test chamber at the value specified in Table 4-1. During this period DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. The test profile is shown graphically in Figure 4-4.

NOTE: This test applies to equipment that requires cooling for proper operation during the operating high temperature test, paragraph 4.5.3, and 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.

4.6 Altitude, Decompression and Overpressure Tests

4.6.1 Altitude Test

Conduct this test at ambient temperature. Operate the equipment at maximum duty cycle. Decrease the pressure in the test chamber to the appropriate maximum operating altitude specified in Table 4-1. Allow the equipment temperature to stabilize. Maintain this pressure for at least two hours. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during the two-hour period or at the maximum duty cycle, whichever is longer. The test profile is shown graphically in Figure 4-5.

NOTE When the equipment manufacturer requires that the equipment be tested for spark-producing conditions at altitude, Sections 9.6a and 9.6b may apply. If so, the procedures of 9.7 shall be conducted at the maximum test altitude, and paragraph 3.3 (Combining Tests) may be applicable.

4.6.2 Decompression Test

Conduct this test at ambient temperature. With the equipment operating, adjust the absolute pressure to an equivalent altitude of 8,000 ft (2,400 m) MSL and allow the equipment temperature to stabilize. Reduce the absolute pressure to the equivalent of the maximum operational altitude for the aircraft on which the equipment will be installed (see Table 4-1). This reduction in pressure shall take place within 15 seconds. Maintain this reduced pressure for at least 10 minutes or as specified in the equipment specification. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during the period at maximum operating altitude. The test profile is shown graphically in Figure 4-6.

NOTE: The decompression test is intended for equipment as follows:

1) Equipment installed in pressurized areas on the aircraft required to operate during and following an emergency descent.

2) Equipment utilizing high voltage electrical/electronics circuits, i.e. displays etc...

Equipment intended for installation in areas that are subject to partial pressurization shall be tested in accordance with paragraph 4.6.2 above.

4.6.3 Overpressure Test

With the equipment not operating, unless otherwise specified in the equipment specification, subject the equipment to an absolute pressure equivalent to -15,000 ft altitude (170 kPa). Maintain this condition for at least 10 minutes. Return the equipment to the ambient atmospheric pressure and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. The test profile is shown graphically in Figure 4-7.

NOTE 1: *This test is for equipment installed in pressurized areas. The test determines whether the equipment will withstand cabin overpressures resulting from routine aircraft pressurization system testing.*

NOTE 2: *Equipment installed in a pressurized area and whose internal sections are vented external to the pressurized area shall have these internal sections exposed to the pressure specified in the equipment specification during the overpressure test.*

Environmental Tests	Category Paragraph 4.3																			
	A				B				C				D			E		F		
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	1	2	3
Operating Low Temp. Degrees C Paragraph 4.5.1	-15	-15	-15	-15	-20	-45	-45	Note (4)	-20	-55	-55	Note (4)	-20	-55	-55	-55	-55	-20	-55	-55
Operating High Temp. Degrees C Paragraph 4.5.3	+55	+70	+70	Note (3)	+55	+70	Note (3)	Note (4)	+55	+70	Note (3)	Note (4)	+55	+70	Note (3)	Note (3)	Note (3)	+55	+70	Note (3)
Short-Time Operating High Temp. Degrees C Paragraph 4.5.2	+70	+70	+85	Note (3)	+70	+70	Note (3)	Note (4)	+70	+70	Note (3)	Note (4)	+70	+70	Note (3)	Note (3)	Note (3)	+70	+70	Note (3)
Loss of Cooling Test Degrees C Paragraph 4.5.4	+30	+40	+45	Note (3)	+30	+40	Note (3)	Note (3)	+30	+40	Note (3)	Note (3)	+30	+40	Note (3)	Note (3)	Note (3)	+30	+40	Note (3)
Ground Survival Low Temperature Degrees C Paragraph 4.5.1	-55	-55	-55	Note (3)	-55	-55	Note (3)	-55	-55	-55	Note (3)	-55	-55	-55	-55	-55	-55	-55	-55	-55
Ground Survival High Temperature Degrees C Paragraph 4.5.2	+85	+85	+85	Note (3)	+85	+85	Note (3)	+85	+85	+85	Note (3)	+85	+85	+85	Note (3)	+85	Note (3)	+85	+85	Note (3)
Altitude Thousands of Feet Thousands of Meters Paragraph 4.6.1	15 4.6	15 4.6	15 4.6	15 4.6	25 7.6	25 7.6	25 7.6	25 7.6	35 10.7	35 10.7	35 10.7	35 10.7	50 15.2	50 15.2	50 15.2	70 21.3	70 21.3	55 16.8	55 16.8	55 16.8
Decompression Test Paragraph 4.6.2	Note (1) (4)	Note (1) (4)	Note (1) (4)	Note (1) (4)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Overpressure Test Paragraph 4.6.3	Note (2)	Note (2)	Note (2)	Note (2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4-1 Temperature and Altitude Criteria

NOTES (1) *The lowest pressure applicable for the decompression test is the maximum operating altitude for the aircraft in which the equipment will be installed.*

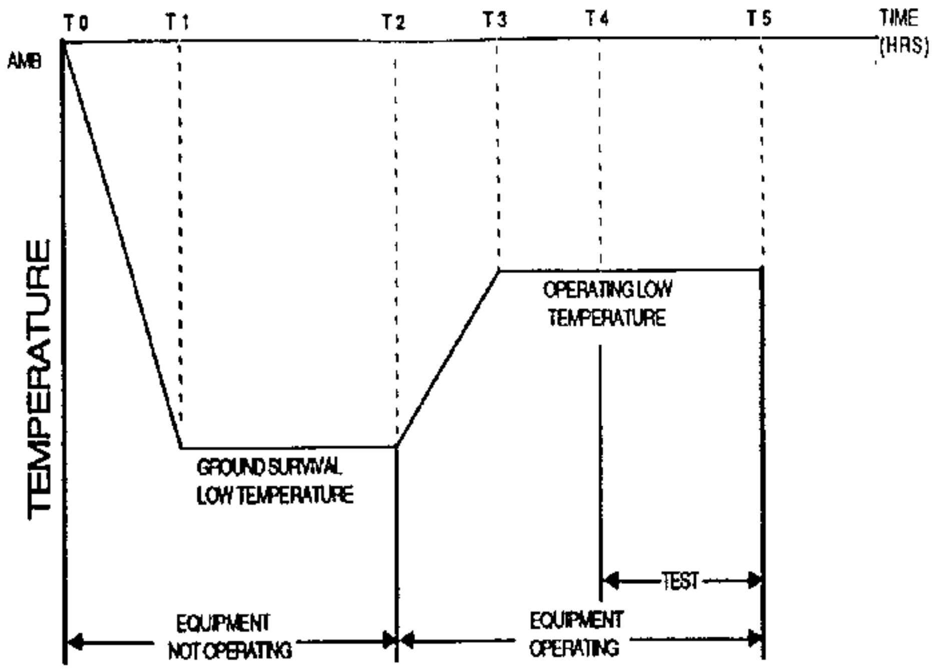
(2) *The absolute pressure is 170 kPa (-15,000 ft or -4,600 m).*

(3) *To be declared by the equipment manufacturer relative to temperature extremes.*

(4) *To be declared by the equipment manufacturer and defined in the manufacturer's installation instructions when specific critical criteria exist.*

Pressure Altitude	Absolute Pressure			
	kPa	(mbars)	(in Hg)	mm Hg
-15,000 ft (-4,572 m)	169.73	1697.3	50.12	1273.0
-1,500 ft (-457 m)	106.94	1069.4	31.58	802.1
0 ft (0m)	101.32	1013.2	29.92	760.0
+8,000 ft (+2,438 m)	75.26	752.6	22.22	564.4
+15,000 ft (+4,572 m)	57.18	571.8	16.89	429.0
+25,000 ft (+7,620 m)	37.60	376.0	11.10	282.0
+35,000 ft (+10,668 m)	23.84	238.4	7.04	178.8
+50,000 ft (+15,240 m)	11.60	116.0	3.42	87.0
+55,000 ft (+16,764 m)	9.12	91.2	2.69	68.3
+70,000 ft (+21,336 m)	4.44	44.4	1.31	33.3

Table 4-2 Pressure Values For Various Pressure Altitude Levels



NOTES:

1) *Temperature rates from T0 to T1 and from T2 to T3 are not specified.*

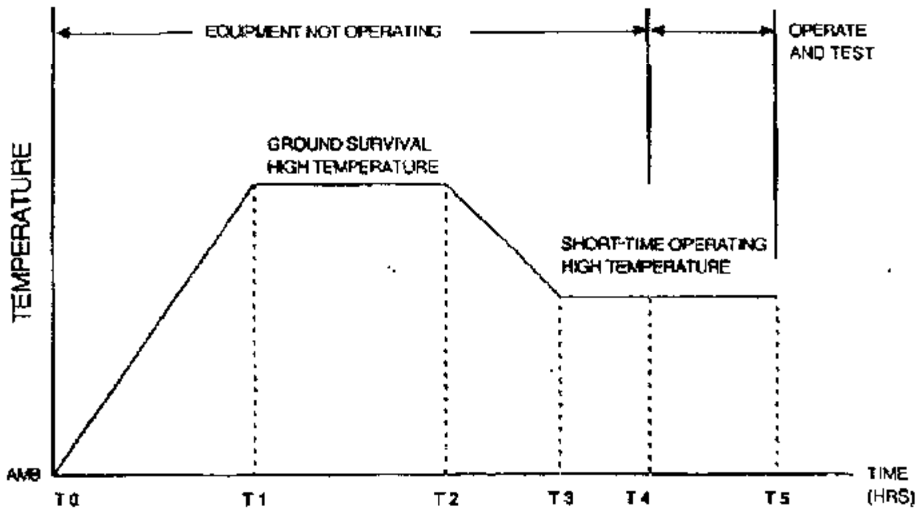
2) *T1 to T2 is time for equipment temperature to stabilize, plus a minimum of three hours.*

3) *T3 to T4 is time for equipment temperature to stabilize.*

4) *T4 to T5 is 0.5 hours, minimum.*

5) *If the ground survival low and operating low temperature are identical, the time from T2 to T4 is zero.*

Figure 4-1 Ground Survival Low Temperature And Operating Low Temperature Test



NOTES:

1) *Temperature rates from T0 to T1 and from T2 to T3 are not specified.*

2) *T1 to T2 is time for equipment temperature stabilization time, plus a minimum of three hours.*

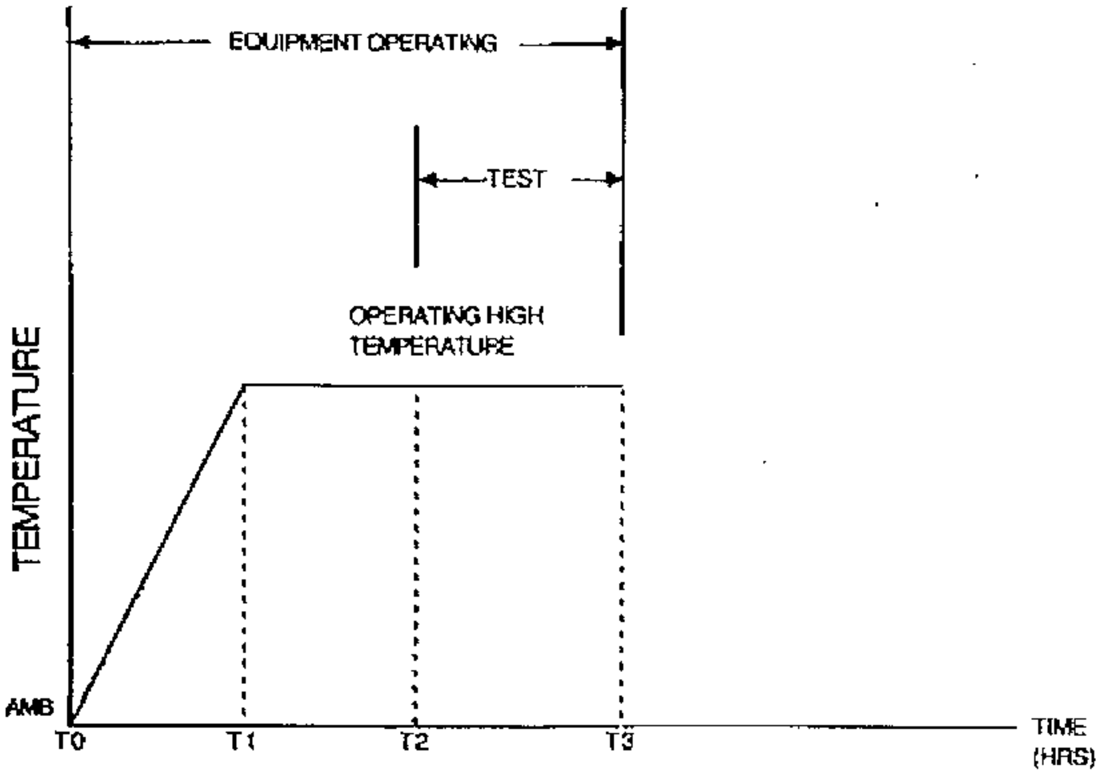
3) *T3 to T4 is 0.5 hours, minimum.*

4) *T4 to T5 is 0.5 hours, minimum.*

5) *If the short-time high and ground survival high temperatures are identical, the time from T2 to T4 is zero.*

6) *See Note 2 of the test procedure if the short-time high operating temperature is the same as the operating high temperature.*

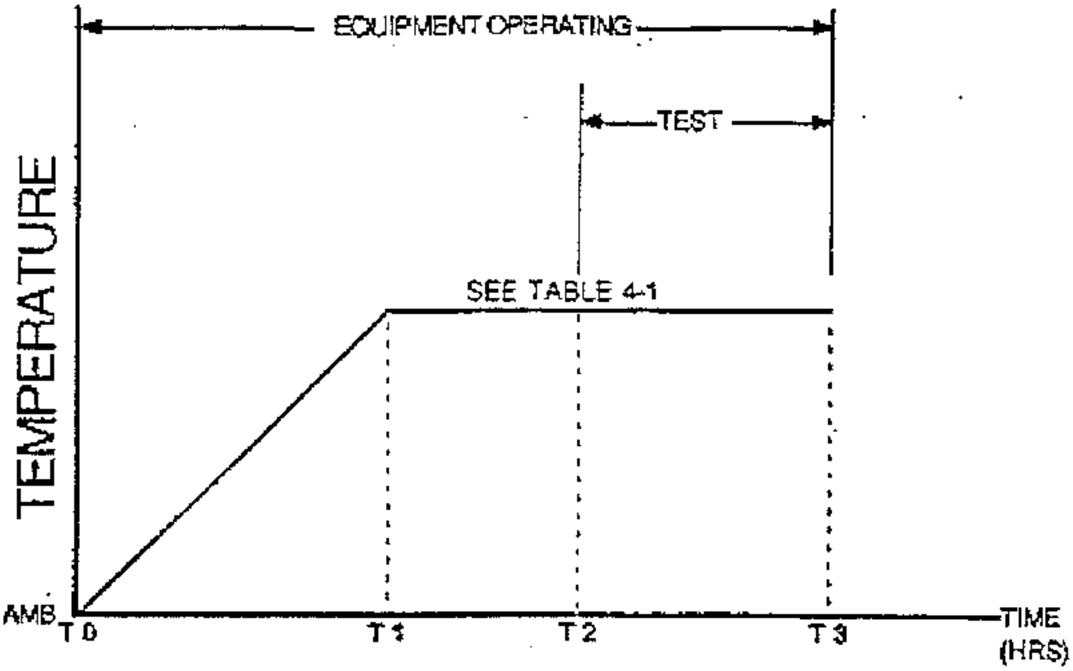
Figure 4-2 Ground Survival High Temperature And Short-Time Operating High Temperature Test



<u>NOTES:</u>

1) *Temperature rate from T0 to T1 is not specified.*
2) *T1 to T2 is time for equipment temperature to stabilize.*
3) *T2 to T3 is 2.0 hours, minimum.*

<u>Figure 4-3</u> Operating High Temperature Test

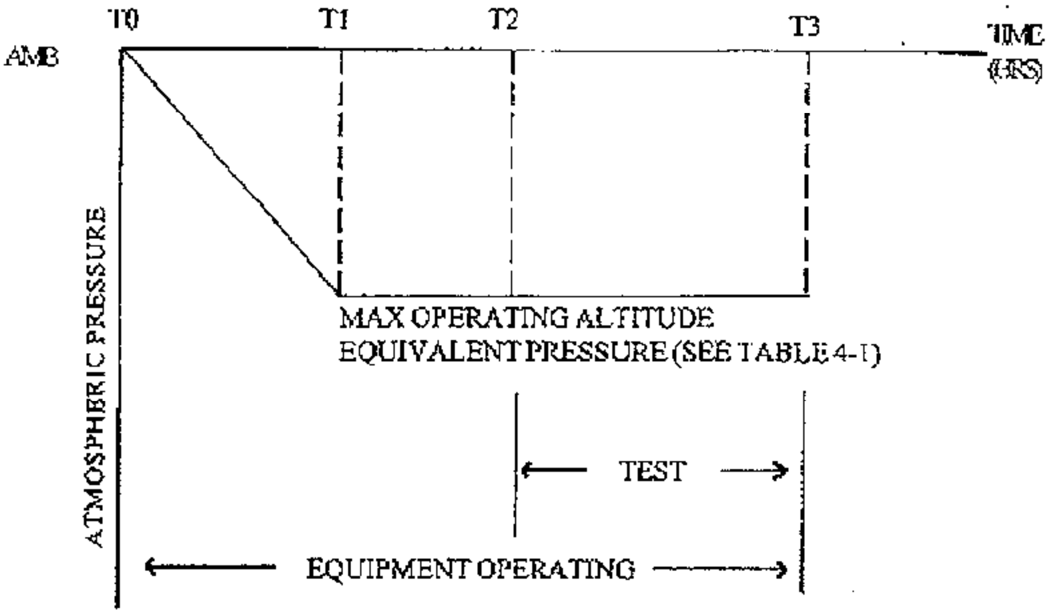


NOTES: 1) *Temperature rate from T0 to T1 is not specified.*

2) *T1 to T2 is time for equipment temperature to stabilize.*

3) *See paragraph 4.5.4 for time duration T2 to T3.*

Figure 4-4 In-Flight Loss Of Cooling Test



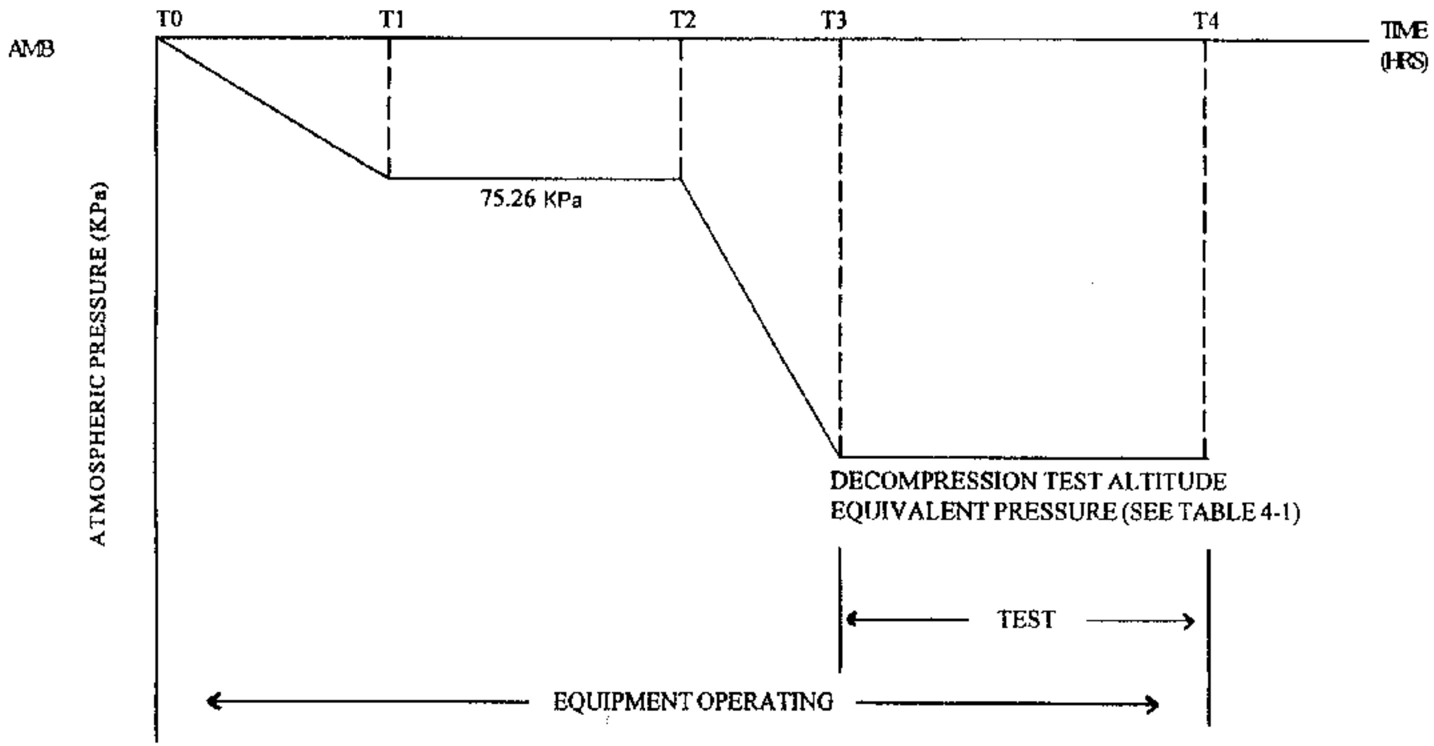
<u>NOTES:</u>

1) Pressure rate from T0 to T1 is not specified.

2) T1 to T2 is time for equipment temperature to stabilize.

3) T2 to T3 is 2.0 hours, minimum.

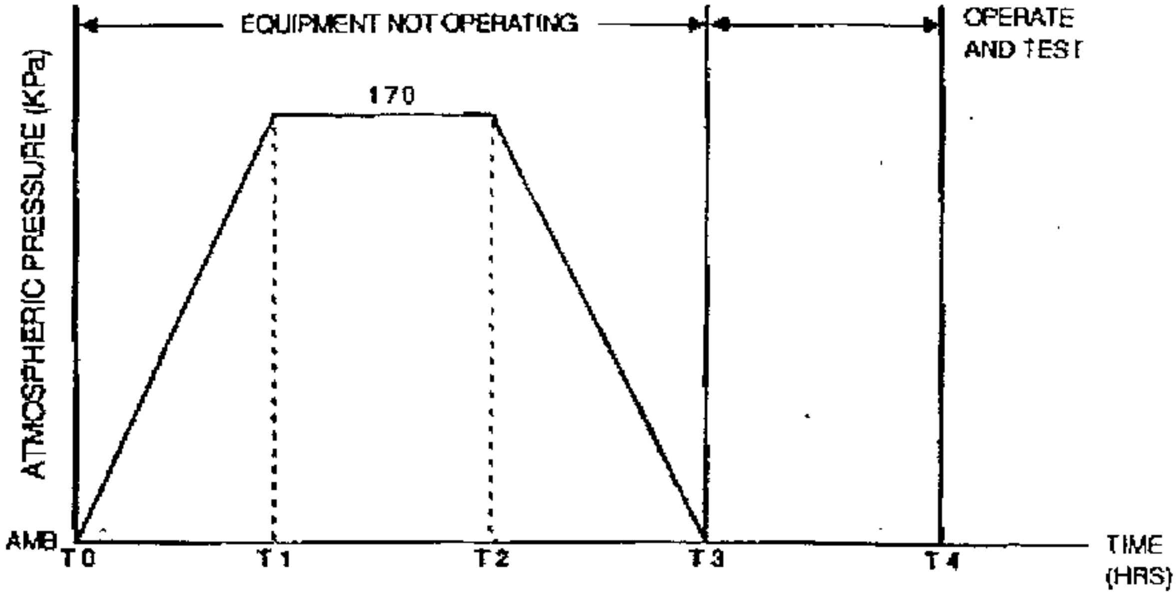
<u>Figure 4-5</u> Altitude Test



NOTES:

1) *Pressure rate from T0 to T1 is not specified*
2) *T1 to T2 is time for equipment temperature to stabilize*
3) *T2 to T3 is 15 seconds, maximum.*
4) *T3 to T4 is 10 minutes, maximum*

Figure 4-6 Decompression Test



NOTES: *1) Pressure rates from T0 to T1 and from T2 to T3 are not specified.*

2) T1 to T2 is 10 minutes, minimum.

3) T3 to T4 is minimum time necessary to operate and test equipment.

Figure 4-7 Overpressure Test

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 5

Temperature Variation

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

5.0 TEMPERATURE VARIATION

5.1 Purpose of the Test

This test determines performance characteristics of the equipment during normal temperature variations between high and low operating temperature extremes specified for the applicable categories of Table 4-1 during flight operations. This is a dynamic test, and it is required that the equipment be subjected to this temperature variation test when such equipment is tested according to the procedures contained in paragraphs 4.5.1, 4.5.2 and 4.5.3.

5.2 Temperature Change Rates

The rates applicable to the temperature variation procedures defined in Subsection 5.3 are as follows:

Category A - For equipment external to the aircraft:

10 degrees Celsius minimum per minute.

Category B - For equipment in a non-temperature-controlled or partially temperature controlled internal section of the aircraft:

5 degrees Celsius minimum per minute.

Category C - For equipment in a temperature-controlled internal section of the aircraft:

2 degrees Celsius minimum per minute.

NOTE: *Equipment qualified to Category B is considered to have met Category C.*

5.3 Test Procedures

The temperature variation test can be combined to include the procedures of the ground survival low temperature test and operating low temperature test, paragraph 4.5.1, the ground survival high temperature test and short-time operating high temperature test, paragraph 4.5.2 and the operating high temperature test, paragraph 4.5.3. The following procedures shall apply:

a. If the test is a combined test, proceed in accordance with paragraph 4.5.1, which describes the ground survival low temperature test and the operating low temperature test. After completion of the test defined in paragraph 4.5.1 proceed to subparagraph c. If the test is not a combined test, commencing at ambient temperature with the equipment operating, lower the temperature in the chamber towards the operating low temperature level at the applicable rates specified in Subsection 5.2.

b. Stabilize the equipment in the operating mode at this operating low temperature level.

c. Raise the temperature in the chamber towards the operating high temperature at the applicable rates specified in Subsection 5.2. During this temperature change, DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

d. Stabilize the equipment at the operating high temperature. If this is a combined test, proceed in accordance with paragraph 4.5.2, and subsequently paragraph 4.5.3. Maintain the equipment in a non-operating state for 2 ±0.5 minutes.

e. Turn the equipment on and lower the temperature in the chamber towards the operating low temperature level at the applicable rates specified in Subsection 5.2. During this temperature change DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

f. Stabilize the equipment temperature with the chamber at the operating low temperature, and then operate the equipment for at least one hour. Then turn off the equipment for 30 minutes, and restart the equipment while maintaining the chamber at the operating low temperature.

g. Change the temperature of the chamber towards the ambient temperature at the applicable rates specified in Subsection 5.2.

h. Stabilize the chamber and the equipment at ambient temperature. DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

A minimum of two cycles (a. through h. above) shall be accomplished. If complete determination of compliance with applicable equipment performance standards can be accomplished during each temperature change period of a single cycle, then testing is required during the second cycle only. If the time during a temperature change period does not allow for complete determination of compliance with applicable equipment performance standards, a sufficient number of cycles shall be accomplished so that complete compliance can be determined. The test profile is shown graphically in Figure 5-1.

NOTE: *If this is a combined test, it is not necessary to repeat the ground survival, short time operating high temperature, operating low temperature and operating high temperature tests as defined in steps a. and d. above during the second cycle.*

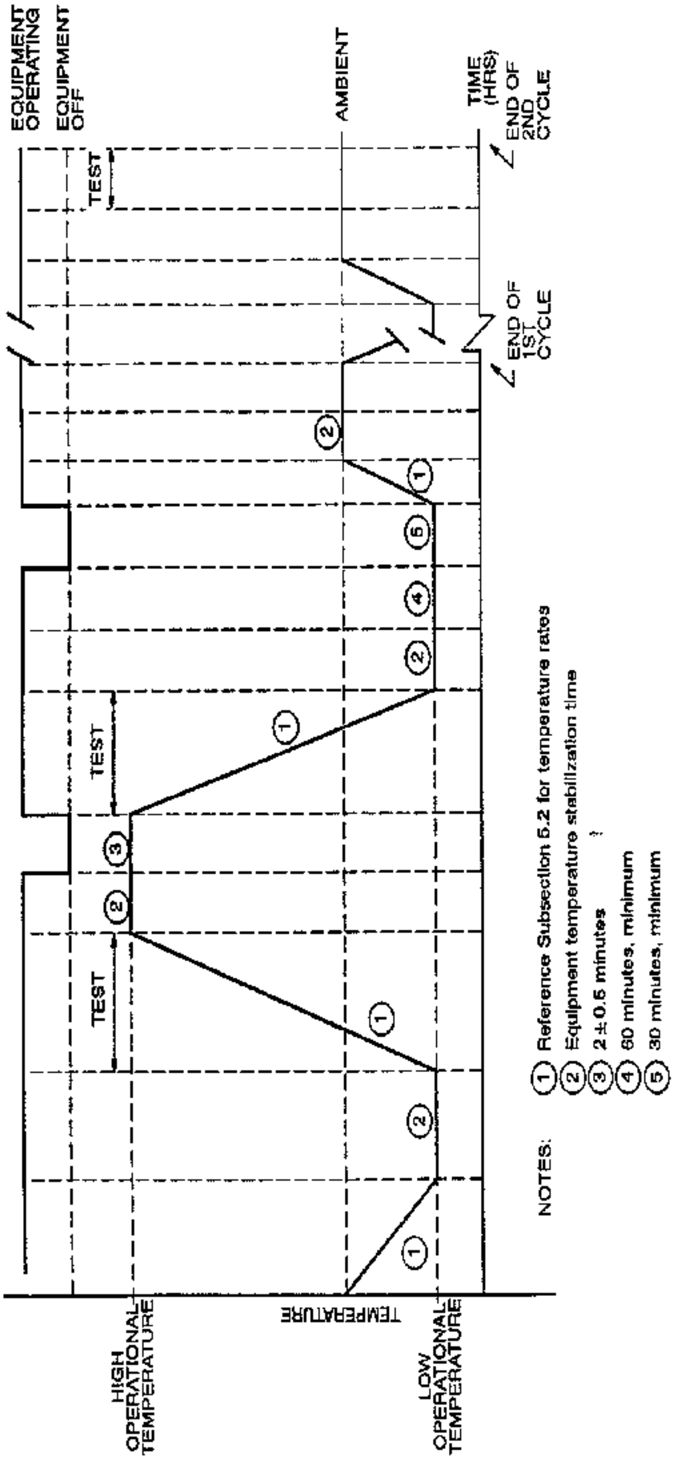


FIGURE 5-1 TEMPERATURE VARIATION TEST

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 6

Humidity

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

6.0 HUMIDITY

6.1 Purpose of the Test

This test determines the ability of the equipment to withstand either natural or induced humid atmospheres. The main adverse effects to be anticipated are:

a. Corrosion.

b. Change of equipment characteristics resulting from the absorption of humidity. For example:

- Mechanical (metals).
- Electrical (conductors and insulators).
- Chemical (hygroscopic elements).
- Thermal (insulators).

NOTE: *The humidity test shall not be conducted prior to the temperature/altitude tests and vibration tests (See Subsection 3.2, «Order of Tests»).*

6.2 Equipment Categories

Category A - Standard Humidity Environment

The standard humidity environment ordinarily provides an adequate test environment for equipment intended for installation in civil aircraft, non-civil transport aircraft and other classes, within environmentally controlled compartments of aircraft in which the severe humidity environment is not normally encountered.

Category B - Severe Humidity Environment

Equipment installed in zones not environmentally controlled may be required to be operated under conditions such that it is subjected to a more severe atmospheric humidity environment for periods of time in excess of that specified for the standard humidity environment.

Category C - External Humidity Environment

Equipment may be required to be operated under conditions such that it is subjected to direct contact with outside air for periods of time in excess of that specified for the standard humidity environment.

6.3 Test Procedures

Subject the equipment to an atmosphere in which the relative humidity is at least 95 percent, unless stated otherwise in the following steps. Moisture shall be provided by steam or by evaporation of water having a pH value between 6.5 and 7.5 or the water resistivity shall not be less than 250,000 ohm centimeters when measured at 25 degrees Celsius. The velocity of air throughout the exposure area shall be between 0.5 and 1.7 meters per second. The test chamber shall be vented to the atmosphere to prevent buildup of pressure, and provisions shall be made to prevent water from dripping onto the equipment.

6.3.1 Category A-Standard Humidity Environment

The test profile is shown graphically in Figure 6-1. The procedure shall be in accordance with the following steps:

Step 1: Over a two-hour period, plus or minus 10 minutes, raise the chamber temperature to 50 degrees Celsius and increase the relative humidity to at least 95 percent.

Step 2: Maintain the chamber temperature at 50 degrees Celsius with the relative humidity at least 95 percent for six hours minimum.

Step 3: During the next 16-hour period, plus or minus 15 minutes, decrease the temperature gradually to 38 degrees Celsius or lower. During this period, keep the relative humidity as high as possible and do not allow it to fall below 85 percent.

Step 4: Steps 1, 2 and 3 constitute a cycle. Repeat these steps until a total of two cycles (48 hours of exposure) have been completed.

Step 5: At the end of the exposure period, remove the equipment from the test chamber and drain off (do not wipe) any condensed moisture. Within one hour after the two cycles are completed, apply normal supply power and turn on the equipment. Allow 15 minutes maximum following the application of primary power for the equipment to warm up. For equipment that does not require electrical power for operation, warm up the equipment for 15 minutes maximum by the application of heat not to exceed the short-time operating high temperature test as required by applicable equipment categories. Immediately following the warm-up periou, make such tests and measurements as are necessary to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

6.3.2 Category B-Severe Humidity Environment

The test profile is shown graphically in Figure 6-2. The procedure shall be in accordance with the following steps:

Step 1: Over a two-hour period, plus or minus 10 minutes, raise the chamber temperature to 65 degrees Celsius and increase the relative humidity to at least 95 percent.

Step 2: Maintain the chamber temperature at 65 degrees Celsius with the relative humidity at least 95 percent for six hours minimum.

Step 3: During the next 16-hour period, plus or minus 15 minutes, decrease the temperature gradually to 38 degrees Celsius or lower. During this period, keep the relative humidity as high as possible and do not allow it to fall below 85 percent.

Step 4: Steps 1, 2 and 3 constitute a cycle. Repeat these steps until a total of 10 cycles (240 hours of exposure) have been completed.

Step 5: At the end of the exposure period, remove the equipment from the test chamber and drain off (do not wipe) any condensed moisture. Within one hour after the 10 cycles are completed, apply normal supply power and turn on the equipment. Allow 15 minutes maximum following the application of primary power for the equipment to warm up. For equipment that does not require electrical power for operation, warm up the equipment for 15 minutes maximum by the application of heat not to exceed the short-time operating high temperature test as required by applicable equipment categories. Immediately following the warm-up period, make such tests and measurements as are necessary to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

6.3.3 Category C-External Humidity Environment

The test profile is shown graphically in Figure 6-3. The procedure shall be in accordance with the following steps:

Step 1: Over a two-hour period, plus or minus 10 minutes, raise the chamber temperature to 55 degrees Celsius and increase the relative humidity to at least 95 percent.

Step 2: Maintain the chamber temperature at 55 degrees Celsius with the relative humidity at least 95 percent for six hours minimum.

Step 3: During the next 16-hour period, plus or minus 15 minutes, decrease the temperature gradually to 38 degrees Celsius or lower. During this period, keep the relative humidity as high as possible and do not allow it to fall below 85 percent.

Step 4: Steps 1, 2 and 3 constitute a cycle. Repeat these steps until a total of six cycles (144 hours of exposure) have been completed.

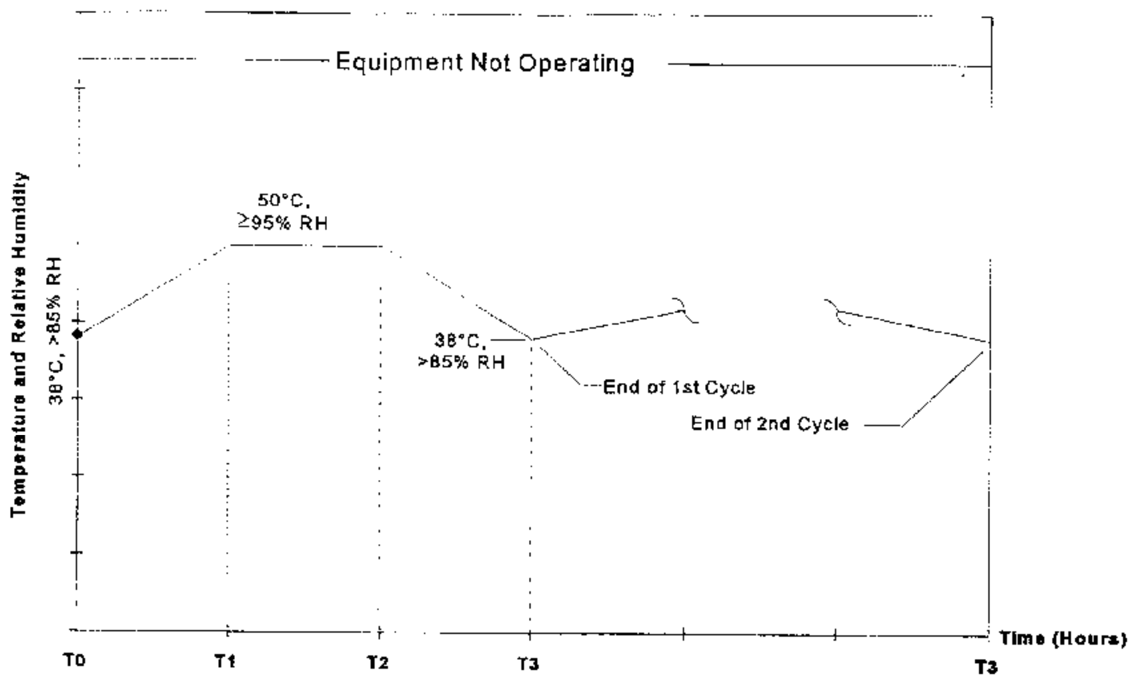
Step 5: At the end of the exposure period, remove the equipment from the test chamber and drain off (do not wipe) any condensed moisture. Within one hour after the six cycles are completed, apply normal supply power and turn on the equipment. Allow 15 minutes maximum following the application of primary power for the equipment to warm up. For equipment that does not require electrical power for operation, warm up the equipment for 15 minutes maximum by the application of heat not to exceed the short-time operating high temperature test as required by applicable equipment categories. Immediately following the warm-up period, make such tests and measurements as are necessary to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

6.3.4 Conducting Spot Checks

For conducting spot checks on the performance of the equipment under test, the equipment may be operated at the end of each of the 6 or 10 cycles as appropriate for a period not to exceed 15 minutes. If the equipment is removed from the test chamber to conduct a spot check, the period of removal shall not exceed 20 minutes, and the equipment shall not be operated for more than 15 minutes of this 20-minute period.

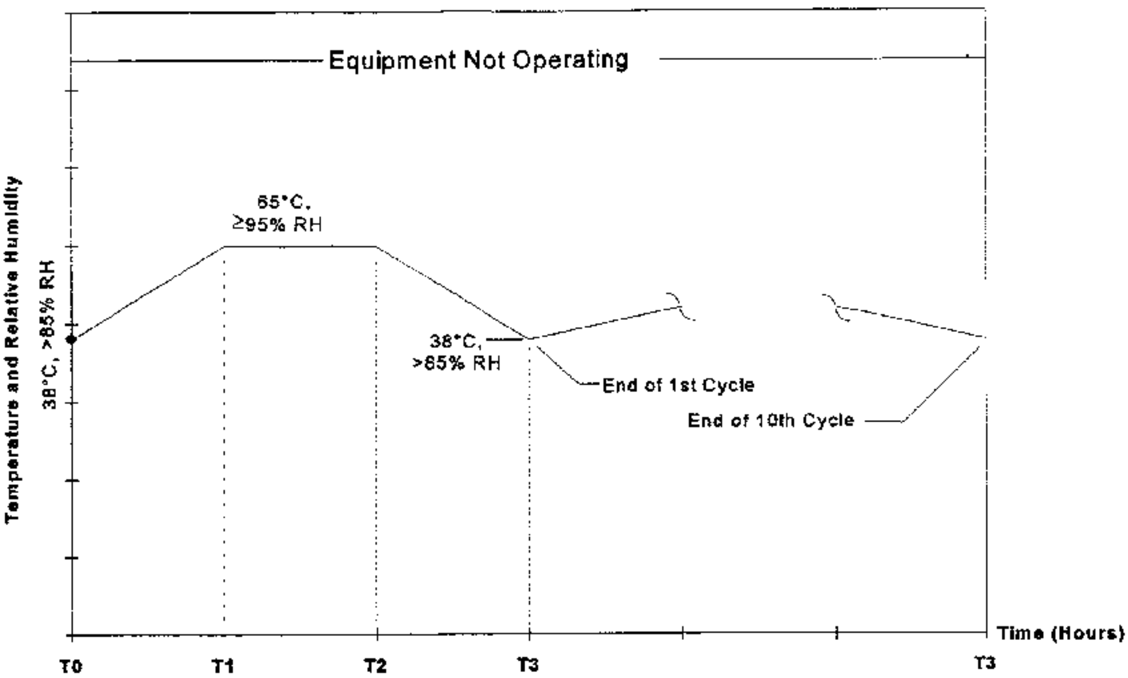
6.3.5 Other Specified Checks

If the applicable performance standard requires that other checks be made to determine compliance, these shall also be performed during this test.



NOTES:
1) *T0 to T1 is 2 hours ±10 minutes.*
2) *T1 to T2 is 6 hours, minimum.*
3) *T2 to T3 is 16 hours ±15 minutes. During this period, relative humidity should not fall below 85%.*
4) *See paragraph 6.3.1, Step 5, for continuation of test after the end of the 2nd cycle.*

Figure 6-1 Category A - Standard Humidity Environment Test



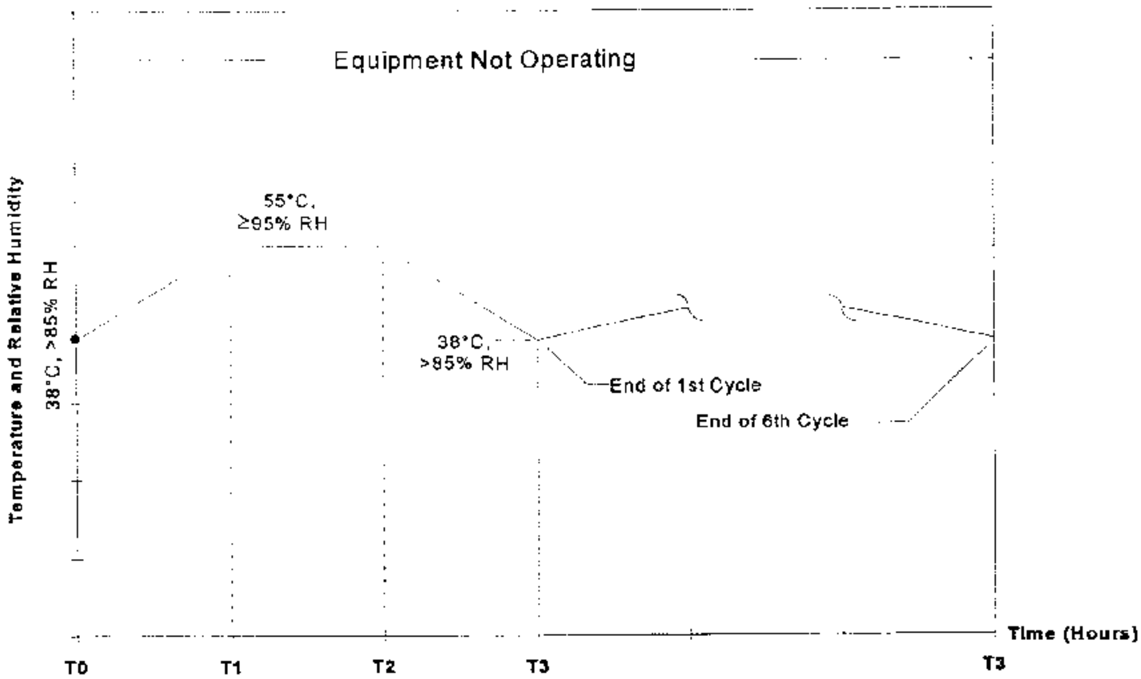
NOTES: 1) *T0 to T1 is 2 hours ±10 minutes.*

2) *T1 to T2 is 6 hours, minimum.*

3) *T2 to T3 is 16 hours ±15 minutes. During this period, relative humidity should not fall below 85%.*

4) *See paragraph 6.3.2, Step 5, for continuation of test after the end of the 10th cycle.*

Figure 6-2 Category B - Severe Humidity Environment Test



<u>NOTES:</u> 1) *T0 to T1 is 2 hours ±10 minutes.*

2) *T1 to T2 is 6 hours, minimum.*

3) *T2 to T3 is 16 hours ±15 minutes. During this period, relative humidity should not fall below 85%.*

4) *See paragraph 6.3.3, Step 5, for continuation of test after the end of the 6th cycle.*

<u>Figure 6-3</u> Category C - External Humidity Environment Test

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 7

Operational Shocks and Crash Safety

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

7.0 OPERATIONAL SHOCKS AND CRASH SAFETY

7.1 Purpose of the Tests

The operational shock test verifies that the equipment will continue to function within performance standards after exposure to shocks experienced during normal aircraft operations. These shocks may occur during taxiing, landing or when the aircraft encounters sudden gusts in flight. This test applies to all equipment installed on fixed-wing aircraft and helicopters. Two operational shock test curves are provided; a standard 11 msec pulse and a low frequency 20 msec pulse. The 20 msec pulse may be selected, instead of the standard curve for equipment items on aircraft designed to operate on exceptionally (not to ICAO standards) rough runways.

The crash safety test verifies that certain equipment will not detach from its mountings or separate in a manner that presents a hazard during an emergency landing. It applies to equipment installed in compartments and other areas of the aircraft where equipment detached during emergency landing could present a hazard to occupants, fuel systems or emergency evacuation equipment. These tests do not satisfy FAR requirements for all equipment, e.g. seats and seat restraints.

NOTE: *For fixed-wing aircraft: a complete installation demonstration, i.e. including aircraft acceleration loads (such as flight maneuvering, gust and landing) in addition to the crash safety loads, may be accomplished by using the "Unknown or Random" orientations for the "sustained" test procedure.*

Using a dummy load on the shock test apparatus may be necessary to ensure that the recorded shock pulse will be within the specified tolerances of Figure 7-2.

7.1.1 Equipment Categories

Category A
Equipment generally installed in fixed-wing aircraft or helicopters and tested for standard operational shocks.

Category B
Equipment generally installed in fixed-wing aircraft or helicopters and tested for standard operational shock and crash safety.

Category C
Equipment generally installed in helicopters and tested for operational shock and crash safety.

Category D
Equipment generally installed in fixed-wing aircraft and tested for operational low-frequency shock.

Category E
Equipment generally installed in fixed-wing aircraft and tested for operational low-frequency shock and crash safety.

7.2 Operational Shocks

Performance compliance requirements are normally required following application of the shocks. If equipment requires monitoring during the application of the shock pulses, the monitoring requirements must be stated in the relevant equipment specification.

7.2.1 Test Procedure

Secure the equipment to a shock table by means of a rigid test fixture and mounting means intended for use in service installations. The mounting of the equipment should include those non-structural connections that are a normal part of the installation. The accelerometer used to measure or control the input shock pulse shall be placed as close as practicable to an equipment attachment point. The test system accuracy to measure acceleration shall be within ±10 percent of standard reading. With the equipment operating and with its temperature stabilized, apply to the test item three shocks in each orientation having a terminal saw-tooth wave shape with an acceleration peak value of six (6) g's. The nominal pulse duration shall be 11 ms for standard shock testing and 20 ms for low frequency shock testing. The characteristics of instrumentation used to demonstrate compliance and the shock pulse tolerance limits are shown in Figures 7-1 and 7-2, respectively. An equivalent shock response spectrum may replace the terminal saw-tooth wave shape.

After application of the shocks, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

When using a conventional drop shock machine, the equipment shall be shock tested in the following orientations:

a. Normal upright.

b. Suspended upside down.

c. At orientations such that the first major orthogonal axis of the equipment successively forms angles of +90 degrees and -90 degrees (two orientations) with the plane of the table.

d. At orientations such that the second major orthogonal axis of the equipment successively forms angles of +90 degrees and -90 degrees (two orientations) with the plane of the table.

7.2.2 Alternate Test Procedure

It is permissible to apply the shocks specified in paragraph 7.2.1 with the equipment mounted in its normal operating orientation (i.e., as spatially oriented in its customary aircraft installation), provided that three shocks are applied in both directions of the three orthogonal axes.

7.3 Crash Safety[1]

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

7.3.1 Test Procedure 1 (Impulse)

Secure the equipment or dummy load to a shock table by means of a rigid test fixture and mounting means intended for use in service installations.

In each of the six equipment orientations listed in paragraph 7.2.1, apply one shock having a wave shape identical to that specified in paragraph 7.2.1, except the acceleration peak value shall be 20 g for fixed-wing aircraft and 20 g for helicopters. After application of the six shocks, bending and distortion shall be permitted. There shall be no failure of the mounting attachment and the equipment or dummy load shall remain in place.

7.3.1.1 Alternate Test Procedure (Impulse)

It is permissible to apply the shocks specified in paragraph 7.3.1 with the equipment mounted in its normal operating orientation provided that these shocks are applied in both directions of the three (3) orthogonal axes.

7.3.2 Test Procedure 2 (Sustained)

Secure the equipment or dummy load to test facility by means of a rigid test fixture and mounting means intended for use in service installation. Apply the appropriate test loads for a minimum of three seconds in each direction of load. "Direction of load" in Table 7-1 applies to the aircraft's major orthogonal axes. The applicable test levels are given in Table 7-1 (*). Where the orientation of the equipment to the aircraft axes is known, then the required load and direction of load relative to the equipment can be determined. If the orientation of the equipment under test is unknown or not fixed in relation to the aircraft axes, then the random orientation is required along each direction of the equipment's three orthogonal axes (Figure 7-3). After application of the six loads, bending and distortion shall be permitted. There shall be no failure of the mounting attachment and the equipment or dummy load shall remain in place.

* Caution: These test levels may not satisfy the installation requirement in the FARs

---

1 During these tests (paragraphs 7.3.1 or 7.3.2), an equivalent weight (dummy load) may be substituted for electrical-mechanical components normally mounted within or on the equipment case. Such equivalent weight shall approximate the weight of the components that it replaces and shall be so located that the center of gravity of the equipment is essentially unchanged. The equivalent weight shall not contribute to the strength of the equipment case or its mounting fastenings to a greater extent than the components it replaces.

It is expected that Test Procedure 2 will normally be carried out using a centrifuge or sled. In certain cases, however, it is acceptable to simulate the effects of inertia by applying forces statically through the center of gravity of the equipment under test, providing it can be determined that other parts within the equipment can be contained within the casing of the equipment should they break loose.

Aircraft Type	Test Type (5)	Sustained Test Acceleration (g Minimum) Direction of Load for Equipment Orientation				
		Up	Down	Forward	Aft	Side (4)
1. Helicopters (1)	F R	4.0 20.0	20.0 20.0	16.0 20.0	NA 20.0	8.0 20.0
2. Fixed-Wing Transport (2)	F R	3.0 9.0	6.0 9.0	9.0 9.0	1.5 9.0	4.0 9.0
3. Fixed-Wing Non-Transport (3)	F R	3.0 18.0	NA 18	18.0 18.0	NA 18.0	4.5 18.0
4. All Fixed-Wing	F R	3.0 18.0	6.0 18	18.0 18.0	1.5 18.0	4.5 18.0
5. Helicopter and All Fixed-Wing	F R	4.0 20.0	20.0 20.0	18.0 20.0	1.5 20.0	8.0 20.0

NOTES: *(1) Reference FAR 27.561*
(2) Reference FAR 25.561
(3) Reference FAR 23.561
(4) Side includes both left and right directions
(5) «F» is known and Fixed orientation. «R» is unknown or Random orientation.

Table 7-1 Crash Safety Sustained Test Levels

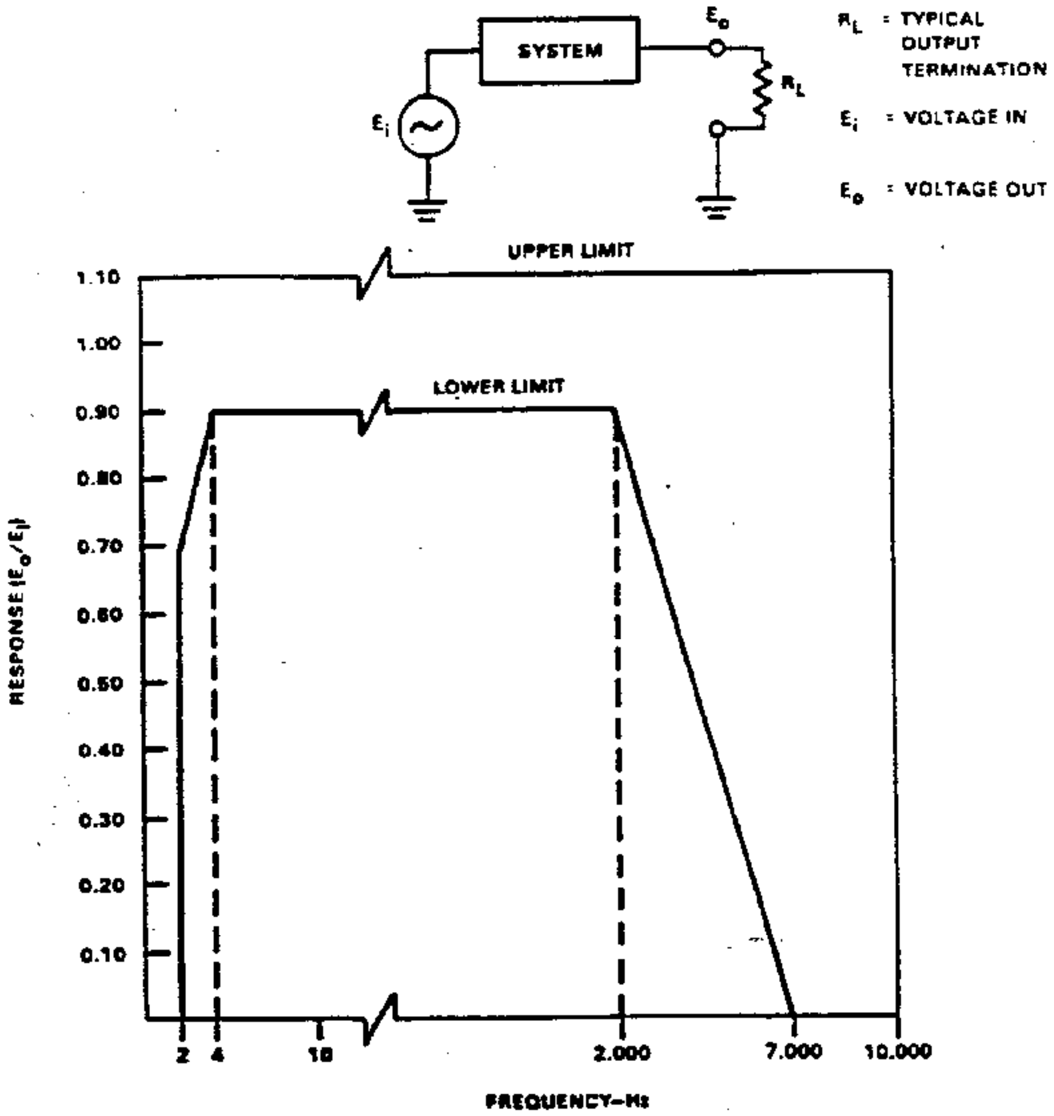
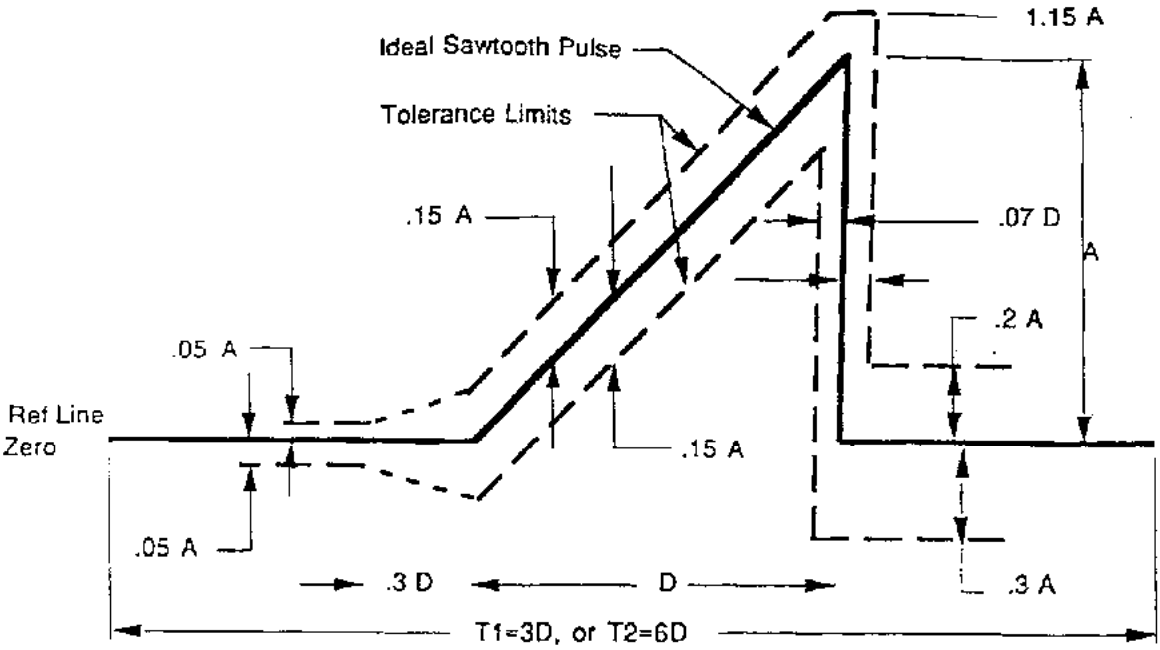


Figure 7-1 Shock Measuring System Frequency Response

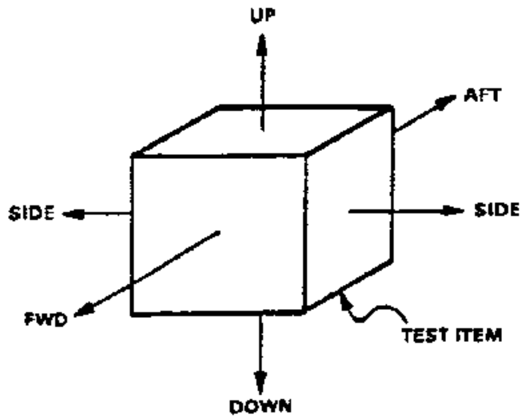


D= Duration of nominal pulse.
A= Peak acceleration of nominal pulse.
T1= Minimum time during which the pulse shall be monitored for shocks produced using a conventional shock testing machine.
T2= Minimum time during which the pulse shall be monitored for shocks produced using a vibration generator.

Test (impulse)	Peak value (A) (g)	Nominal duration (D) (ms)
Fixed-wing a/c		
Operational Standard	6	11
Operational Low-frequency	6	20
Crash safety	20	11
Helicopter		
Operational	6	11
Crash safety	20	11

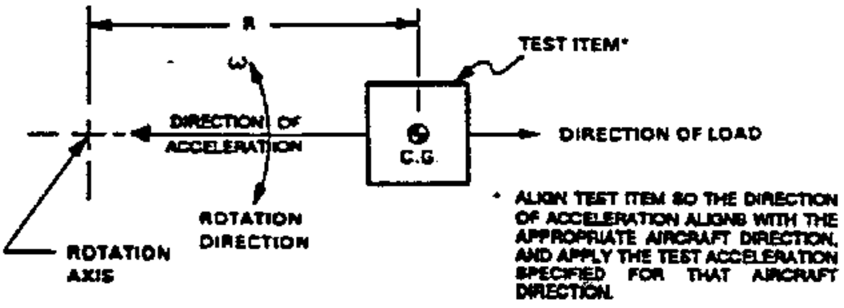
NOTE: *The oscillogram shall include a time duration T_1 or T_2 with a pulse located approximately in the center. The acceleration amplitude of the terminal saw-tooth pulse is A and its duration is D. The measured acceleration pulse shall be contained within the dashed line boundaries and the measured velocity change (which may be obtained by integration of the acceleration pulse) shall be within the limits $V_i \pm 0.1\ V_i$, where V_i is the velocity change associated with the ideal pulse which equals 0.5 DA. The integration to determine velocity change shall extend from 0.4 D before the pulse to 0.1 D after the pulse.*

Figure 7-2 Terminal Saw-Tooth Shock Pulse Configuration
And Its Tolerance Limits



AIRCRAFT DIRECTIONS

NOTE: If a centrifuge is used, the effects of rotational acceleration and rate of acceleration on the specimen should be considered.



LOOKING DOWN ON PLANE OF ROTATION

$$\text{ACCELERATION (G's)} = \frac{R\omega^2}{9.81} = (11.18) \times (10^{-4}) \times (R) \times (RPM)^2$$

R = RADIUS, METERS

ω = ANGULAR ROTATION, RADIANS/SECOND

RPM = REVOLUTIONS PER MINUTE

CENTRIFUGE DEFINITIONS

Figure 7-3 Definitions for Crash Safety Sustained Test

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 8

Vibration

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

8.0 VIBRATION

8.1 Purpose of the Tests

These tests demonstrate that the equipment complies with the applicable equipment performance standards when subjected to vibration levels specified for the appropriate category.

8.2 Applicability

Vibration tests apply to equipment installed on fixed-wing propeller aircraft, fixed-wing turbojet, turbofan, and propfan aircraft and helicopters.

Vibration tests to be performed on any equipment item are selected in this paragraph and are specified by three identifiers: 1) aircraft type, 2) category and 3) aircraft zone location. The test curves to be applied are then specified in paragraph 8.2.2. Requirements and procedures to accomplish these tests are specified in subsequent paragraphs herein.

8.2.1 Vibration Test Definitions

8.2.1.1 Standard Vibration Test

The standard vibration tests demonstrate that equipment will meet its functional performance requirements during normal operating conditions of the aircraft.

8.2.1.2 High Level-Short Duration Vibration Test

High-level short duration transient vibration levels are encountered during abnormal aircraft vibration conditions which occur during blown tires and engine fan blade loss. This test should be applied to equipment in which a functional loss of performance can hazardously affect the aircraft's performance.

8.2.1.3 Robust Vibration Test

The robust vibration test demonstrates that equipment will operate satisfactorily while subjected to a performance vibration level and continue to operate satisfactory after being subjected to an endurance vibration level. It combines a demonstration of the equipments functional performance and structural integrity. This test should be performed on all equipment where its resistance to effects of long duration exposure to vibration must be demonstrated. The necessity for conducting this test in lieu of the standard vibration test shall be determined by the relevant equipment specification.

8.2.2 Category and Test Curve/Level Selection

8.2.2.1 Category Selection

The appropriate test category selected for the equipment from the categories defined below, should be based upon the level of assurance required for the equipment's demonstration of performance. Categories denoted by the number two (2) are the same as those in EUROCAE ED-14C/RTCA DO-160C. They are representative of levels expected on many fixed wing aircraft but may not be sufficient for all. Categories without the number two (2) contain higher levels and reflect the expected environment for all cases.

Category	Aircraft Type	Standard Vibration	High Level - Short Duration Vibration	Robust Vibration
S or S2	Fixed-Wing	1 Hr/Axis sine or random at perf. level	NA	NA
H or H2	Fixed-Wing	1 Hr/Axis sine or random at perf. level	24 Min/Axis sine (10-250 Hz)	NA
R or R2	Fixed-Wing	NA	NA	Sine of 3 Hrs/Axis less 30 min/dwell (max 4 dwells) or Random at 30 min perf. level, 3 Hrs Endurance level and 30 min perf. level (repeated in all 3 axis)
R	Helicopter w/Known Frequencies	NA	NA	Sine-On-Random; 30 min at perf. level, 3 Hrs Endurance level and 30 min at perf. level (repeated in all 3 axis)
T or T2	Fixed-Wing	NA	24 Min/Axis sine (10-250 Hz)	Sine of 3 Hrs/Axis less 30 min/dwell (max 4 dwells) or Random at 30 min perf. level, 3 Hrs Endurance level and 30 min perf. level (repeated in all 3 axis)
U	Helicopter w/Unknown Frequencies	NA	NA	Random; 30 min at perf. level, 3 Hrs Robust level and 30 min at perf. level (repeated in all 3 axis)

Category S or S2: (Standard vibration.) Demonstrates functional performance during normal operational vibration environments.

Category H or H2: (Standard vibration and high-level short duration vibration.) Demonstrates functional performance during normal operational environments and high-level short duration vibration.

Category R or R2: (Robust vibration.) Demonstrates performance at higher vibration levels and after long term vibration exposure.

Category T or T2: (Robust and high-level short duration vibration.) Demonstrates performance at higher vibration levels and after long term vibration exposure. It also demonstrates performance during high level - short duration vibration.

Category U: (Robust vibration-helicopter with unknown rotor frequencies.) Demonstrates performance at higher vibration levels and after long term vibration exposure for fuselage and instrument panel equipment when the specific rotor frequencies are unknown.

8.2.2.2 Test Curves

Table 8-1 specifies the appropriate test curves to be used for the applicable category and aircraft zone for each aircraft type. The test levels for the curves of Table 8-1 are shown in Figures 8-1 to 8-5, for fixed-wing aircraft and Tables 8-2a and 8-2b for helicopters with Figure 8-7 for Category U. All test curves specified for a given category and zone must be performed.

Note that the zone for "instrument panel, console and racks" includes interior items attached to the galley interior partitions and cabin floor and is separate from the "fuselage" zone. The "fuselage" zone applies to all equipment not installed in multiple slot equipment racks but that is attached to frames, stringers, skin and other fuselage structure or brackets.

Weight Allowance -- For equipment items weighing greater than 22.7kg (50 lbs), a reduction in standard and robust test levels for frequencies above 60 Hz is allowed using the following schedule: The random and sinusoidal standard and robust test levels may be reduced by 0.10 dB for each 0.454 kg (1.0 lb) equipment weight increment above 22.7 kg (50 lb) to a maximum reduction of 6.0 dB. (Note that a 6.0 dB reduction would reduce the APSD level to 1/4 and the sinusoidal level to 1/2 of the original level.)

Equipment on external vibration/shock isolators -- Equipment that is provided with external vibration isolators shall be tested with the isolators.

8.3 Vibration Test Requirements

The following general requirements apply for all vibration tests:

a. Install the equipment under test so the input vibratory motion is parallel to one of its three major orthogonal axes. Any test fixture used shall be as rigid and symmetrical as practicable. The equipment shall be attached to the fixture or vibration table by the means specified in the equipment specification. Where applicable, accelerometers shall be attached to the equipment item undergoing vibration to measure and record the equipment's vibration response in the axis of vibration to determine resonant frequencies and amplification factors. Locations selected may include principal structure, printed circuit boards, large components and modules, where practicable.

b. The control accelerometer(s) shall be attached to the test fixture as near as practicable to the equipment mounting location for each axis of test. When more than one accelerometer is employed for test level control, the average of the accelerometer control signals for sinusoidal tests or the average of the acceleration power spectral densities (APSDs) for random tests shall be used as the test level control. For all vibration input types, spectrum or APSD plots as appropriate shall be made to demonstrate that the control levels meet the test level requirements.

c. The random vibration signal should have a Gaussian distribution, and the instantaneous vibration acceleration peaks of the control signal may be limited to three times the g rms acceleration level.

d. The accuracy of the instrumentation system for measuring sinusoidal acceleration shall be $\pm$10 percent for acceleration and $\pm$2 percent for frequency.

e. If the random vibration test requirements exceed the power capability of the vibration test system, the test may be performed in separate frequency bands of 10 to 600 Hz and 600 to 2000 Hz. The specified test time shall be applied to each frequency band.

8.4 Vibration Test Level Requirements

8.4.1 Control Level Tolerance Requirements

8.4.1.1 Sinusoidal Control Input

The acceleration test levels specified for any sinusoidal input curve shall be within ±10 percent of the specified level over the specified frequency range.

8.4.1.2 Random Control Input

The acceleration power spectral density (APSD) of the test control signal shall not deviate from the specified requirements by more than +3 dB or -1.5 dB below 500 Hz and ±3.0 dB from 500 to 2,000 Hz. The overall g rms level of the control signal shall be within +20 and -5 percent of the overall rms value for the specified APSD curve.

8.4.2 Measurement of Acceleration Power Spectral Density

Analysis and control systems shall use a bandwidth-time (BT) product greater than or equal to 50. Specific analyzer characteristics or their equivalent shall be as specified below. Discrete FFT analysis methods are preferred for APSD measurements.

8.4.2.1 Analog Analyzer Requirements

a. On-line contiguous filter, equalization/analysis system having a bandwidth, B, less than or equal to 50 Hz.

b. Swept frequency analysis systems characterized as follows:

(1) Constant bandwidth analyzer.

(a) Filter bandwidths.

B = 10 Hz, maximum from 10 to 200 Hz.B = 50 Hz, maximum from 200 to 2,000 Hz.

(b) Analyzer averaging time = T = 2RC = 1 s minimum, where T = true averaging time and RC = analyzer time constant.

(c) Analysis linear sweep rate = R = B/4RC or $B^2/8$ Hz/s maximum, whichever is smaller.

(2) Constant percentage bandwidth analyzer.

(a) Filter bandwidth = Pf_c = one third octave maximum (0.23 f_c where P = percentage and f_c = analyzer center frequency).

(b) Analyzer averaging time = T = $50/Pf_c$ minimum.

(c) Analysis logarithmic sweep rate = R.

$$R = \frac{Pf_c}{4RC} or \frac{(Pf_c)^2}{8}$$ Hz/s maximum, whichever is smaller

8.4.2.2 Digital Analyzer Requirements

Digital power spectral density analysis system employing discrete frequency analysis techniques shall have a minimum of 400 lines of frequency resolution (i.e., Δf equal to or less than five Hz). The bandwidth-time product is equal to the number of records used to obtain one APSD (i.e., the number of ensemble averages should be 50 or greater when measuring an APSD).

8.5 Standard Vibration Test Procedure-Fixed Wing Aircraft

The standard vibration test curves to be used in Table 8-1 for the specified category and zone are given in Figures 8-1 through 8-3 which define either sinusoidal or random test vibration levels. Although both sinusoidal and random test procedures for the applicable test curves are defined below, only the sinusoidal or random test needs to be performed.

DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS DURING AND AT THE CONCLUSION OF STANDARD VIBRATION TESTING.

8.5.1 Sinusoidal Test Procedure

In each of the equipment's three orthogonal axes perform the following tests using the appropriate test curves of Figure 8-2 or Figure 8-3.

With the equipment operating, sweep cycle the vibration frequency over the appropriate frequency range from lowest to the highest (up-sweep) to the lowest (down-sweep) specified frequencies with a logarithmic sweep rate not exceeding 1.0 octave/minute. During the initial up-sweeps, record plots of the accelerometers at the response locations selected and identify the critical frequencies. Critical frequencies are defined as those frequencies where: (1) mechanical vibration resonances have peak acceleration amplitudes greater than twice the input acceleration amplitude, or (2) a change in performance or behavior is noticeable whether or not performance standards are exceeded.

Continue vibration sweep cycling and operation for one hour minimum to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. Any changes in the critical frequencies that occur during the test shall be noted on the Environmental Qualification Form (see Appendix A).

Any difficulty in reading any display feature of the test item, when the total displacement of applied input vibration exceeds 0.5 mm, shall not be a cause for failing the test.

8.5.2 Random Test Procedure

In each of the equipment's three orthogonal axes perform the following test using the appropriate test levels of Figure 8-1.

With the equipment operating, apply the appropriate acceleration power spectral density (APSD) vibration level for a minimum of one-hour-per-axis to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

At the beginning and end of the vibration period, perform an APSD analysis of the vibration acceleration response at the selected positions on the equipment. Changes in the measured performance or vibration resonances shall be noted on the Environmental Qualification Form (see Appendix A).

8.6 High Level - Short Duration Vibration Test Procedure

With the equipment operating, apply sinusoidal vibration at the levels shown in Figure 8-5 for the appropriate equipment zone location. Perform one sinusoidal linear frequency sweep in each of the equipment's three orthogonal axes from 10 to 250 Hz at a sweep rate not to exceed 0.167 Hz/sec. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARD. Operational performance during and after the test shall be defined by the equipment specification.

8.7 Robust Vibration Test Procedure-Fixed-Wing Aircraft

The robust vibration test curves to be used in Table 8-1 for the specified category and zone location are given in Figure 8-1 to Figure 8-4 which define either sinusoidal or random vibration levels for the applicable test curve. Although sinusoidal and random test procedures are defined below, only the sinusoidal or random test needs to be performed.

8.7.1 Sinusoidal Test Procedure

In each of the equipment's three orthogonal axes, perform the following test using the appropriate sinusoidal test levels of Figure 8-2.

DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS DURING AND AT THE CONCLUSION OF VIBRATION TESTING.

a. With the equipment operating, unless otherwise specified in the equipment specification, sweep cycle the vibration frequency over the appropriate frequency range from the lowest to the highest (up-sweep) to the lowest (down-sweep) specified frequencies with a logarithmic sweep rate not exceeding 1.0 octave/minute. During the initial up-sweeps, record plots of the accelerometers at the selected response locations and identify the critical frequencies. The time spent performing these sweeps may be included in the total sweep time of subparagraph 8.7.1 c. Critical frequencies are defined as those frequencies where: (1) mechanical vibration resonances have peak acceleration amplitudes greater than twice the input acceleration amplitude, or (2) a change in performance or behavior is noticeable whether or not performance standards are exceeded.

b. For the critical frequencies identified, select the four most severe frequencies. Dwell at each of these selected frequencies for 30 minutes. During each resonance dwell, the applied frequency shall be adjusted, if necessary, to maintain the maximum acceleration response at the vibration resonance being dwelled. If fewer than four critical frequencies are identified, dwell at each one for a 30-minute period. If no critical frequencies are identified, then no dwells need be performed.

c. Following the vibration dwell test, complete vibration testing by frequency sweep cycling. The time spent at frequency cycling will be three hours minus the time spent at dwells.

   Any changes in the critical frequencies that occur during the test shall be noted on the Environmental Qualification Form (see Appendix A). If no change occurs, a statement to that effect shall be included in the declaration. Any difficulty in reading any display feature of the test item, when the total excursion of applied input vibration exceeds 0.5 mm, shall not be a cause for failing the test.

d. At the completion of the tests, the equipment shall be inspected and shall show no evidence of structural failure of any internal or external component.

8.7.2 Random Test Procedure

In each of the equipment's three orthogonal axes, perform the following tests using the appropriate test curves of Figure 8-1 and Figure 8-4.

a. With the equipment operating, apply the appropriate performance level test APSD of Figure 8-1 for a minimum of 30 minutes to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS DURING VIBRATION.

   During this vibration period, also perform an APSD analysis of the vibration acceleration response at selected positions on the equipment.

b. Apply the appropriate endurance level test APSD of Figure 8-4 for three hours. Unless otherwise defined in the equipment specification, the test item shall be operating during vibration.

c. After the three-hour test, repeat the test of subparagraph 8.7.2. a. Any change in the performance or the vibration resonance's shall be noted on the Environmental Qualification Form (see Appendix A).

d. At the completion of the tests, the equipment shall be inspected and shall show no evidence of structural failure of any internal or external component.

8.8 Vibration Test for Helicopters

The test herein is a default test that can be performed on equipment installed on helicopters in which no measured vibration data is available. For helicopters where data have been measured, "tailored" tests may be applied using accepted standard procedures for helicopter tests standards.

For all equipment in all zones on helicopters when the primary frequencies of the rotational vibration sources are known, the test method of Paragraph 8.8.1 applies. The vibration test is sine-on-random using the test procedure given herein.

For the fuselage and instrument panel zones only, when the helicopter frequencies are not known, the random vibration test of Paragraph 8.8.2 may be applied. For all other zones, the sine-on-random test must be applied.

8.8.1 Sine-on-Random Test Procedure - Known Helicopter Frequencies

The test frequencies, test levels and test procedure for performing a sine-on-random vibration test are defined below.

8.8.1.1 Test Frequencies

The one-per-revolution frequencies of the four primary rotational sources are defined as:

FM = Main rotor one/rev frequency, Hz
FT = Tail rotor one/rev frequency, Hz
FE = Engine one/rev frequency, Hz
FG = Main gearbox one/rev frequency, Hz

The blade passage frequencies of the rotor blades are defined using the number of blades for the main and tail rotors:

NM = Number of blades on the main rotor
NM*FM = First blade passage main rotor frequency, Hz
NT = Number of blades on the tail rotor
NT*FT = First blade passage tail rotor frequency, Hz

When the above frequencies are known, the test frequencies to be used for each helicopter zone are defined in Table 8-2a.

8.8.1.2 Sine and Random Test Levels

Using the four sinusoidal frequencies selected from Table 8-2a for the appropriate zone, the sinusoidal levels for each frequency are given in Table 8-2b as well as the random levels. The combination of the sinusoidal and random curves appear (generically) as shown in Figure 8-6 which defines the total test curve.

8.8.1.3 Procedure

The applied controlled input vibration level shall have a frequency content of the sum of the four sinusoidal frequencies and the wide-band random test levels determined above.

The sinusoidal frequencies shall be varied at a logarithmic sweep rate not exceeding 1 Oct/min from fi*(0.94) to fi*(1.06) (where fi are the four sinusoidal frequencies).

A performance level and endurance level vibration test shall be performed in each of the equipment's three orthogonal axes using the test procedure defined below.

a. With the equipment operating, apply the appropriate performance level test curve of Table 8-1 for a minimum of 30 minutes to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS DURING VIBRATION.

   During this vibration period, also perform appropriate spectra analysis of the vibration acceleration responses at selected positions on the equipment.

b. With the equipment non-operating, unless otherwise specified in the applicable equipment specification, apply the appropriate endurance level test curve of Table 8-1 for three hours.

c. After the three-hour test, repeat the test of subparagraph 8.8.1.3.a. Any change in the performance of the vibration resonances shall be noted on the Environmental Qualification Form (see Appendix A).

d. At the completion of the tests, the equipment shall be inspected and shall show no evidence of structural failure of any internal or external component.

8.8.2 Random Test Procedure - Unknown Helicopter Frequencies (fuselage and instrument panel only)

In each of the equipment's three orthogonal axes, perform the following tests using the test curve and test levels of Figure 8-7.

a. With the equipment operating, apply the performance level test APSD for a minimum of 30 minutes to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS DURING VIBRATION.

During this vibration period, also perform an APSD analysis of the vibration acceleration response at selected positions on the equipment.

b. Apply the endurance level test APSD for three hours. During this period, unless otherwise specified, the equipment need not be operating.

c. After the three-hour test, repeat the test of subparagraph 8.8.2. a. Any change in the performance or the vibration resonance's shall be noted on the Environmental Qualification Form (see Appendix A).

d. At the completion of the tests, the equipment shall be inspected and shall show no evidence of structural failure of any internal or external component.

AIRCRAFT TYPE	TEST CATEGORY	AIRCRAFT ZONE 1 FUSELAGE	2 INSTRUMENT PANEL, CONSOLE & EQUIPMENT RACK	3 NACELLE & PYLON	4 ENGINE & GEAR BOX	5 WING & WHEEL WELL	6 LANDING GEAR	7 EMPENNAGE
		VIBRATION TEST CURVES (1) (2)						
1. Helicopters (Reciprocating & Turbojet Engines)	R	(G, G1)	(G, G1)	(H, H1)	(I, I1)	(J, J1)		(J, J1)
	U	(F, F1)	(F, F1)					
2. Fixed Wing Turbojet or Turbofan Engines (Subsonic & Supersonic)	S or S2	(C) (3)	(B) or (B2) (4)	(D)	(W)	(E)	(W)	(E)
	H or H2	(C, R) (3)	(B, R) or (B2, R) (4)	(D, P)	(W, P)	(E, P)	(W, P)	(E, P)
	R or R2	(C, C1) (3)	(B, B1) or (B2, B12) (4)	(D, D1)	(W)	(E, E1)	(W)	(E, E1)
	T or T2	(C,C1,R) (3)	(B, B1, R) or (B2, B12, R) (4)	(D, D1, P)	(W, P)	(E, E1, P)	(W, P)	(E, E1, P)
3. Fixed Wing Reciprocating & Turboprop Engines Multi Eng over 5,700 KG (12,500 lbs)	S	L(3)	M	T	U	T		
4. Multi Eng Less than 5,700 KG (12,500 lbs)	S	M(3)	M	L	L	L		
5. Single Eng Less than 5,700 KG (12,500 lbs)	S	M	M	M	L	M		
6. Fixed Wing Unducted Turbofan Engines (Propfan)	S or S2	(Y) (3)	(B) or (B2) (4)	(D)	(W)	(E)	(W)	(E) or (Z)
	H or H2	(Y, R) (3)	(B, R) or (B2, R) (4)	(D, P)	(W, P)	(E, P)	(W, P)	(E, P) or (Z, P)
	R or R2	(Y)	(B, B1) or (B2, B12) (4)	(D, D1)	(W)	(E, E1)	(W)	(E1) or (Z)
	T or T2	(Y, R)	(B, B1, R) or (B2, B12, R) (4)	(D, D1, P)	(W, P)	(E, E1, P)	(W, P)	(E1, P) or (Z, P)

NOTES:

1. *Unless otherwise noted, all curves in parentheses for a given category and zone must be performed.*
2. *Curves B to F are random; curves G to J are Sine-on-Random; all others are sinusoidal.*
3. *Does not include equipment mounted on structure directly affected by jet efflux.*
4. *Curves B2 and B12 are the same as those found in EUROCAE ED-14C/RTCA DO-160C as B and B', respectively. They are representative of levels expected on many fixed wing aircraft but may not be sufficient for all. Curves B and B1 contain higher levels and reflect the expected environment for all cases.*

Table 8-1: Categorization and vibration Tests by Aircraft Types and Equipment Locations

Helicopter Zone Vibration Test Frequencies					
Sinusoidal	1	2	3	4	5
(1) Test Frequencies	Fuselage	Instrument Panel Console & Equipment Rack	Nacelle & Pylon	Engine & Gear Box	Empennage, & Fin Tip
f1	FM	FM	FM	FE	FM
f2	NM•FM	NM•FM	NM•FM	2•FE	NM•FM
f3	FT	2•NM•FM	2•NM•FM	FG	FT
f4	NT•FT	3•NM•FM	3•NM•FM	2•FG	NT•FT

Table 8-2a Sine-on-Random Vibration Test Frequencies for Helicopters

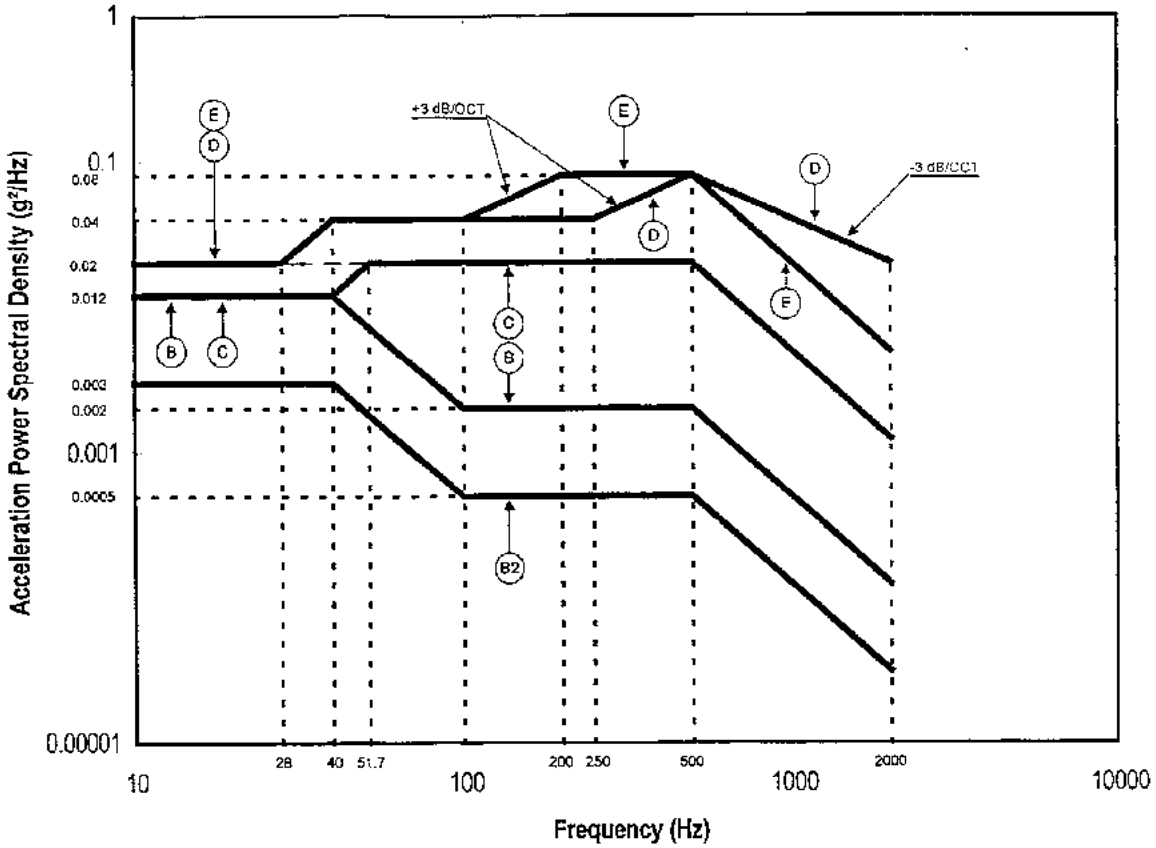
(1) NOTE: FM, FT, FE, FG, NM and NT are defined in Paragraph 8.8.1.1

HELICOPTER VIBRATION TEST CURVE LEVELS										
Test [1]	**Sinusoidal Curve Levels (g-PK)**									
Frequency	Performance Level Curves					Endurance Level Curves				
Range, Hz	F	G	H	I	J	F1	G1	H1	I1	J1
3 to 25	0.04 x f	0.04 x f	0.05 x f	0.08 x f	0.17 x f	0.05 x f	0.05 x f	0.06 x f	0.1 x f	0.2 x f
25 to 40	0.04 x f	0.04 x f	0.05 x f	0.08 x f	4.20	0.05 x f	0.05 x f	0.06 x f	0.1 x f	5.00
40 to 50	1.60	1.60	0.05 x f	0.08 x f	4.20	2.00	2.00	0.06 x f	0.1 x f	5.00
50 to 200	1.60	1.60	2.50	0.08 x f	4.20	2.00	2.00	3.00	0.1 x f	5.00
200 to 2000				16.70					20.00	
PSD	**Random Curve Levels (g^2/Hz)**									
W_0	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02

[1] <u>NOTE</u>: *The four sinusoidal frequencies, f1, f2, f3 and f4 for each zone are determined in Table 8.2a.*

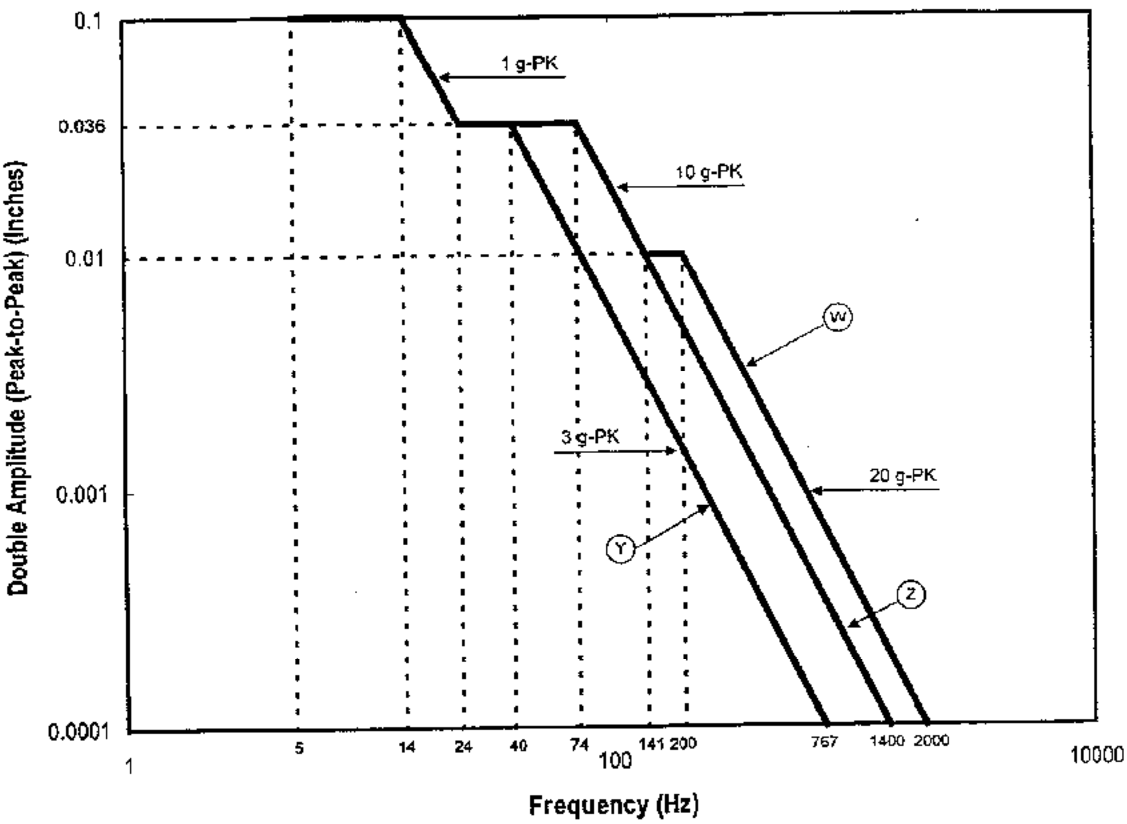
Table 8-2b Sine-on-Random Vibration Test Levels for Helicopters

CURVES	grms
B2	0.7
B	1.48
C	4.12
D	8.92
E	7.94



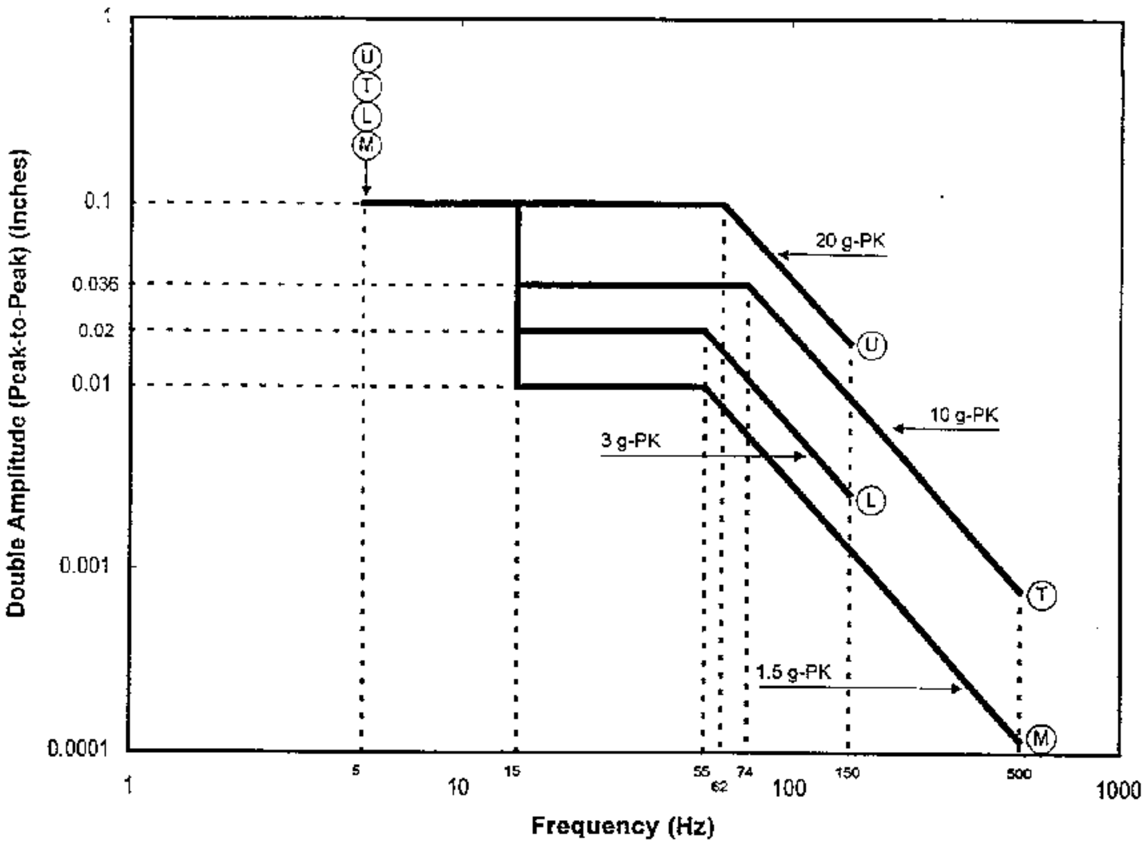
NOTE: All slopes are ± 6 dB/OCT except as noted on curves D and E.

Figure 8-1 Standard Random Vibration Test Curves for Equipment Installed in Fixed-Wing Aircraft with Turbojet or Turbofan Engines



NOTE: In this figure the use of English units was retained because the graphs were derived from these units originally.

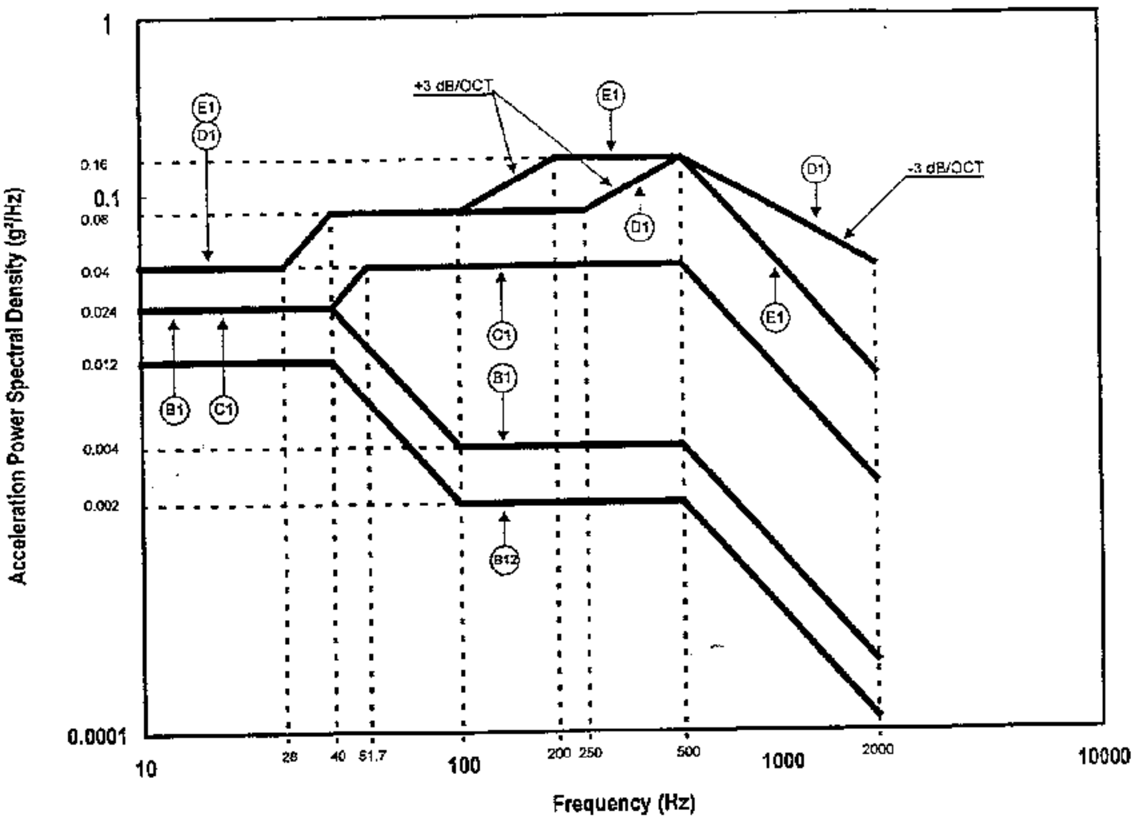
Figure 8-2 Standard and Robust Sinusoidal Vibration Test Curves for Equipment Installed in Applicable Zones in Fixed-Wing Aircraft with Turbojet or Turbofan Engines and Unducted Fan Engines



NOTE: In this figure the use of English units was retained because the graphs were derived from these units originally.

Figure 8-3 Standard Sinusoidal Vibration Test Curves for Equipment Installed in Fixed-Wing Aircraft with Reciprocating or Turbopropeller Engines

CURVES	grms
B12	1.48
B1	2.09
C1	5.83
D1	12.61
E1	11.23



NOTE: All slopes are ±6 dB/OCT except as noted on curves D and E.

Figure 8-4 Robust Random Vibration Test Curves for Equipment Installed in Fixed-Wing Aircraft with Turbojet or Turbofan Engines

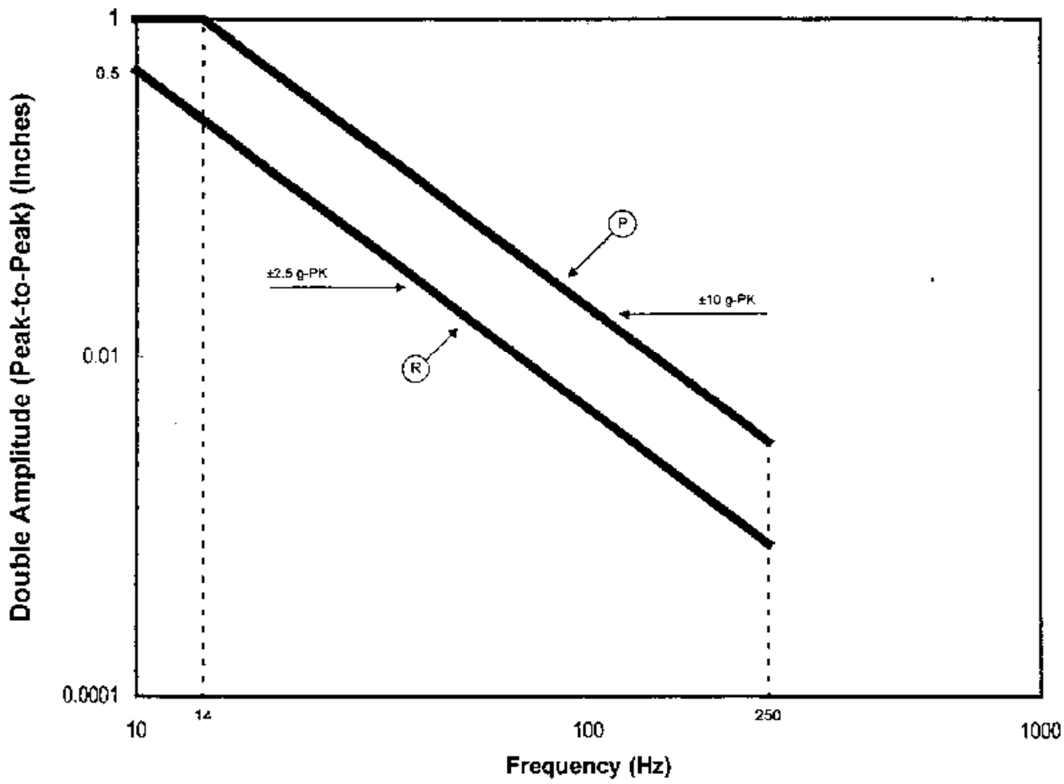
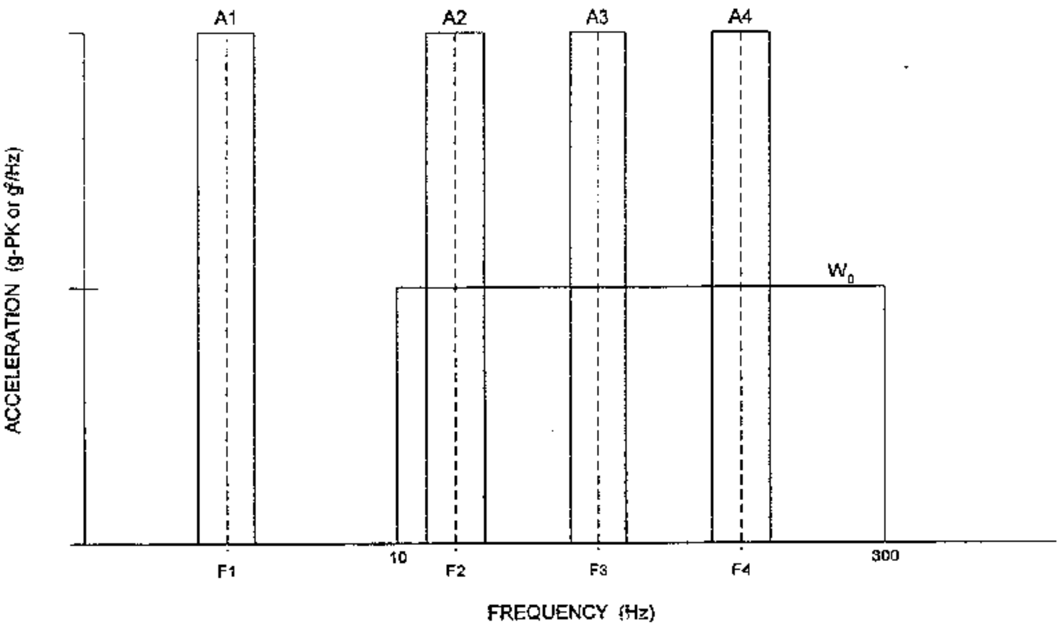


Figure 8-5 High-Level Short Duration Sinusoidal Vibration Test Curves for Equipment Installed on Fixed-Wing Aircraft with Turbojet or Turbofan Engines



NOTE: W_0 is a Random PSD Curve, g^2/Hz; A1-A4 are Sinusoidal Curves, g-PK. Vibration levels are given in Tables 8-2a and 8-2b.

Figure 8-6 Sine-On-Random Vibration Test Curve for Helicopters

TEST	TEST CURVES	W_0	grms
Performance	F	0.05	2.97
Endurance	F1	0.10	4.20

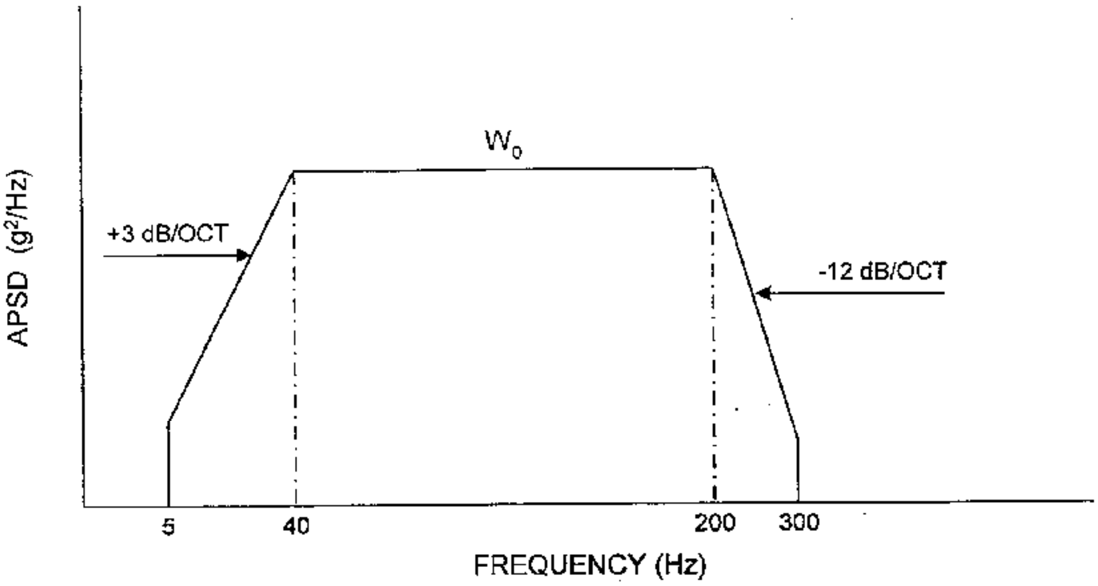


Figure 8-7 Random Test Curves for Helicopters Fuselage and Instrument Panel (Unknown Frequencies)

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 9

Explosion Proofness

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

9.0 EXPLOSION PROOFNESS

9.1 Purpose of the Test

This test specifies requirements and procedures for aircraft equipment that may come into contact with flammable fluids and vapors such as those specified herein. It also refers to normal and fault conditions that could occur in areas that are or may be subjected to flammable fluids and vapors during flight operations.

The flammable test fluids, vapors or gases referred to in this section simulate those normally used in conventional aircraft and that require oxygen for combustion (e.g., monofuels are not included).

These standards do not relate to potentially dangerous environments occurring as a result of leakage from goods carried on the aircraft as baggage or cargo.

NOTE: *The explosion proofness tests should normally be conducted after the article being tested has been subjected to other environmental tests of this document (see Subsection 3.2, «Order of Tests»).*

9.2 Explosion Proof

Equipment is explosion proof when it has been determined that there is negligible risk that it will cause an explosion of a flammable gas or vapor within the declared environment.

9.3 Environment Definitions and Equipment Requirements

Equipment Environments and related requirements shall be as follows (See Table 9-1).

9.3.1 Environment I

Environment I is an atmosphere in a space in which uncovered flammable fluids or vapors exist, or can exist, either continuously or intermittently (e.g., in fuel tanks or within fuel systems). Installed equipment shall meet the standards and test procedures of explosion proof Category A.

9.3.2 Environment II

Environment II is an atmosphere in which flammable mixtures can be expected to occur only as a result of a fault-causing spillage or leakage. Installed equipment shall meet the standards and test procedures for any one of the explosion proof categories (paragraphs 9.4.1, 9.4.2 or 9.4.3).

9.3.3 Environment III

Environment III is an atmosphere within a designated fire zone. The equipment test requirements are the same as for Environment II except that fault conditions in Category A equipment need not be considered.

9.4 Equipment Categories

9.4.1 Category A Equipment

Category A equipment is designed so that:

a. Ignition of an explosive mixture is contained within the equipment without igniting an explosive atmosphere surrounding it and so that it meets the Category A tests specified in paragraph 9.7.1.

b. During normal operation, or as a result of any fault, the temperature of any external surface will not rise to a level capable of causing ignition (subparagraph 9.7.1.4).

Hermetically sealed equipment meeting subparagraph 9.4.1 b. shall be identified as Category A equipment.

9.4.2 Category E Equipment

Category E equipment is not hermetically sealed and not contained in cases designed to prevent flame and explosion propagation. Category E equipment is not intended for installation in Environment I.

Such equipment shall be designed so that in normal operation the temperature of any external surface will not rise to a level capable of causing ignition, nor will any operating part cause ignition.

9.4.3 Category H Equipment

Category H equipment, including those hermetically sealed, contain hot spot surfaces (external or internal) and are non-spark producing under normal operating conditions (see paragraph 4.6.1).

Such equipment shall be designed so that in normal operation the temperature of any external surfaces will not rise to a level capable of causing ignition.

9.5 General Test Requirements

9.5.1 General

The test requirements specified below are necessary to assure that the equipment, when tested in accordance with the applicable test procedure, will comply with the standards established in Subsection 9.3.

9.5.2 Test Specimen

The test specimens selected shall be representative of production equipment.

9.5.3 Fuel

Unless otherwise specified, the fuel used may be grade 100/130 octane gasoline, propane or normal hexane.

9.5.4 Fuel Mixtures

a. For gasoline, a stoichiometric mixture of 13 parts of air and one part of fuel by mass.

b. For propane, a 1.05 stoichiometric mixture of 3.85% to 4.25% by volume of propane to 96.15% to 95.75% by volume of air. For an example of test apparatus see Figure 9-1.

c. For hexane, a 1.80 stoichiometric fraction of normal hexane shall be calculated according to the following equations:

(1) Volume (ml) of 95% normal hexane (metric units) =

$$(4.27\text{x}10^{-4})\ \frac{[\text{net chamber volume (liters)}]\ [\text{chamber pressure pressure (pascals)}]}{[\text{Chamber temp (K)}]\ [\text{Relative density of n-hexane}]}$$

2) Volume (ml) of 95% normal hexane (english units) =

$$(150.41)\ \frac{[\text{net chamber volume (ft}^3)]\ [\text{chamber pressure (psia)}]}{[\text{Chamber temp (R)}]\ [\text{Relative density of n- hexane}]}$$

NOTE *K = the thermodynamic temperature and is °C + 273.15*
R = the thermodynamic temperature and is °F + 459.67
The relative density of normal hexane can be determined from Figure 9-2.

The equipment used to vaporize the fuel for use in the explosion proofness test should be so designed that a small quantity of air and fuel vapor will be heated together to a temperature such that the fuel vapor will not condense as it is drawn from the vaporizer into the chamber.

When the test facility is designed for fuel vaporization inside the explosion chamber, the fuel may be introduced at the ambient temperature of the test site.

The following sample problem is presented as an illustration of the procedure for calculating the mass of 100/130 octane gasoline required to produce the desired 13-to-1 air-vapor ratio:

Required information:

Chamber air temperature during test: 27.2°C
Fuel temperature: 24°C
Relative density of fuel at 16.1°C: 0.704
Test altitude: 1,524 m (5,000 ft) 85 kPa (P=12.33 lb/sq in)
Air-vapor ratio (desired): 13-to-1

Step 1 - Employing the following equation, calculate the apparent air-vapor ratio:

$$AAV = \frac{AV\ (desired)}{1.04\left(\frac{P}{101.32}\right) - 0.04}$$

$$15.62 = \frac{13}{1.04\left(\frac{85}{101.32}\right) - 0.04}$$

where: AAV = Apparent air-vapor ratio
AV = Desired air-vapor ratio
P = Pressure equivalent of altitude, kPa

At ground level up to 1,524 m (5,000 ft) altitude, with chamber air temperature above 16.1°C and at AV ratio of five or greater, air-vapor ratio = air-fuel ratio (AF) for 100/130 octane fuel. Since the conditions of the explosion test under consideration will always be well above these values, AV will equal AF in all cases.

Step 2 - Since AV = AF, use Figure 9-3 to determine mass of air (WA) and divide by AAV to obtain uncorrected mass of fuel required (W_{fu}).

$$W_{fu} = \frac{WA}{15.62} = \frac{1570}{15.62} = 100\text{ g, fuel mass (uncorrected)}$$

NOTE: Figure 9-3 pertains to a specific test chamber volume and shall not be used for all test facilities. It only illustrates the employment method. Each test chamber must have its own chamber volume chart.

Step 3 - Knowing fuel temperatures and relative density at 16.1°C, use Figure 9-4 to determine relative density at a given temperature.

Step 4 - Using Figure 9-5, obtain correction factor K for the relative density determined during Step 3. Apply factor to obtain mass of fuel corrected (W_{fc}).

$$W_{fc} = KW_{fu} = 1.01 \times 100 = 101\text{ g fuel mass (corrected).}$$

9.6 Equipment Design and Installation Information

Equipment specifications should detail any design constraints applicable to the particular category of equipment enclosure. Such design constraints should include the following as appropriate:

a. Equipment that may come into contact with flammable fluids or vapors and that in normal operations may produce arcs, sparks or hot surfaces shall be designed, considering its likely manner of installation, to be explosion proof.

b. Equipment that may come into contact with flammable fluids or vapors, and that under fault conditions may produce arcs, electrical sparks, friction sparks or hot surfaces shall be designed and installed to reduce to an acceptable minimum the overall risk of a fault occurring that will ignite the flammable vapors.

c. In designing the air supply system for forced air ventilated equipment, the possibility of contamination of the air by flammable vapors shall be taken into account. If the equipment and its ducting, including joints, are in an area that can be so contaminated, they shall be capable of meeting the conditions appropriate to the environment.

d. The specification for Category A equipment, paragraph 9.4.1, should consider the design requirements of flange and hole dimensions or other equivalent means, such as flame traps, for adequate safety from flame propagation. This information is contained in national documents.

9.7 Test Procedures

9.7.1 Category A Test

9.7.1.1 Preparation for Test

a. Preparation of Test Case or Enclosure - When necessary, the test case or enclosure shall be prepared for explosion proof testing by drilling and tapping openings in the case or enclosure for inlet and outlet hose connections to the fuel-vapor-air mixture circulation system and for mounting a spark gap device. The case volume shall not be altered by more than ±5 percent by any modification to facilitate the introduction of explosive vapor.

b. Hose Installation - When inserting a hose from a blower, adequate precaution shall be taken to prevent ignition of the ambient mixture by backfire or the release of pressure through the supply hose.

c. Spark Gap Device - A spark gap device for igniting the explosive mixture within the case or enclosure shall be provided. The case or enclosure may be drilled and tapped for the spark gap device, or the spark gap device may be mounted internally.

d. Case Installation - The case or enclosure with either the test item or a model of the test item of the same volume and configuration in position within the case or enclosure shall be connected and oriented in the explosion chamber mechanically and electrically, as recommended by the manufacturer for normal service installation. This shall include any cooling provisions, as necessary to perform the tests described herein.

9.7.1.2 Performance of Test

The following test sequence shall be performed three times as follows:

Step 1: The chamber shall be sealed and the internal pressure maintained at site level pressure. The ambient chamber temperature shall be at least 25°C. An explosive mixture within the chamber shall be obtained by using the mixture defined in paragraphs 9.5.3 and 9.5.4.

Step 2: The internal case ignition source shall be energized in order to cause an explosion within the case. The occurrence of an explosion within the case may be detected by use of a thermocouple inserted in the case and connected to a sensitive galvanometer outside the test chamber. If ignition of the mixture does not occur immediately, the test shall be considered void and shall be repeated with a new explosive charge.

Step 3: At least five internal case explosions shall be performed. If the case tested is small (not in excess of 1/50 of the test chamber volume) and if the reaction within the case upon ignition is of an explosive nature without continued burning of the mixture as it circulates into the case, more than one internal case explosion, but not more than five, may be produced without recharging the entire chamber. Ample time shall be allowed between internal case explosions for replacement of burnt gases with fresh explosive mixture within the case. If the internal case explosions produced did not cause a main chamber explosion, the explosiveness of the fuel-air mixture in the main chamber shall be verified by igniting a sample of the mixture with a spark plug or glow plug. If the air-vapor mixture in the main chamber is found not to be explosive, the test shall be considered void and the entire procedure repeated.

9.7.1.3 Failure Criteria

If the internal case explosion causes a main chamber explosion, the test item shall have failed the test and no further tests need be conducted.

9.7.1.4 External Surface Temperature Tests

If required, test procedures shall be specified in the individual equipment specification (subparagraph 9.4.1 b.).

9.7.2 Category E Test

9.7.2.1 Preparation for Test

a. The test item shall be connected and oriented mechanically and electrically as recommended by the manufacturer for normal service installation. This shall include any cooling provisions as necessary to perform the tests described herein so that normal electrical operation is possible and mechanical controls may be operated through the pressure seals from outside the chamber. External covers of the test item shall be removed or loosened to facilitate the penetration of the explosive mixture. Large test items may be tested one or more units at a time by extending electrical connections through the cable port to the balance of the associated equipment located externally.

b. The test item shall be operated to determine that it is functioning properly.

c. Mechanical loads on drive assemblies and servomechanical and electrical loads on switches and relays may be simulated if proper precaution is given to duplicating the normal load in respect to torque, voltage, current, inductive reactance, etc. In all instances, it is preferable to operate the test item as it normally functions in the installed environment.

9.7.2.2 Performance of Test

The test shall be conducted at site level pressure.

Step 1: The test chamber shall be sealed and the ambient temperature within shall be raised to the Operating High Temperature, given in Table 4-1, for which the equipment is designed to operate. The temperature of the test chamber and the chamber walls shall be permitted to rise to within 11°C of the chamber ambient air, prior to the introduction of the explosive mixture, to prevent condensation of the explosive medium.

Step 2: The required quantity of fuel (paragraph 9.5.4) shall be introduced into the chamber. Circulate the test atmosphere for at least three minutes to allow for complete vaporization of fuel and the development of a homogenous mixture.

Step 3: At this time all electrical contacts of the test item shall be actuated. The operation of the test item shall be continuous throughout this period and all making and breaking of electrical contacts shall be conducted as frequently as deemed practicable.

Step 4: If no explosion has occurred as a result of the test item operation, the potential explosiveness of the air-vapor mixture shall be verified by igniting a sample of the mixture with a spark gap or glow plug. If the air-vapor mixture is not found to be explosive, the test shall be considered void and the entire procedure repeated.

9.7.2.3 Failure Criteria

If the item causes an explosion, it shall have failed the test and further tests need not be conducted.

9.7.3 Category H Test

9.7.3.1 Preparation for Test

The test item shall be placed in the test chamber in accordance with subparagraph 9.7.2.1. the suspected components or surfaces to be tested for thermal ignition shall be instrumented with thermocouples operating in a range of 65 to 260°C.

9.7.3.2 Performance of Test

The test shall be conducted as follows:

Step 1: The test chamber shall be sealed and the ambient temperature within shall be raised to the Operating High Temperature, given in Table 4-1, for which the equipment is designed to operate. The temperature of the test chamber and the chamber walls shall be permitted to rise to within 11°C of the chamber ambient air.

Step 2: The equipment shall be turned on and operated in its normal mode until thermal stabilization of the equipment has been attained. The maximum temperatures attained at the suspected components or surfaces shall be recorded. If a temperature in excess of 204°C is attained, the test shall be terminated.

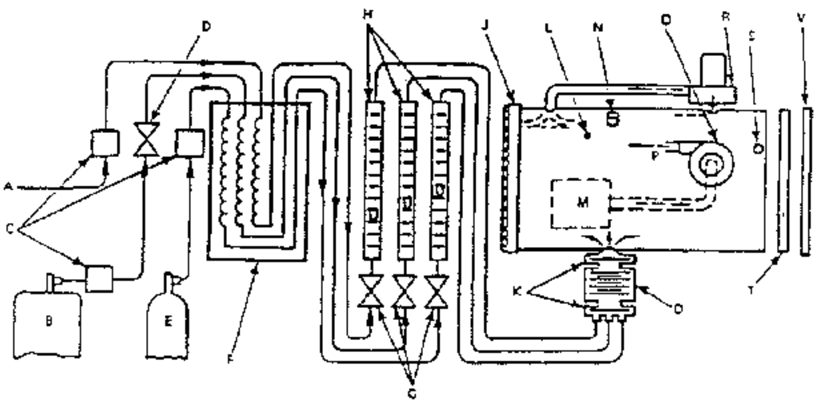
9.7.3.3 Failure Criteria

In Step 2 above, if the item exceeds 204°C, the test item shall have failed the test and further tests need not be conducted.

Environment	Equipment Categories	Requirements and Tests	Notes
I	A A (hermetically sealed)	See paragraph 9.7.1 See paragraph 9.7.1.2	1/
II	A E H	See paragraph 9.7.1 See paragraph 9.7.2 See paragraph 9.7.3	2/
III	A E H	As for Environment II, but fault cases are not applicable	3/

NOTES 1/ *Paragraph 9.3.1 applies*
2/ *Paragraph 9.3.2 applies*
3/ *Paragraph 9.3.3 applies*

Table 9-1 Equipment Categories and Test Requirements



Legend

A AIR
B PROPANE GAS CONTAINER
C REDUCING VALVES
D GAS CUT-OFF VALVE OPERATED BY MICRO-SWITCHES ON EXPLOSION CHAMBER
E OXYGEN BOTTLE
F HEAT EXCHANGER TO BRING THE GASES TO STANDARD TEMPERATURE
G NEEDLE VALVES
FLOW METERS
J BOTH ENDS COVERED BY DIAPHRAGMS (E G PAPER, POLYETHYLENE) HELD ON BY RUBBER BANDS
K DIAPHRAGM CHECK VALVES
L CYLINDRICAL EXPLOSION CHAMBER
M UNIT UNDER TEST
N VENT
O MIXING CHAMBER
P WASTE TO ATMOSPHERE
Q EXTRACTOR FOR CHARGING UNIT UNDER TEST
R STIRRING BLOWER
S MICRO-SWITCH (ONE T EACH END) RELEASED WHEN H RUBBER BAND IS DISPLACED BY EXPLOSION
T DIAPHRAGM
V RUBBER BAND

Figure 9-1 Example of Apparatus for Testing in Explosive Atmospheres

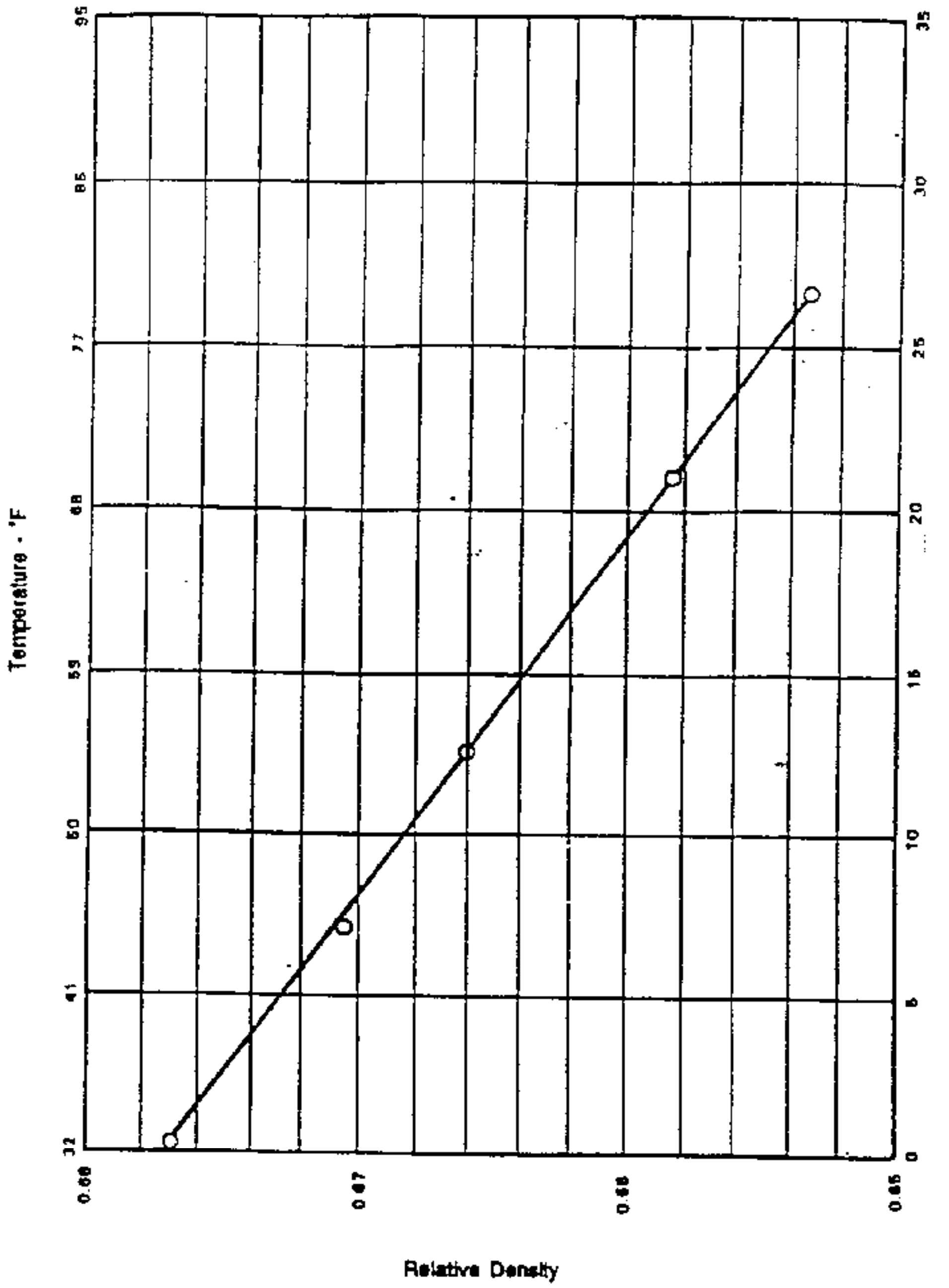


Figure 9-2 : Relative Density of N-Hexane

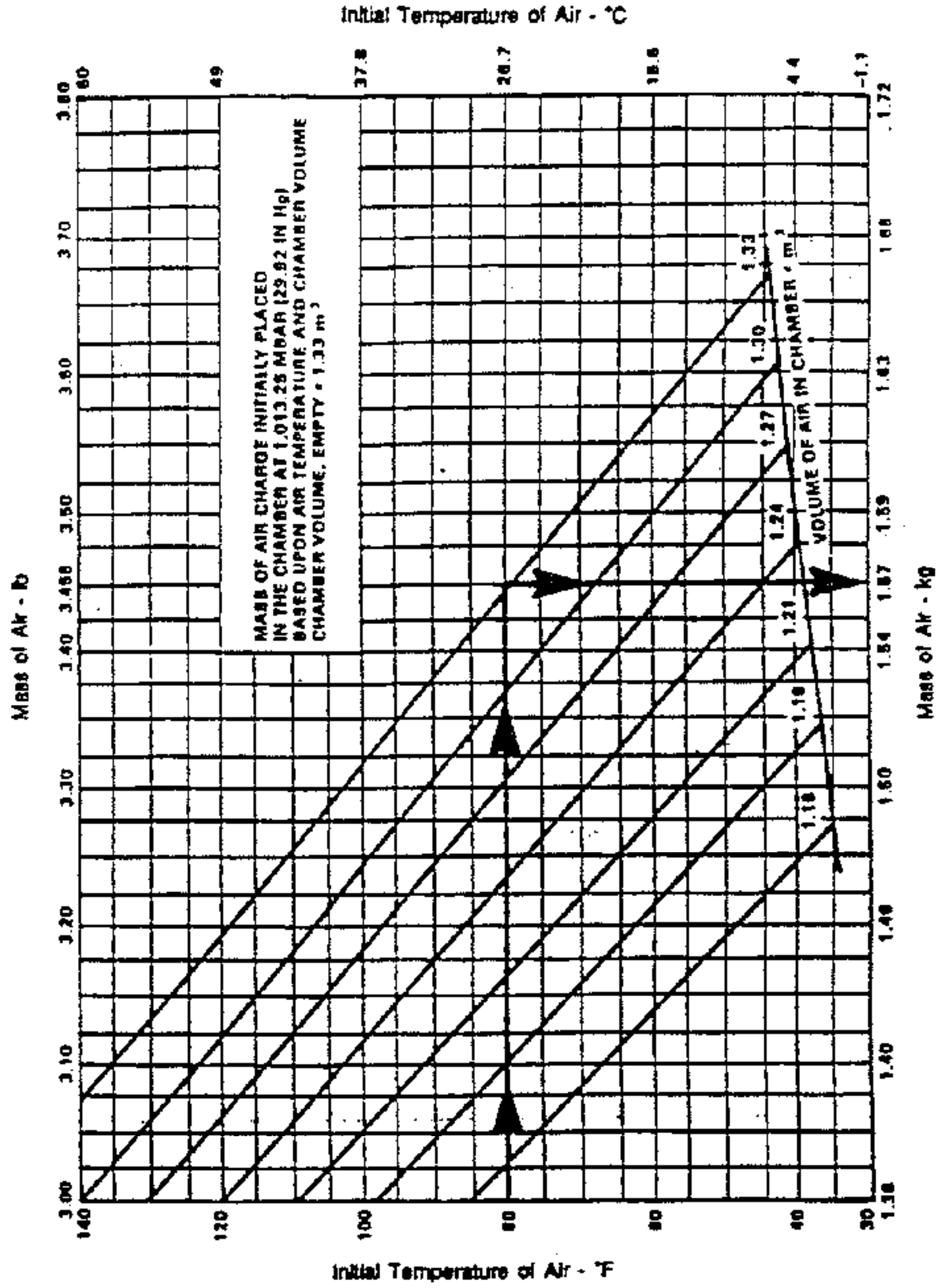


Figure 9-3 : Mass of Air Charge VS Temperature

9-12

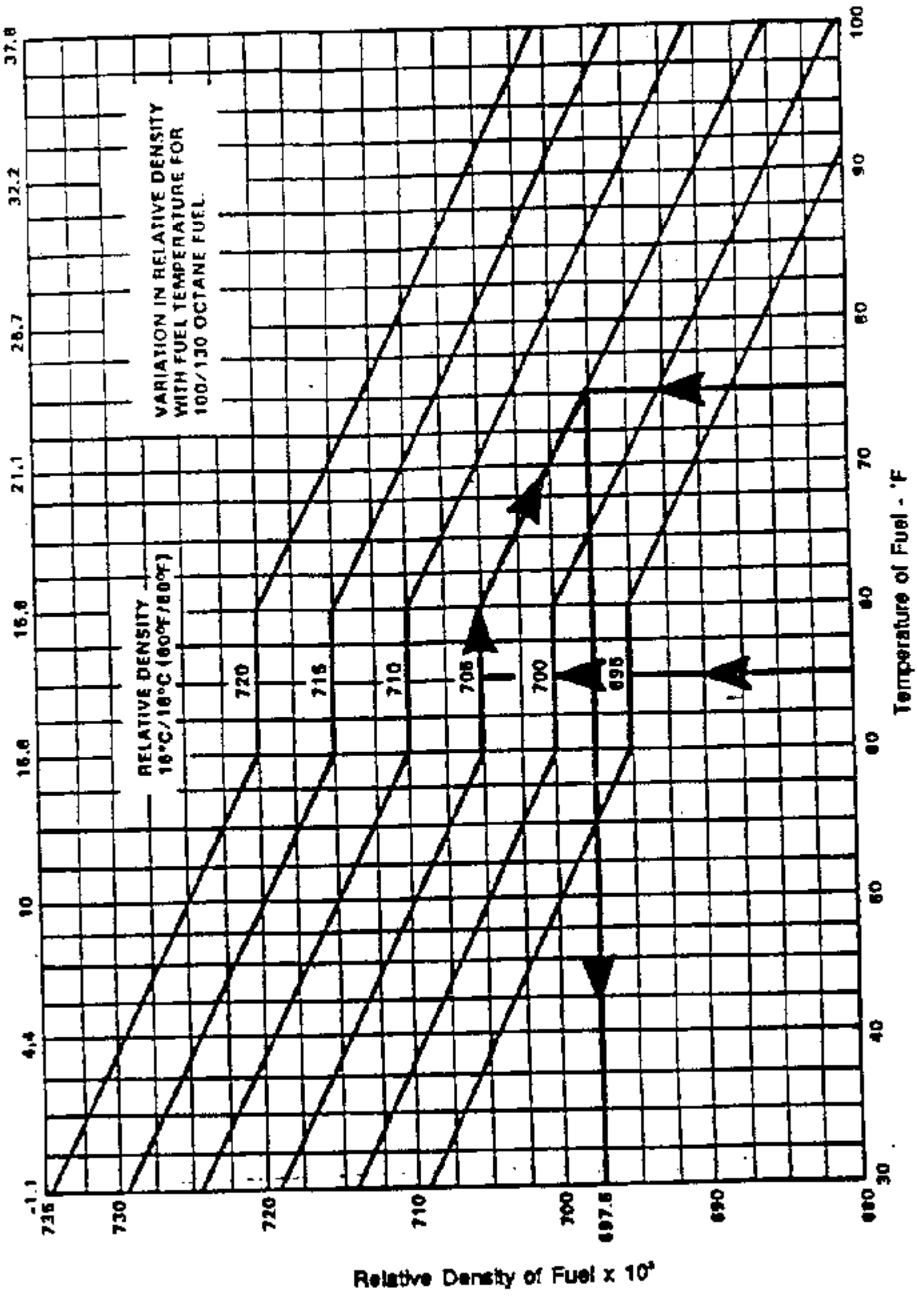


Figure 9-4 : Relative Density VS Temperature

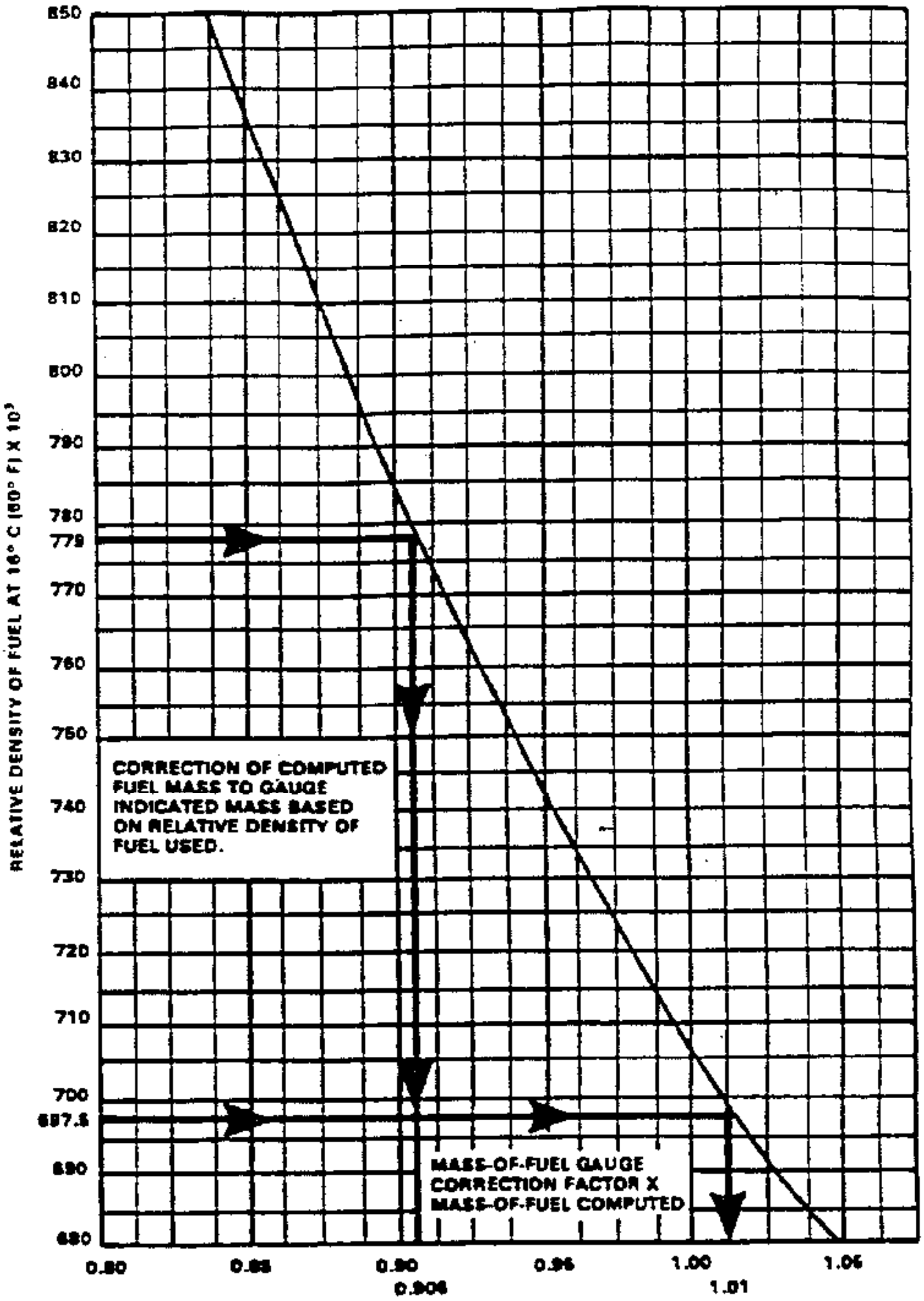


Figure 9-5 : Fuel Mass to Gauge Indicated Mass Correcton Factor

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 10

Waterproofness

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

10.0 WATERPROOFNESS

10.1 Purpose of the Test

These tests determine whether the equipment can withstand the effects of liquid water being sprayed or falling on the equipment.

These tests are not intended to verify performance of hermetically sealed equipment. Therefore, hermetically sealed equipment may be considered to have met all waterproofness requirements without further testing. Equipment shall be considered hermetically sealed when the seal is permanent and air-tight.

10.2 Equipment Categories

Category W

Equipment that is installed in locations where it is subjected to falling water (generally the result of condensation) in the course of normal aircraft operations is identified as Category W. For equipment intended for installation in such locations, the drip proof test procedure applies and the equipment is identified as Category W.

Category R

Equipment installed in locations where it may be subjected to a driving rain or where water may be sprayed on it from any angle is identified as Category R. For equipment intended for installation in such locations, the spray proof test procedure applies. Equipment that has passed the Category R requirements may be considered to meet the Category W requirement without further testing.

Category S

Equipment installed in locations where it may be subjected to the forces of a heavy stream of fluid such as would be encountered in aircraft de-icing, washing or cleaning operations is identified as Category S. For equipment intended for installation in such locations the continuous stream proof procedure applies. Water is used in this test to simulate the actual fluid forces. Equipment that has passed the Category S requirements may be considered to meet the Category W requirements without further testing.

10.3 Test Procedures

10.3.1 Drip Proof Test

Mount the equipment according to the manufacturer's specifications with all connectors and fittings engaged. With the equipment operating, subject it to water falling at a uniform rate from a minimum height of one meter above the top surface of the equipment under test for a minimum of 15 minutes. The test equipment shall emit a volume of water greater than 280 $l/m^2/hr$ dripping from a dispenser with 0.33 mm nominal diameter drip holes on a 25 mm pattern as shown in Figure 10-1. The drip hole pattern shall be sufficiently large to meet or exceed the horizontal cross sectional area of the equipment under test when installed in its normal position. At the conclusion of the test DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

10.3.2 Spray Proof Test

Mount the equipment according to the manufacturer's specification with all connectors and fittings engaged. With the equipment operating, subject it to a shower of water from a shower head nozzle as depicted in Figure 10-2. The water shall be directed perpendicular to the most vulnerable area(s) of the equipment as stated in the applicable equipment performance standards.

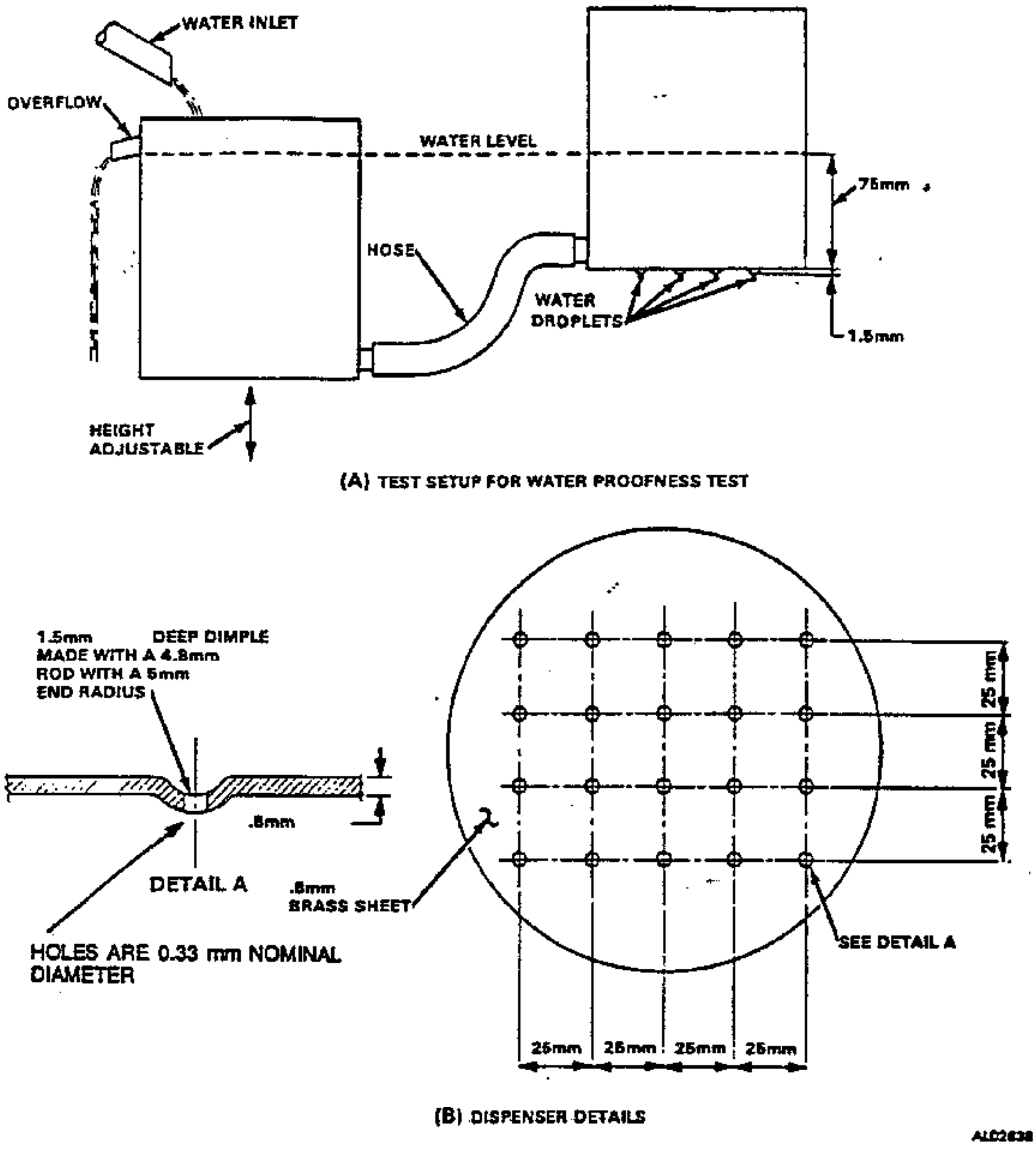
Each of the areas under test shall be subjected to the spray for a minimum of 15 minutes. If desired, the test may be applied simultaneously to more than one area at a time by using an appropriate number of shower heads. The shower head shall be located not more than 2.5 m from the area under test and shall emit a volume of water greater than 450 liters per hour. At the conclusion of the test DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

10.3.3 Continuous Stream Proof Test

This test is used to supplement the fluids susceptibility test in Section 11.0. Susceptible materials such as gaskets shall be subjected to the appropriate tests of Section 11.0 prior to the performance of this test. This test shall be performed with water at a temperature of 50 degrees C.

Mount the equipment according to the manufacturer's installation instructions in a manner that simulates the aircraft installation. Connectors or other fittings shall be connected as in normal operation. The equipment need not be operated during this test.

Subject the equipment, particularly in areas where parts are mated with a resilient gasket, to a continuous stream of water on all sides for a minimum five minutes on each side. The stream of water shall be of sufficient pressure to produce, through a 6.4 mm diameter nozzle, at least a six meter vertical stream of water. The equipment shall be subjected to this stream of water from a distance of one to two meters. At the conclusion of the test DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.



NOTE: Container size and number of holes as required to meet the flow rate requirement of paragraph 10.3.1.

Figure 10-1 Drip Proof Test Details

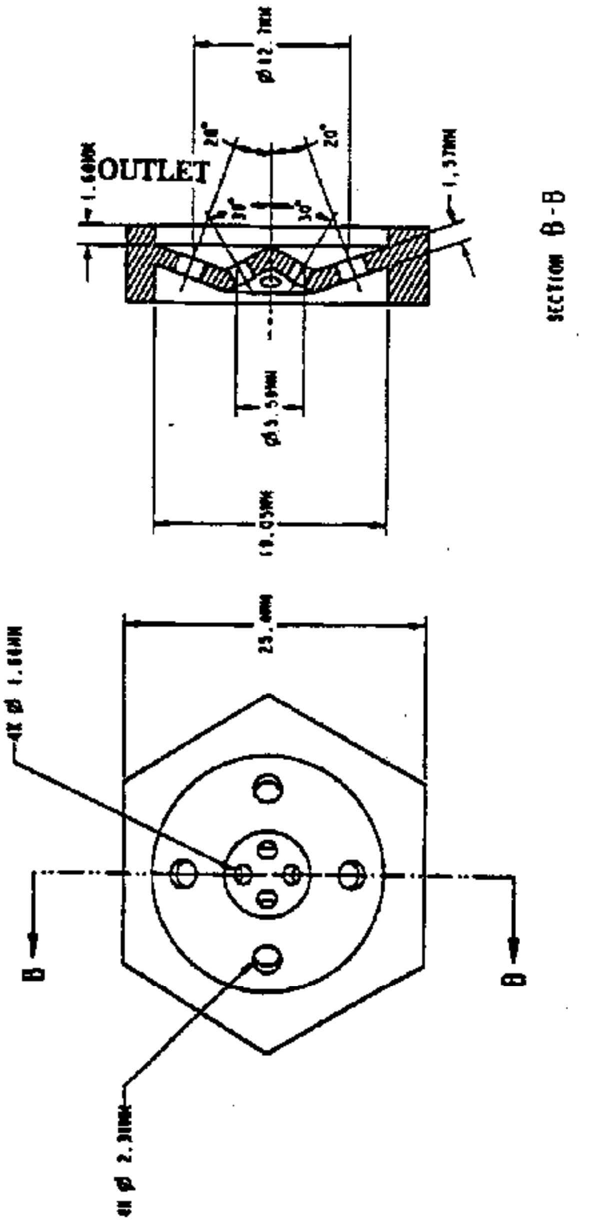


Figure 10-2 Shower Head Details

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 11

Fluids Susceptibility

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

11.0 FLUIDS SUSCEPTIBILITY

11.1 Purpose of the Test

These tests determine whether the materials used in the construction of the equipment can withstand the deleterious effects of fluid contaminants. Fluids susceptibility tests should only be performed when the equipment will be installed in areas where fluid contamination could be commonly encountered. The fluids are representative of those commonly used fluids encountered in airborne and ground operations. Fluids not listed herein and for which susceptibility tests are indicated shall be included in the relevant equipment specification.

11.2 Precautions

Since many contaminants may have flash points within the test temperature range, care should be taken to ensure that adequate safety measures are taken to limit the possibility of fire or explosion.

Some contaminants may themselves or in combination with other contaminants or with the test sample be toxic. Due consideration should be given to this possibility before commencing the tests.

11.3 Equipment Categories

Category F

Equipment that has passed the tests covered in this section is identified as Category F. Details of the test fluids involved and the methods used shall be provided in the Environmental Qualification Form (See Appendix A).

NOTE: *Sections 10.0 and 14.0 of this document cover waterproofness and salt spray tests, respectively. Section 11.0 covers seven general classes of other contaminating fluids. In addition there are 19 specific fluids that are used to test these classes. Table 11-1 contains the class of fluids, the specific fluids and the temperatures required in these tests.*

11.4 Test Procedures

11.4.1 Spray Test

Connect the equipment mechanically and electrically as defined in the relevant equipment specification. The equipment is not required to operate during this test and shall be at room ambient.

Spray the equipment with the appropriate fluid one or more times per day as necessary to maintain a wetted condition for a minimum of 24 hours. If it is difficult to maintain a wetted condition and the equipment specification requires the spray test rather than the immersion test, it shall be acceptable to thoroughly spray the equipment at intervals of four hours maximum. The spray shall be a fine mist maintained at the temperatures in Table 11-1 and shall be directed toward every major surface, seal and connector of the equipment sample under test. At the end of 24 hours, operate the equipment for at least 10 minutes.

Following this period, and without removing the excess fluid, the test specimen shall be placed in an appropriate chamber and subjected to a constant temperature of +65 degrees C for a minimum of 160 hours. At the end of this period, the test specimen shall be returned to room temperature and operated for a minimum of two hours.

NOTE: If the equipment is to be tested with more than one class of contaminating fluid, it should normally be tested with each fluid separately. However, simultaneous testing is permitted if required by the equipment specification. Fluids should not be pre-mixed prior to spraying, and the order of application should be as specified in the equipment specification. Unless otherwise noted in the equipment specification, the total exposure time for simultaneous application of fluids should be the same as the exposure time for a single fluid. The precautions noted elsewhere in this section should be observed.

Following the two-hour period, DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

11.4.2 Immersion Test

Connect the equipment mechanically and electrically as defined in the relevant equipment specification. The equipment is not required to operate during this test and shall be at ambient temperature.

Immerse the equipment in the appropriate fluid for a minimum of 24 hours. The fluid temperature shall be maintained at the temperature shown in Table 11-1 and shall cover the test specimen completely.

At the end of 24 hours, operate the equipment for at least 10 minutes while it is completely immersed in the fluid.

Following this period, remove the test specimen, place in an appropriate chamber and subject it to a constant temperature of +65 degrees C for minimum of 160 hours. At the end of this period, the test specimen shall be returned to room temperature and operated for a minimum of two hours.

Following the two-hour period, DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

11.5 Use of Material Specimens

Material specimen test may be used in place of equipment tests. The results of these tests shall assure that the material will protect the equipment from deleterious effects after being exposed to the relevant fluid in the manner defined in the equipment test procedures (Subsection 11.4).

NOTE: Material specimen tests are not permitted if the equipment is to be subsequently subjected to the continuous stream proof test (paragraph 10.3.3).

Class of Contaminating Fluid	Test Fluid	Fluid Temperature Degrees C
Fuels	Aviation Jet A Fuel Aviation Piston Engine Fuel	40 1/ 40 1/
Hydraulic Fluids	Mineral-Based Non-mineral Based Phosphate Ester-Based (Synthetic), Type IV 2/ Silicate Ester-Based (Synthetic) Silicone-Based (Synthetic) Synthetic Hydrocarbon Base	80 50 70 80 80 70
Lubricating Oils	Mineral-Based Ester-Based (Synthetic)	70 150
Solvents and Cleaning Fluids	Isopropyl Alcohol Denatured Alcohol 1,1,1 Trichloroethane	50 1/ 50 1/ 50
De-Icing Fluid	Ethylene Glycol Propylene Glycol AEA Type 1 3/ AEA Type 2 3/	50 50 50 50
Insecticides	Dichlorvos (DDVP) Pyrethrum-Based	20 20
Sullage	To be defined by the equipment specification	20

NOTES:

1/ *This temperature exceeds the critical flash point temperature. Testing should always be performed in a suitable pressure vessel.*

2/ *These fluids are electrically conductive. Suitable precautions should be taken after exposure to the fluids before operating the equipment.*

3/ *Association of European Airlines.*

Table 11-1 Classes of Test Fluids and Fluid Temperatures

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 12

Sand and Dust

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

12.0 SAND AND DUST

12.1 Purpose of the Test

This test determines the resistance of the equipment to the effects of blowing sand and dust where carried by air movement at moderate speeds. The main adverse effects to be anticipated are:

a. Penetration into cracks, crevices, bearings and joints, causing fouling and/or clogging of moving parts, relays, filters, etc.

b. Formation of electrically conductive bridges.

c. Action as nucleus for the collection of water vapor, including secondary effects of possible corrosion.

d. Pollution of fluids.

12.2 Categories of Equipment

Category D

Equipment installed in locations where the equipment is subjected to blowing sand and dust in the course of normal aircraft operations is identified as Category D and should be tested as recommended in the following paragraphs.

12.3 Test Procedure

12.3.1 Agent

Sand and dust used in a suitable test chamber vented to the atmosphere shall be raised and maintained at a concentration of 3.5 to 8.8 g/m^3 and shall meet the following characteristics:

a. 100 percent shall pass through a 100-mesh screen, i.e., diameter 0.15 mm.

b. 98 ±2% shall pass through a 140-mesh screen, i.e., diameter 0.10 mm.

c. 90 ±2% shall pass through a 200-mesh screen, i.e., diameter 0.075 mm.

d. 75 ±2% shall pass through a 325-mesh screen, i.e., diameter 0.045 mm.

e. The chemical composition shall be 97% to 99% silicon dioxide.

NOTE: 140-mesh silica flour is satisfactory for use in the performance of these tests but health and safety regulations regarding the use of this flour should be observed.

12.3.2 Exposure of the Equipment

The equipment shall be submitted to the sand and dust jet along each direction of each major orthogonal axis in succession. The jet velocity shall be maintained between 0.5 and 2.5 m/second.

NOTE *Unless otherwise required in the relevant specification, the equipment is not required to operate during the exposure period.*

12.3.3 First Cycle

With the internal temperature of the test chamber maintained at +25 degrees C and the relative humidity at not more than 30 percent, submit the equipment to a minimum exposure period of one hour along each direction of each major orthogonal axis in succession.

12.3.4 Second Cycle

With the internal temperature of the test chamber raised and stabilized at +55 degrees C and the relative humidity at not more than 30 percent, submit the equipment to a minimum exposure period of one hour along each direction of each major orthogonal axis in succession.

At the end of this exposure period, the equipment shall be removed from the chamber and cooled to room temperature. Externally accumulated sand and dust only on surfaces of the equipment required to verify proper operation (e.g. displays, connectors, test ports etc.) shall be removed by brushing or wiping, with care being taken to avoid introducing additional dust into the equipment. Under no circumstances shall dust be removed by either air blast or vacuum cleaning. After removing the excess sand and dust DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 13

Fungus Resistance

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

13.0 FUNGUS RESISTANCE

13.1 Purpose of the Test

These tests determine whether equipment material is adversely affected by fungi under conditions favorable for their development, namely, high humidity, warm atmosphere and presence of inorganic salts.

NOTES

A. *If all materials used in the construction of the equipment can be shown to be non-nutrients for the growth of fungi, either through their composition or through previous testing, this test is not required (See Subsection 13.3, Category F).*

B. *This test shall not be conducted after Salt Spray or Sand and Dust. A heavy concentration of salt may effect the fungal growth, and sand and dust can provide nutrients, which could compromise the validity of this test (see Subsection 3.2, "Order of Tests").*

13.2 General Effects

Typical problems caused by fungi growing on equipment are:

a. Microorganisms digest organic materials as a normal metabolic process, thus degrading the substrate, reducing the surface tension and increasing moisture penetration.

b. Enzymes and organic acids, produced during metabolism, diffuse out of the cells and onto the substrate and cause metal corrosion, glass etching, hardening of grease and other physical and chemical changes to the substrates.

c. The physical presence of microorganisms produces living bridges across components that may result in electrical failures.

d. The physical presence of fungi can also cause health problems and produce aesthetically unpleasant situations in which users will reject using the equipment.

13.3 Categories of Equipment

Category F

Equipment that is installed in an environment where it will be exposed to severe fungus contamination is identified as Category F and shall be subjected to the fungus resistance test. Equipment composed completely of proven non-nutrient materials can be identified as Category F without being subjected to the fungus resistance test. Nutrient materials that have been treated in a manner to render them non-nutrient may be considered non-nutrient. If non-nutrient material certification is utilized for this verification, this fact shall be declared on the Environmental Qualification Form (see Appendix A).

13.4 Apparatus

The apparatus required to conduct this test consists of chambers or cabinets together with auxiliary instrumentation capable of maintaining the specified condition of temperature and humidity. Provisions shall be made to prevent condensation from dripping on the test item. There shall be free circulation of air around the test item and the contact area of fixtures supporting the test item shall be kept to a minimum. When forced air is employed, the flow should not exceed one meter per second over the surface of the test specimen.

13.5 Test Procedures

13.5.1 Preparation of Mineral-Salts Solution

The solution shall contain the following:

Potassium dihydrogen orthophosphate	0.7 g
Potassium monohydrogen orthophosphate	0.7 g
Magnesium sulfate heptahydrate	0.7 g
Ammonium nitrate	1.0 g
Sodium chloride	0.005 g
Ferrous sulfate heptahydrate	0.002 g
Zinc sulfate heptahydrate	0.002 g
Manganous sulfate monohydrate	0.001 g
Distilled Water	1000 ml

Sterilize the mineral salts solution by autoclaving at 121 degrees C for 20 minutes. Adjust the pH of the solution by the addition of 0.01 normal solution of sodium hydroxide so that after sterilization the pH level is between 6.0 and 6.5. Prepare sufficient salt solutions for the required tests.

13.5.1.1 Purity of Reagents

Reagent grade chemicals shall be used in all tests. Unless otherwise specified, it is intended that all reagents shall conform to the specification of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

13.5.1.2 Purity of Water

Unless otherwise specified, references to water shall be understood to mean distilled water or water of equal purity.

13.5.2 Preparation of Mixed Spore Suspension

The following test fungi shall be used:

Fungi	ATCC[1]	NLABS[2]
Aspergillus niger	9642	386
Aspergillus flavus	9643	380
Aspergillus versicolor	11730	432
Penicillium funiculosum	11797	474
Chaetomium globosum	6205	459

Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. However, the culture of chaetomium globosum shall be cultured on strips of filter paper on the surface of mineral salts agar. (Mineral salts agar is identical to the mineral salts solution described in paragraph 13.5.1, but contains in addition 15.0 g of agar/liter.) The stock cultures may be kept for not more than four months at 6 ±4 degrees C, at which time subcultures shall be made and new stocks shall be selected from the subcultures. If genetic or physiological changes occur, obtain new cultures as specified above. Subcultures used for preparing new stock cultures or the spore suspension shall be incubated at 30 degrees C for seven to ten days. Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus a 10 ml portion of a sterile solution containing 0.05 g/liter of a non-toxic wetting agent such as sodium dioctyl sulfosuccinate or sodium lauryl sulfate. Use a sterile platinum or nichrome inoculating wire to scrape gently the surface growth from the culture of the test organism. Pour the spore charge into a sterile l25 ml glass-stoppered Erlenmeyer flask containing 45 ml of sterile water and 10 to 15 solid glass beads, five millimeters in diameter. Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps. Filter the dispersed fungal spore suspension through a six millimeter layer of glass wool, contained in a glass funnel, into a sterile flask. This process should remove large mycelial fragments and clumps of agar that could interfere with the spraying process. Centrifuge the filtered spore suspension aseptically and discard the supernatant. Resuspend the residue in 50 ml of sterile water and centrifuge. Wash the spores obtained from each of the fungi in this manner three times. Dilute the final washed residue with sterile mineral-salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ±200,000 spores/milliliter as determined with a counting chamber. Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension. The spore suspension may be prepared fresh each day and maintained at 6 ±4 degrees C not more than four days.

13.5.3 Viability of Inoculum Control

With each daily group of tests, place each of three pieces of sterilized filter paper, 2.54 cm square on hardened mineral-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer[3] until initiation of droplet coalescence. Incubate these at 30 degrees C at a relative humidity not less than 85 percent, and examine them after seven days of incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

1 American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland, 20852.

2 Pioneering Research Division, U.S. Army Natick Laboratories, Natick, Massachusetts, 01760.

3 An atomizer capable of providing 15,000 ±3,000 spores/cm^2.

13.5.4 Control Items

In addition to the viability of inoculum control, known susceptible substrates shall be inoculated along with the test item to insure that proper conditions are present in the incubation chamber to promote fungus growth. The control items shall consist of cotton duck 234 g strips that are 3.2 cm wide, that have been dipped into a solution containing 10% glycerol, 0.1% potassium dihydrogen orthophosphate, 0.1% ammonium nitrate, 0.025% magnesium sulfate, and 0.05% yeast extract (pH level 5.3), and from which the excess liquid has been removed. The strips should be hung to air dry before being inoculated and placed into the chamber.

13.5.5 Inoculation of Test Control

a. Mount the test and control items on suitable fixtures or suspend from hangers.

b. Precondition the chamber and its contents at 30 degrees C and 97 ±2% relative humidity for at least four hours.

c. Inoculate the test and control items with the mixed fungus spore suspension (paragraph 13.5.2) by spraying it on the test and control items in the form of a fine mist from a previously sterilized atomizer or nebulizer. In spraying the test and control items, care should be taken to cover all surfaces. If the surfaces are non-wetting, spray until initiation of droplet coalescence. Incubation is to be started immediately following the inoculation.

13.5.6 Incubation

a. Maintain the test chamber at 30 degrees C and 97 ±2% relative humidity (minimum) during the life of the test. Keep the test chamber closed during the incubation period, except during inspection or for addition of other test items.

b. After seven days, inspect the growth on the control items to be assured that the environmental conditions are suitable for growth. If inspection reveals that the environmental conditions are unsuitable for growth, the entire test shall be repeated.

c. If the control items show satisfactory fungus growth, continue the test for a period of 28 days from the time of inoculation or as specified in the equipment specification.

13.5.7 Inspection

At the end of the incubation period, inspect the test item immediately. If possible, inspect the item within the chamber. If the inspection is not completed in eight hours, return the test item to the humid environment for a minimum of twelve hours. Except for hermetically sealed equipment, open the equipment enclosure and examine both the interior and exterior for evidence of deterioration. The equipment shall then be tested to DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

13.5.8 Precautions

The fungi specified for this test are not normally considered a serious hazard for human handling. It is possible for an individual to be allergic to one of them, and for this reason it is wise to exercise care when performing the test. Surgical gloves may be worn to protect the hands, and care should be taken not to splash the suspension on other areas of the skin or on clothes.

It is also possible, during the incubation period in the test chamber, for a foreign spore, present as an unintentional intruder, to develop; some of these fungi thus present as native to some testing locations, may be injurious to the human system. For this reason there is a possibility that the specimen after exposure may be a hazard, and it should be handled with care.

The greatest danger, if some hazardous foreign spore is present on exposed specimens, is that small, dry, detached particles may become airborne and be carried into the lungs. This is only likely to happen after the specimen has dried out. If the specimen is carried quickly from the test chamber to a normal chemical fume hood before it has time to dry, the flow of air does not reach the operator and detached fragments cannot enter the nasal passages.

Detached portions of growth may be so small that no protection is offered by wearing a gauze mask and only a special respirator for sub-micron particles is effective. The use of a fume hood as suggested above, however, is considered an adequate precaution when performing this test.

Where the test location may contain such a harmful fungus, vestiges of it may remain in the test chamber and present a similar danger when it is being cleansed. High temperature steam, the preferred cleansing treatment, will render the chamber completely harmless. Where, however, fumigation with propylene oxide is adopted, it will be noted that fumigation prior to washing will ensure that all residues washed from the chamber are completely harmless.

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 14

Salt Spray

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

14.0 SALT SPRAY

14.1 Purpose of the Test

This test determines the effects on the equipment of prolonged exposure to a salt atmosphere or to salt spray experienced in normal operations.

The main adverse effects to be anticipated are:

a. Corrosion of metals.
b. Clogging or binding of moving parts as a result of salt deposits.
c. Insulation fault.
d. Damage to contacts and uncoated wiring.

NOTE *The salt spray test shall not be conducted prior to the fungus resistance test (see Subsection 3.2, «Order of Tests»).*

14.2 Categories of Equipment

Category S

When the equipment is installed in locations where it is subjected to a salt atmosphere in the course of normal aircraft operations, the equipment is identified as Category S and the salt spray test is applicable.

14.3 Apparatus

The apparatus used in the salt spray test shall include the following:

a. Exposure chamber with racks for supporting test items.

b. A salt solution reservoir with means for maintaining an adequate level of solution.

c. A means for atomizing the salt solution, including suitable nozzles and compressed air supply.

d. A means of heating and controlling chamber temperature.

e. A means for humidifying the air at temperatures above the chamber temperature.

14.3.1 Chamber

The chamber and all accessories shall be made of material that will not affect the corrosiveness of the fog, e.g. glass, hard rubber, plastic or kiln-dried wood other than plywood. In addition, all parts that come in contact with test items shall be made of materials that will not cause electrolytic corrosion. The chamber and accessories shall be constructed and arranged so that there is no direct impingement of the fog or dripping of the condensate on the test items; the fog circulates freely about all test items to the same degree, and no liquid that has come in contact with the test item returns to the salt-solution reservoir. The chamber shall be properly vented to prevent pressure build-up and allow uniform distribution of the salt fog. The discharge end of the vent shall be protected from strong drafts to prevent strong air currents in the test chamber.

14.3.2 Atomizers

The atomizers shall be designed and constructed to produce a finely divided, wet, dense fog. Atomizing nozzles shall be made of materials that are non-reactive to the salt solution.

14.3.3 Air Supply

The compressed air entering the atomizers shall be essentially free from all impurities, such as oil and dirt. Means shall be provided to humidify and warm the compressed air as required to meet the operating conditions. The air pressure shall be suitable to produce a finely divided dense fog with the atomizer or atomizers used. To avoid clogging the atomizers with salt deposition, the air should have a relative humidity of at least 85 percent at the point of release from the nozzle. A satisfactory method is to pass the air in very fine bubbles through a tower containing heated water that is automatically maintained at a constant level. The temperature of the water should be at least 35 degrees C. The permissible water temperature increases with the increasing volume of air and with the decreasing heat insulation of the chamber and the chamber's surroundings. However, the temperature should not exceed a value above which excessive moisture is introduced into the chamber (for example 43 degrees C at an air pressure of 84 kPa) or a value that makes it impossible to meet the requirements for operating temperature.

14.3.4 Preparation of Salt Solution

The salt shall be sodium chloride containing on the dry basis not more than 0.1 percent sodium iodide and not more than 0.5 percent of total impurities. Unless otherwise specified, a five ±l percent solution shall be prepared by dissolving five parts by weight of salt in 95 parts by weight of distilled or demineralized water. The solution shall be adjusted to and maintained at a relative density between the limits shown on Figure 14-1 by utilizing the measured temperature and density of the salt solution.

14.3.4.1 Adjustment of pH

The pH of the salt solution shall be maintained so that the solution atomized at 35 degrees C and collected by the method specified in subparagraph 14.3.6.3 will be in the pH range of 6.5 to 7.2. Only diluted chemically pure hydrochloric acid or chemically pure sodium hydroxide shall be used to adjust the pH. The pH measurement shall be made electrometrically, using a glass electrode with a saturated potassium chloride bridge, by a colorimetric method such as bromothymol blue or other measuring instruments, provided the results are equivalent to those obtained with the electrometric method. The pH shall be measured when preparing each new batch of solution and as specified in subparagraph 14.3.6.4.

14.3.5 Filter

A filter fabricated of noncorrosive materials similar to that shown in Figure 14-2 shall be provided in the supply line and immersed in the salt solution reservoir as illustrated in Figure 14-2.

14.3.6 Test Procedure

14.3.6.1 Temperature

The test shall be conducted with a temperature in the exposure zone maintained at 35 degrees C. Satisfactory methods for controlling the temperature accurately are by housing the apparatus in a properly controlled constant temperature room, by thoroughly insulating the apparatus and preheating the air to the proper temperature prior to atomization or by jacketing the apparatus and controlling the temperature of the water or of the air used in the jacket. The use of immersion heaters within the chamber for the purpose of maintaining the temperature within the exposure zone is prohibited.

14.3.6.2 Atomization

Suitable atomization has been obtained in chambers having a volume of less than 0.34 m^3 with the following conditions:

a. Nozzle pressure shall be as low as practicable to produce fog at the required rate.

b. Orifices shall be between 0.5 mm and 0.8 mm in diameter.

c. Atomization of approximately three liters of salt solution per 0.28 m^3 of chamber volume per 24 hours.

When using large size chambers having a volume considerably in excess of 0.34 m^3, the condition specified may require modification to meet the requirements for operating conditions.

14.3.6.3 Placement of Salt Fog Collection Receptacles

The salt fog conditions maintained in all parts of the exposure zone shall be such that a clean fog-collecting receptacle placed at any point in the exposure zone will collect from 0.5 to three milliliters of solution per hour for each 80 cm^2 of horizontal collecting area (10 cm diameter) based on an average test of at least 16 hours. A minimum of two receptacles shall be used, one placed at the perimeter of the test item nearest to the nozzle, and the other also at this perimeter of the test item but at the farthest point from the nozzle. Receptacles shall be placed so that they are not shielded by test items and so that drops of solution from test items or other sources will not be collected.

14.3.6.4 Measurement of Salt Solution

The solution, collected in the manner specified in subparagraph 14.3.6.3, shall have the sodium chloride content and pH specified in paragraph 14.3.4 when measured at a temperature of 35 degrees C. The salt solution from all collection receptacles used can be combined to provide the quantity required for the measurements specified.

14.3.6.4.1 Measurement of Sodium Chloride Content

The solution, maintained at the specified temperature, can be measured in a graduate of approximately 2.5 cm inside diameter. A small laboratory type hydrometer will be required for measurement within this volume.

14.3.6.4.2 Measurement of PH

The pH shall be measured as specified in paragraph 14.3.4.1.

14.3.6.4.3 Time of Measurements

The measurement of both sodium chloride and pH shall be made at the following times:

a. For salt fog chambers in continuous use, the measurements shall be made following each test.

b. For salt fog chambers that are used infrequently, a 24-hour test run shall be accomplished followed by the measurements. The test item shall not be exposed to this test run.

14.3.6.5 Preparation of Test Item

The test item shall receive minimum handling, particularly on the significant surfaces, and shall be prepared for test immediately before exposure. Unless otherwise specified, uncoated metallic or metallic-coated devices shall be thoroughly cleaned of oil, dirt and grease as necessary until the surface is free from water break. The cleaning methods shall not include the use of corrosive or protective films, nor the use of abrasives other than a paste of pure magnesium oxide. Test items having an organic coating shall not be cleaned with a solvent. Those portions of test items which come in contact with the support and, unless otherwise specified in the case of coated devices or samples, cut edges and surfaces not required to be coated, shall be protected with a suitable coating of wax or similar substance impervious to moisture.

14.3.6.6 Performance of Test

The test item shall be placed in the chamber and exposed to the salt fog for a period of a minimum of 48 hours or as specified in the equipment specification.

The test item shall then be stored in an ambient atmosphere for a minimum of 48 hours or as specified in the equipment specification for drying. At the end of the drying period, operate the test item and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

The test item shall then be inspected for corrosion. If necessary, a gentle wash in running water not warmer than 28 degrees C may be used. Any corrosion must be analyzed for its immediate or potential effect on proper functioning of the test item.

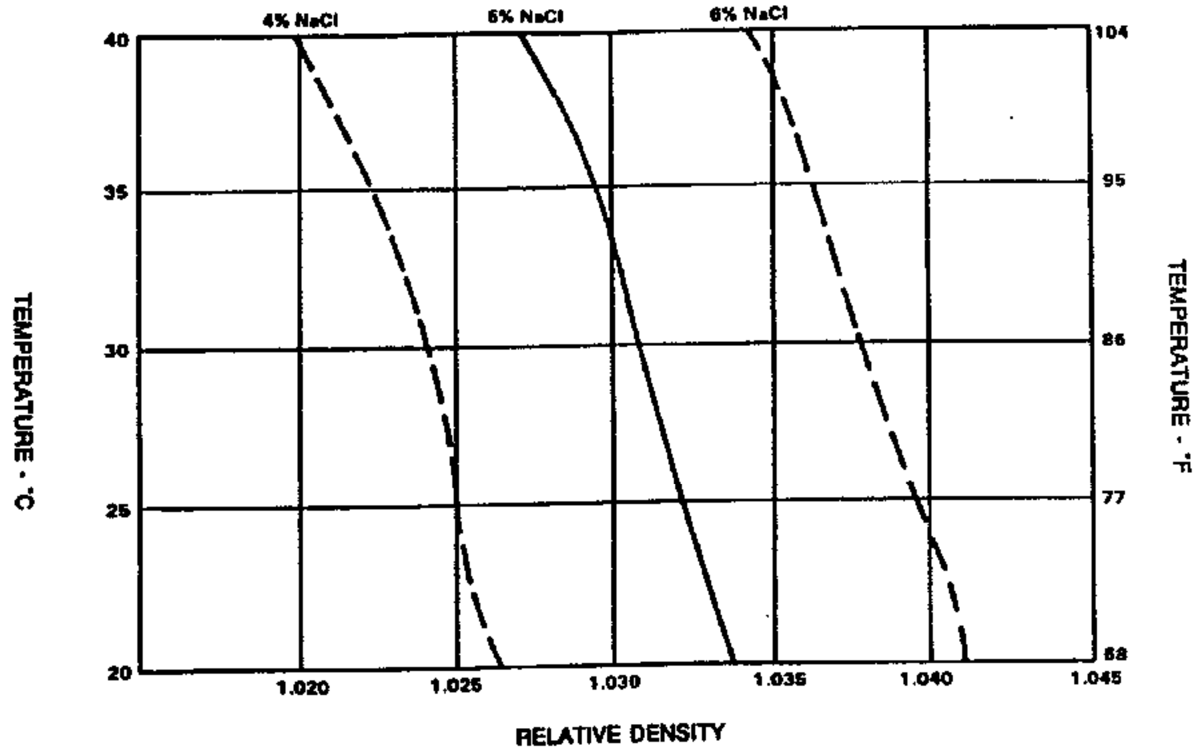


Figure 14-1 Relative Density Variations of the Salt Solution with Temperature

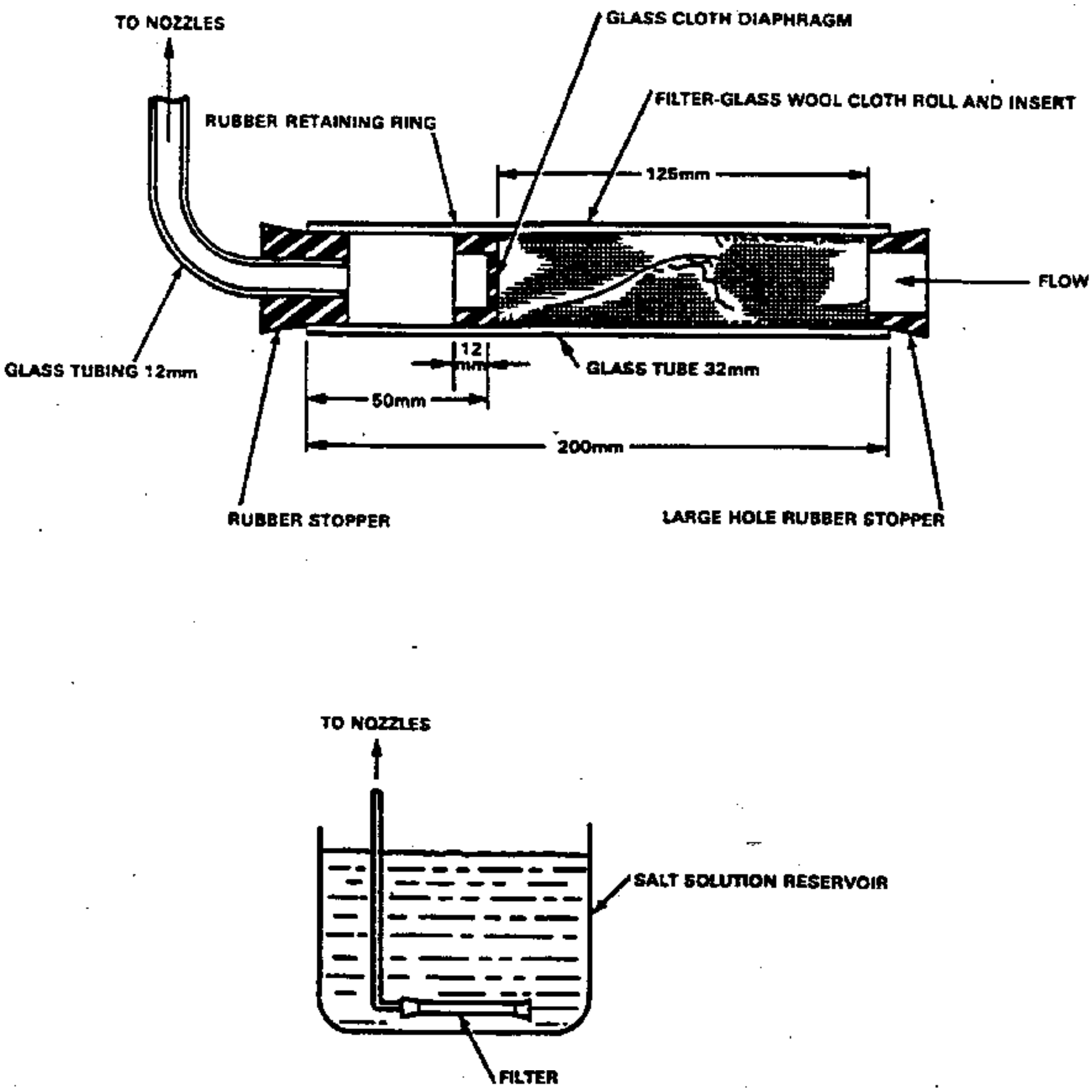


Figure 14-2 Location of Salt Solution Filter

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 15

Magnetic Effect

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

15.0 MAGNETIC EFFECT

15.1 Purpose of the Test

This test determines the magnetic effect of the equipment to assist the installer in choosing the proper location of the equipment in the aircraft.

15.2 Test Description

The magnetic effect of the equipment shall be determined in terms of the deflection of a free magnet (e.g., uncompensated compass) in a uniform magnetic field (as produced by the earth) having a horizontal intensity of 14.4 A/m ±10% when the equipment under test is positioned on the east-west line through the pivot of a magnet.

NOTE 1: *If the horizontal component of the magnetic field produced by the earth at the location of the test lab is within the tolerance stated above, the angular deflection used to determine equipment class in paragraph 15.3 shall be one degree (Dc = 1).*

NOTE 2: *If the horizontal component of the magnetic field produced by the earth at the location of the test lab exceeds the tolerance stated above, the angular deflection used to determine the equipment class in Subsection 15.3 shall be adjusted using the following formula:*

$$Dc = \frac{14.4}{\text{Horizontal Component of Ambient Field Strength}}$$

where,

Dc is the equivalent deflection angle to be used in determining equipment class.

15.3 Test Procedure

With the equipment operated in the steady state mode that produces the maximum magnet deflection and also oriented to produce the maximum magnet deflection, measure the distance between the magnet pivot and the nearest part of the equipment at which a deflection angle of Dc exists.

Equipment Class	Distance for a Deflection of Dc
Z	less than 0.3 m
A	between 0.3 m and I.0 m
B	between I.0 m and 3.0 m
C	greater than 3.0 m

NOTE 1: *To determine the distance accurately, record the distance measurements, which produce the deflection angle of Dc, while bringing the equipment and the magnet closer together and then further away. Use the minimum distance measured to determine the equipment class.*

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 16

Power Input

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

16.0 POWER INPUT

16.1 Purpose of the Test

This section defines test conditions and procedures for 115 Vac, 28 Vdc and 14 Vdc electrical power applied to the terminals of the equipment under test. Test conditions and procedures for equipment using other electrical power must be defined in applicable equipment performance standards.

16.2 Equipment Categories

Category A

Equipment intended for use on aircraft electrical systems where the primary power is from a constant frequency ac system, and where the dc system is supplied from transformer-rectifier units, is identified as Category A. A battery may be floating on the dc bus.

Category B

Equipment intended for use on aircraft electrical systems supplied by engine-driven alternator/rectifiers, or dc generators where a battery of significant capacity is floating on the dc bus at all times, is identified as Category B. Unless otherwise specified, test levels for 14 Vdc equipment are one half that shown for 28 Vdc equipment.

Category E

When equipment requires only ac input power and is tested to the ac input parameters, the equipment is identified as Category E.

Category Z

Equipment that may be used on all other types of aircraft electrical systems applicable to these standards is identified as Category Z. Category Z shall be acceptable for use in lieu of Category A. Examples of this category are dc systems supplied from variable speed generators where:

a. The dc supply does not have a battery floating on the dc bus, or

b. The control or protective equipment may disconnect the battery from the dc bus, or

c. The battery capacity is small compared with the capacity of the dc generators.

16.3 Emergency Electrical System Operation

Emergency electrical system operation is defined as the condition of the electrical system during flight when the primary electrical system becomes unable to supply sufficient or proper electrical power, thus requiring the use of an independent source(s) of emergency power which is limited in power output capabilities.

16.4 Standard Electrical Power Input Parameters (ac)

Certain electrical parameters are considered standard, i.e., not varying from nominal limits throughout the requirements of this section. All tests shall be conducted with the following standard parameters:

a. Phase Sequence

The voltage of the individual phases of a three phase supply are mutually displaced from each other by 120 electrical degrees; they are designated A, B and C, and reach their respective peak values in that sequence.

b. Phase Displacement

The phase displacement will be within the limits of 120 ±4 electrical degrees. This angle will be the relative displacement between the zero voltage points on the waveforms of the three phases.

c. Phase Voltage Unbalance

For normal electrical system operation, the maximum spread in phase voltages will not exceed *six* volts root-mean-square (rms) between the phase with the highest voltage and the phase with the lowest voltage for all aircraft operations. This spread will not exceed *eight* volts rms when the source of power is the emergency power system.

d. Waveform

The waveform will have a crest factor 1.41 ±0.15, a total harmonic content not exceeding five percent of the fundamental and an individual harmonic content not exceeding four percent of the fundamental. The total harmonic content will not exceed eight percent of the fundamental and the individual harmonic content will not exceed five percent of the fundamental when the source of power is the emergency power system.

e. Requirement

Compliance with subsequent requirements in this section infers compliance under these standard conditions.

16.5 Variable Electrical Power Input Parameters

The following defines quantitatively those parameters of electrical power input that are variable and the related test conditions where applicable, and are divided into those associated with NORMAL and ABNORMAL electrical system operation.

NOTE: The used power source should be able to supply the maximum current absorbed by the EUT.

16.5.1 Normal Operating Conditions (ac)

The following conditions and tests are applicable to Category A, Category E and Category Z equipment.

16.5.1.1 Voltage and Frequency (ac)

a. Definition

Maximum:	122 V - rms (highest phase) 120.5 V - rms (average of three phases) 420 Hz - normal 440 Hz - emergency
Nominal:	115 V - rms 400 Hz - normal
Minimum:	100 V - rms (lowest phase) 101.5 V - rms (average of three phases) 380 Hz - normal 360 Hz - emergency

b. Requirement for Single Phase Equipment

(1) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to 122 V rms at 420 Hz. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period.

(2) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to 100 V rms at 380 Hz. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period.

(3) For equipment designated to operate under emergency electrical system conditions:

(a) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to 100 V rms at 360 Hz. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period. Repeat, with operation of the equipment at 122 V rms 360 Hz.

(b) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to 122 V rms at 440 Hz. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period. Repeat, with operation of the equipment at 100 V rms 440 Hz.

c. Requirement for Three Phase Equipment

(1) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to an average of 120.5 V rms at 420 Hz. DETERMINE COMPLIANCE WITH APPLICABLE PERFORMANCE STANDARDS during this 30-minute period.

(2) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to an average of 101.5 V rms at 380 Hz. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period.

(3) For equipment designated to operate under emergency electrical system conditions:

(a) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to 101.5 V rms at 360 Hz. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period. Repeat with operation of the equipment at 120.5 V rms at 360 Hz.

(b) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to 120.5 V rms at 440 Hz. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period. Repeat with operation of the equipment at 101.5 V rms at 440 Hz.

(4) For equipment that operates from a three-phase electrical supply, operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted for a phase unbalance. The phase with the highest voltage shall be six volts rms (8 volts rms for equipment designed to operate under emergency electrical conditions) greater than the phase with the lowest voltage. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period.

16.5.1.2 Voltage Modulation (ac)

a. Definition

Voltage modulation is the cyclic variation, random variation, or both, about the mean level of the ac peak voltage that may be encountered during steady state electrical system operation caused by voltage regulation variations and speed variations. The voltage modulation will be 3.5 volts maximum peak-to-valley difference between the minimum and the maximum voltage reached on the modulation envelope applied for at least two minutes, or as indicated in the equipment specification.

The frequency components of the voltage modulation envelope waveform will not exceed the limits of Figure 16-1.

b. Requirement

The equipment, when subjected to this condition, shall operate within the applicable equipment performance standards. Any test requirement, if applicable, will be specified in the individual equipment performance standard.

16.5.1.3 Frequency Modulation (ac)

a. Definition

Frequency modulation is the cyclic or random variation, or both, of instantaneous frequency about a mean frequency during steady-state electrical system operation. The frequency modulation is normally within narrow frequency limits and occurs as a result of speed variations in a generator coupling and drive speed regulation. The variations of primary system frequency due to frequency modulation during any two-minute period or as specified in the equipment specification will be within a band about the mean frequency defined by Figure 16-2.

b. Requirement

The equipment, when subjected to this condition, shall operate within the applicable equipment performance standard. Any test requirement, if applicable, will be specified in the individual equipment performance standard.

16.5.1.4 Momentary Power Interruptions (ac)

a. Definition

Transfer of power sources can result in power interruptions for periods up to 200 ms.

b. Requirement for Equipment with Digital Circuits

This test is applicable only to equipment that incorporates digital circuitry and/or memory devices, including equipment with delay circuits.

This type of equipment is sensitive to momentary power interruptions that can cause aberrations in performance. Such transient power interruptions may be of any function of V-transient and T-transient where V_t may have any value between V-steady state and zero, and T_t may be any value from 0 to 200 milliseconds. Since there are a multitude of such combinations, this test procedure selects discrete values that are considered effective for determining equipment performance.

Test Procedures

The equipment shall be fully operational.

Nominal voltage and frequency shall be applied prior to each test condition.

Enterable data, whether manually or automatically loaded, shall be entered and all related displays functioning prior to each test condition.

In each operating mode of the equipment, apply each of the test conditions of Table 16-1 at least twice.

Monitor the performance of the equipment (including any equipment/system normally operated in parallel) both during and subsequent to application of the test.

After exposure, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE : *Any requirement for performance of the equipment during application of test will be specified in the equipment performance standard.*

c. Requirement for Other Equipment

This test is applicable to all equipment that does not incorporate digital circuitry and/or memory devices as defined in subparagraph 16.5.1.4 b.

Test Procedures

With the equipment operating at its design voltage(s) and nominal frequency, interrupt the power a minimum of five times for a period of 50 ms. Repeat this procedure for an interrupt period of 200 ms. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. Manual or automatic reset is permitted if allowed by the individual specification.

16.5.1.5 Normal Surge Voltage (ac)

a. Definition

A normal surge is a variation from the controlled steady-state level, resulting from the inherent regulation of the electrical power supply system in response to disturbances imposed by normal system operations, such as load switching and remedial action by the regulator.

b. Requirement

(1) Operate the equipment at a voltage of 115 V rms ±1 V rms for five minutes. Then cycle the voltage three times as indicated below:

Increase the voltage to 160 V rms ±2 V rms for 30 ms. Return the voltage to 115 V rms ±1 V rms for five seconds.

Decrease the voltage to 60 V rms ±1 V rms for 30 ms. Return the voltage to 115 V rms ±1 V rms for five seconds.

(2) The supply frequency shall be 400 Hz ±5 Hz. The voltage surges should be applied and monitored in a manner similar to that in Figure 16-3.

(3) During the normal electric system surges, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE: *Unless so stated in the equipment performance standard, equipment may have degraded performance during the surge and must meet the specified performance when returned to nominal voltage and frequency.*

(4) Following application of the voltage surges, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE: If the equipment performance standard requires that performance be met during the abnormal surge voltage test of subparagraph 16.5.3.3 and abnormal undervoltage test of subparagraph 16.5.3.2, it is not necessary to run the above test.

16.5.2 Normal Operating Conditions (dc)

The following conditions and tests are applicable to Category A, Category B and Category Z equipment.

16.5.2.1 Voltage (Average Value dc)

a. Definition

Voltage	Categories		
	A and Z	Category B	
Maximum:	30.3 V	30.3 V	15.1 V
Nominal:	27.5 V	27.5 V	13.8 V
Minimum:	22.0 V	22.0 V	11.0 V
Emergency Operation:	18.0 V	18.0 V	9.0 V

b. Requirement

(1) Operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to the appropriate maximum voltage. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period. The test may be run at the abnormal voltage levels to satisfy both normal and abnormal operating conditions.

(2) Operate the equipment at the nominal voltage for at least one minute, then adjust the primary power to the appropriate minimum voltage and operate the equipment at maximum duty cycle for at least 30 minutes. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period. The test may be run at the abnormal voltage levels to satisfy both normal and abnormal operating conditions.

(3) For equipment designated to operate under emergency electrical system conditions, operate the equipment at maximum duty cycle for at least 30 minutes with the primary power adjusted to the appropriate emergency voltage. DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS during this 30-minute period.

16.5.2.2 Ripple Voltage (dc)

The requirements of this condition are found in Subsection 18.3.

16.5.2.3 Momentary Power Interruptions (dc)

a. Definition

Transfer of power sources can result in power interruptions for any period up to 200 ms for Category A and 50 ms for Category B equipment, and 1.0 second for Category Z equipment.

b. Requirement for Equipment With Digital Circuits

For equipment that incorporates digital circuitry and/or memory devices, including equipment with delay circuits, conduct the test defined in subparagraph 16.5.1.4 b.

c. Requirement for Other Equipment

This test is applicable to all equipment that does not incorporate digital circuitry and/or memory devices.

Test Procedures

With the equipment operating at its design voltage(s), interrupt the power a minimum of five times for a period of 50 ms for each category of equipment. Repeat this procedure for an interrupt period of 200 ms for Category A equipment, and 1 second for category Z equipment.

DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. Manual reset is permitted if allowed by the individual specification.

16.5.2.4 Normal Surge Voltage (dc)

a. Definition

A normal surge is a variation from the controlled steady-state level. It results from the inherent regulation of the electrical power supply system in response to disturbances that are imposed by normal system operations, suck as load switching and remedial action by the regulator.

b. Requirement

(1) Operate the equipment at a voltage of 27.5 V dc ±0.5 V dc for five minutes, then cycle the voltage three times as indicated below:

Increase the voltage to 40 V dc ± V dc for 30 ms for Category A and Category B equipment, and to 50 V dc ± V dc for 50 ms for Category Z equipment. Return the voltage to 27.5 V dc ± for five seconds.

Decrease the voltage to 15 V dc ±0.5 V dc for Category A and Category B equipment, and to 12 V dc ±0.5 V dc for Category Z equipment for 30 ms. Return the voltage to 27.5 V dc ±0.5 V dc for five seconds.

(2) The voltage surge should be applied and monitored in a manner similar to that in Figure 16-4. (These voltage values are halved for 14.0 V dc nominal equipment.)

(3) During the normal electrical system surges, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE : *Unless so stated in the individual equipment performance standard, equipment may have degraded performance during the surge and must meet the specified performance when returned to nominal voltage.*

(4) Following application of the voltage surges, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE: *If the individual equipment performance standard requires that performance be met during the abnormal voltage of 15 V dc ±0.5 V dc or lower, it is not necessary to run the above test.*

16.5.2.5 Engine Starting Undervoltage Operation (dc)

a. Definition

This requirement applies to category Z and 28 volt category B equipments. During engine starting, momentary voltages in the range from 10.0 to 20.5 V dc may occur for any duration up to 30 seconds or as indicated in the equipment specification.

b. Requirement

With the equipment energized at nominal rated voltage, decrease the input voltage to 10.0 V dc and increase 0.15 volts per second for 30 seconds, then return to rated voltage or as indicated in the equipment specification. During this period the equipment performance can fall to a level stipulated in the equipment specification. Return the voltage to its nominal value and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

16.5.3 Abnormal Operating Conditions (ac)

The following conditions and tests are applicable to Category A, Category E and Category Z equipment.

16.5.3.1 Voltage Steady State (ac)

a. Definition

Abnormal voltage limits which may be encountered are:

Maximum: 134 V - rms (highest phase)
132.5 V - rms (average of three phases)

Minimum: 97 V - rms (lowest phase)
98.5 V - rms (average of three phases)

Nominal power supply frequency shall be applied for the following requirements.

b. Requirement for Single Phase Equipment

(1) Operate the equipment for at least five minutes with the primary power adjusted to 134 V rms. With the equipment still energized, reduce the primary power to nominal rated voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

(2) Operate the equipment for at least five minutes with the primary power adjusted to 97 V rms. With the equipment still energized, increase the primary power to nominal rated voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE: Any requirement for performance of the equipment during application of the abnormal voltage will be specified in the equipment performance standard.

c. Requirement for Three Phase Equipment

(1) Operate the equipment for at least five minutes with the primary power adjusted to an average of 132.5 V rms. With the equipment still energized, reduce the primary power to nominal rated voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

(2) Operate the equipment for at least five minutes with the primary power adjusted to an average of 98.5 V rms. With the equipment still energized, increase the primary power to nominal rated voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE : Any requirement for performance of the equipment during application of the abnormal voltage will be specified in the equipment performance standard.

16.5.3.2 Momentary Undervoltage Operation (ac)

a. Definition

Momentary voltages in the range from zero to 97 V rms may occur for any duration up to seven seconds.

b. Requirement

The equipment, when exposed to this condition, shall operate within the applicable equipment performance standards when returned to its normal operating voltage range.
With the equipment energized at nominal rated voltage and frequency, decrease the input ac voltage to 60 V rms, or as otherwise specified in the equipment specification, for seven seconds. With the equipment still energized, adjust the primary power to nominal rated voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

16.5.3.3 Abnormal Surge Voltage (ac)

a. Definition

An abnormal surge is a variation from the controlled steady-state level, resulting from the inherent regulation of the electrical power supply system and remedial action by the regulator, such as during fault clearance. The envelope of equipment step function of ac voltage surges shall be within the limits defined by Figure 16-5.

b. Requirement

With the equipment operating at its design voltage(s) and nominal frequency, apply to each of the primary input leads, voltage surges of 180 V rms for 100 ms and 148 V rms for one second. The voltage surges should be applied and monitored in a manner similar to that in Figure 16-3.

Apply each surge three times at ten-second intervals. Following application of voltage surges, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

16.5.4 Abnormal Operating Conditions (dc)

The following conditions and tests are applicable to Category A, Category B and Category Z equipment. Since all testing is conducted at nominal voltage, all environments may be performed and voltage set back to nominal then DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. Instead of testing following each set of environment conditions.

16.5.4.1 Voltage Steady State (dc)

a. Definition

Abnormal voltage limits that may be encountered are:

Voltage	Categories		
	A and Z	Category B	
Maximum:	32.2 V	32.2 V	16.1 V
Nominal:	27.5 V	27.5 V	13.8 V
Minimum:	20.5 V	20.5 V	10.0 V

b. Requirement

(1) Operate the equipment for at least five minutes with the primary power adjusted to the appropriate maximum voltage. With the equipment operating, reduce the primary power to nominal rated voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

(2) Operate the equipment at the nominal voltage for at least one minute, then adjust the primary power to the appropriate minimum voltage and operate the equipment for at least five minutes. With the equipment still energized, increase the primary power to nominal rated voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE: Any requirement for performance of the equipment during application of the abnormal voltage will be specified in the equipment performance standard.

16.5.4.2 Low Voltage Conditions (dc) (Category B Equipment)

a. Definition

Voltages in the range from zero to the appropriate minimum voltage may occur for any duration up to ten minutes.

b. Requirement

Operate the equipment at the nominal voltage for at least one minute, then adjust the input power voltage(s) to the appropriate minimum voltage and operate the equipment for at least one minute. With the equipment still energized, decrease the input power voltage(s) linearly to zero over a period of 10 minutes. With the equipment still connected, adjust the input power voltage(s) to the equipment's appropriate nominal voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE: For this test, equipment which derives ac power from an inverter shall be considered as dc-operated equipment.

16.5.4.3 Momentary Undervoltage Operation (dc)

a. Definition

Voltages may momentarily vary below nominal for any duration up to seven seconds.

b. Requirement

The equipment, when exposed to this condition, shall operate within the applicable equipment performance standards when returned to normal operating voltage range.

With the equipment energized at nominal rated voltage, decrease the input dc voltage to 12.0 V (or 6 V for 14 Vdc equipments) for seven seconds. With the equipment still energized, adjust the input dc voltage to nominal rated value and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

16.5.4.4 Abnormal Surge Voltage (dc)

a. Definition

An abnormal surge is a variation from the controlled steady-state level, resulting from the inherent regulation of the electrical power supply system and remedial action by the regulator, such as during fault clearance. The transient surge voltages that may be encountered are shown in Figure 16-6.

b. Category Z Requirements

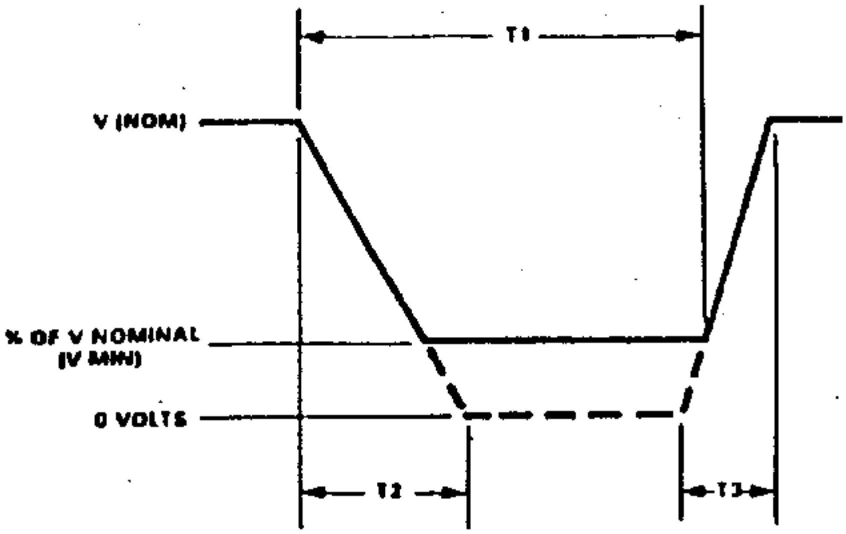
With the equipment operating at its appropriate nominal voltage, apply to the positive (dc) input lead voltage surges of 80 V dc for 100 ms and 48 V dc for one second. The voltage surges should be applied and monitored in a manner similar to that in Figure 16-4. Apply each voltage surge three times at ten-second intervals. Following this test, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

c. Category A

With the equipment operating at its appropriate nominal voltage, apply to the positive (dc) input lead voltage surges of 46.3 V dc for 100 ms and 37.8 V dc for one second, unless otherwise specified in the equipment specifications. The voltage surges should be applied and monitored in a manner similar to that in Figure 16-4. Apply each voltage surge three times at ten-second intervals. Following this test, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

d. Category B

With the equipment operating at its appropriate nominal voltage, apply to the positive (dc) input lead voltage surges of 60 V dc for 100 ms and 40 V dc for one second, unless otherwise specified in the equipment specifications. The voltage surges should be applied and monitored in a manner similar to that in Figure 16-4. (These voltage values are halved for 14.0 V equipment.) Apply each voltage surge three times at ten-second intervals. Following this test, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.



NOTES 1. *Definitions:*

T1 Power interrupt time.

T2 Time it would take for the applied voltage to decay from V (nom) to zero volts.

T3 Time it would take for the applied voltage to rise from zero to V (nom) volts.

V MIN The minimum level (expressed as a percentage of V NOMINAL) to which the applied voltage is permitted to decay.

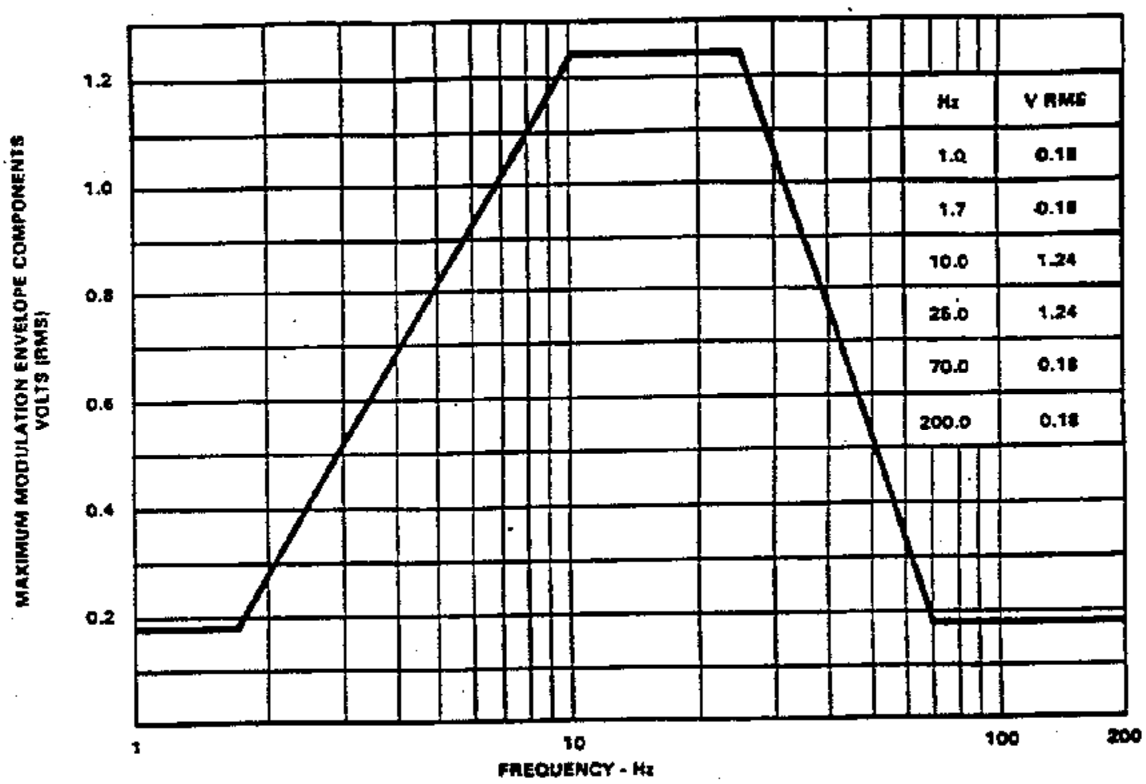
2. *Tolerance to T1, T2, T3 = ±10%.*

3. *Test condition numbers 8 and 15 are for category Z, dc powered equipment only.*

Applicable Category	A, B, E, Z				A, E, Z			Z	A, B, E, Z			A, E, Z			Z
Test Condition No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T1 (Milliseconds)	2	10	25	50	75	100	200	1000	10	25	50	75	100	200	100 0
T2 (Milliseconds)	<1	20*	20	20	20	20	20	20	50*	50*	50	50	50	50	50
T3 (Milliseconds)	<1	5	5	5	5	5	5	5	20	20	20	20	20	20	20
% of V Nominal (V min)	0	50	15	10	5	0	0	0	80	50	0	15	5	0	0

* Voltage will not reach zero in this test condition.

Table 16-1 Test Conditions for Equipment with Digital Circuits



RMS VOLTAGE OF COMPONENTS OF VOLTAGE MODULATION ENVELOPE

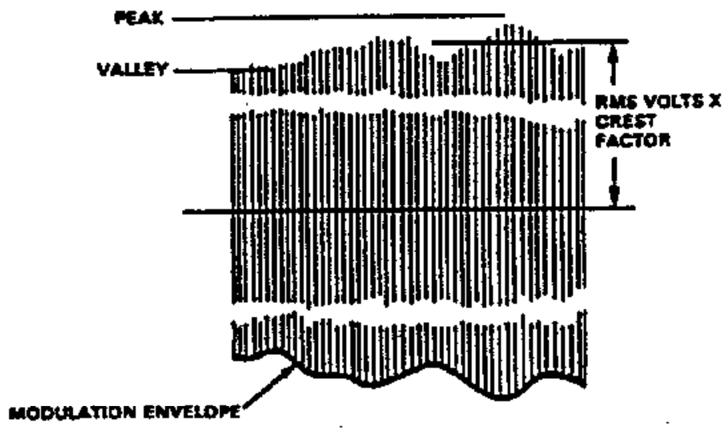


Figure 16-1 Frequency Characteristics of AC Voltage Modulation Envelope

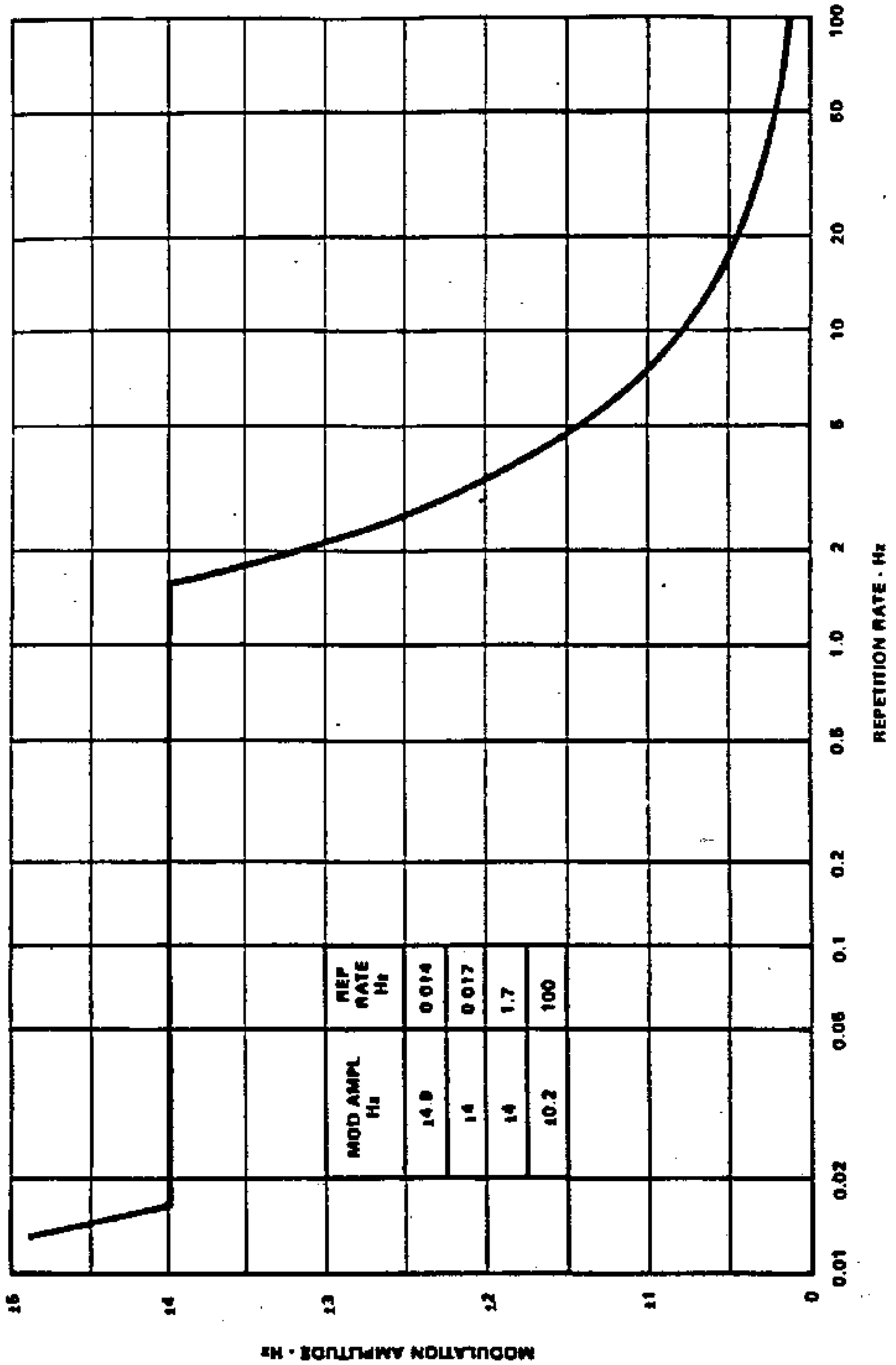
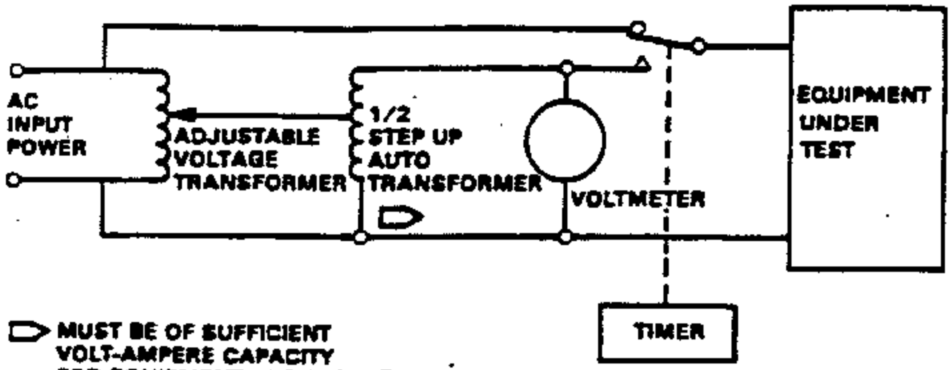


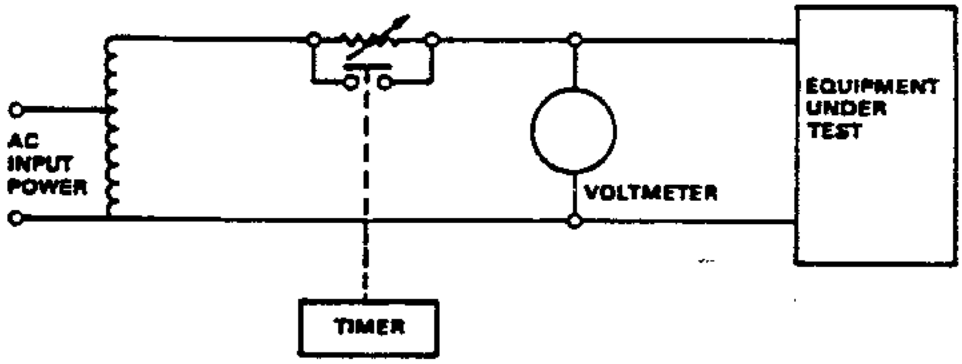
Figure 16-2 Characteristics of AC Frequency Modulation



MUST BE OF SUFFICIENT VOLT-AMPERE CAPACITY FOR EQUIPMENT UNDER TEST

CIRCUIT A

NOTE: EQUIPMENT UNDER TEST WILL RECEIVE ZERO POWER DURING TIMER SWITCHING.



CIRCUIT B

NOTE: CIRCUIT B IS OPTIONAL AND CAN ONLY BE USED WHEN THE SOURCE IMPEDANCE IS NOT CRITICAL TO THE EQUIPMENT PERFORMANCE.

Figure 16-3 AC Equipment Surge Voltage Test

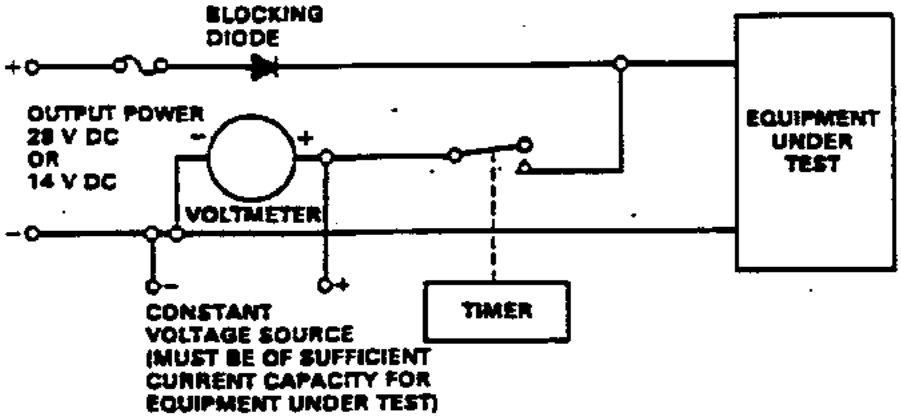


Figure 16-4 DC Equipment Surge Voltage Test

SURGE LIMIT	
SEC	$V_P/\sqrt{2}$
5.0	132
3.0	135
1.0	148
0.4	168
0.2	176
0.1	180
0.01	180

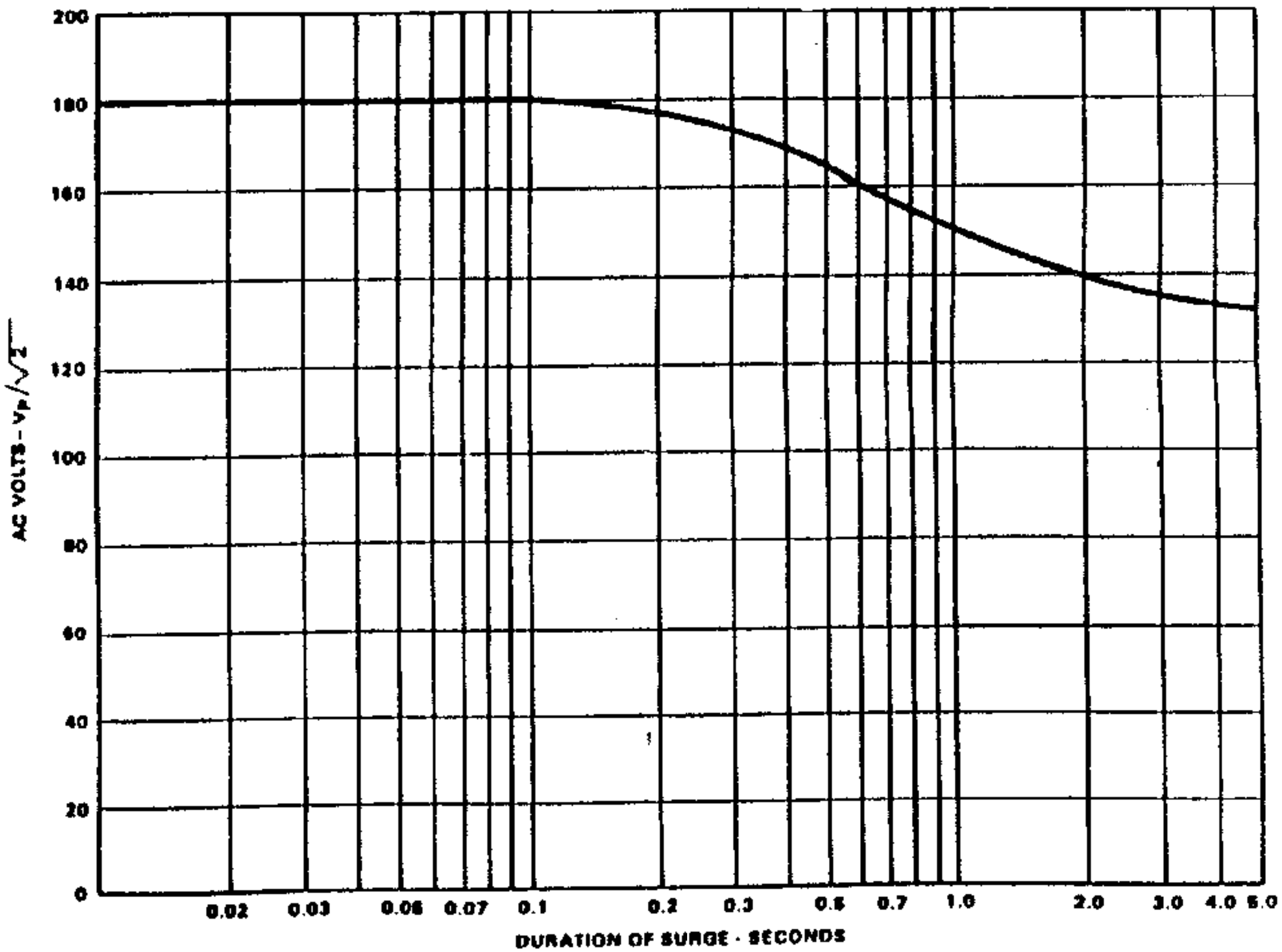


Figure 16-5 Envelope of Equivalent Step Functions of AC Voltage Surges

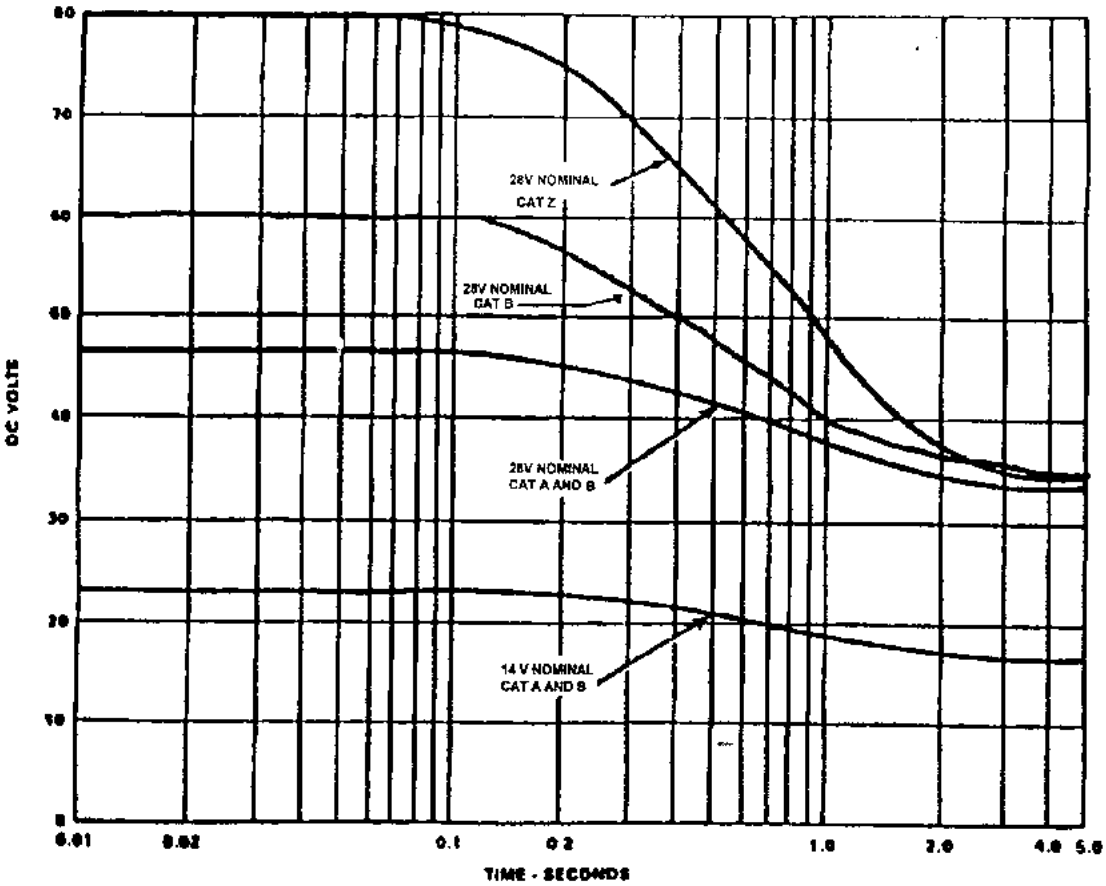


Figure 16-6 Typical dc Surge Voltage Characteristics

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 17

Voltage Spike

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

17.0 VOLTAGE SPIKE

17.1 Purpose of the Test

This test determines whether the equipment can withstand the effects of voltage spikes arriving at the equipment on its power leads, either ac or dc. The main adverse effects to be anticipated are:

a. Permanent damage, component failure, insulation breakdown.

b. Susceptibility degradation, or changes in equipment performance.

17.2 Equipment Categories

Category A

Equipment intended primarily for installation where a high degree of protection against damage by voltage spikes is required is identified as Category A.

Category B

Equipment intended primarily for installations where a lower standard of protection against voltage spikes is acceptable is identified as Category B.

17.3 Test Setup and Apparatus

The transient generator used shall produce the waveform shown in Figure 17-1. A typical test setup is shown in Figure 17-2. Any method of generating the spike may be used if the waveform complies with Figure 17-1.

17.4 Test Procedure

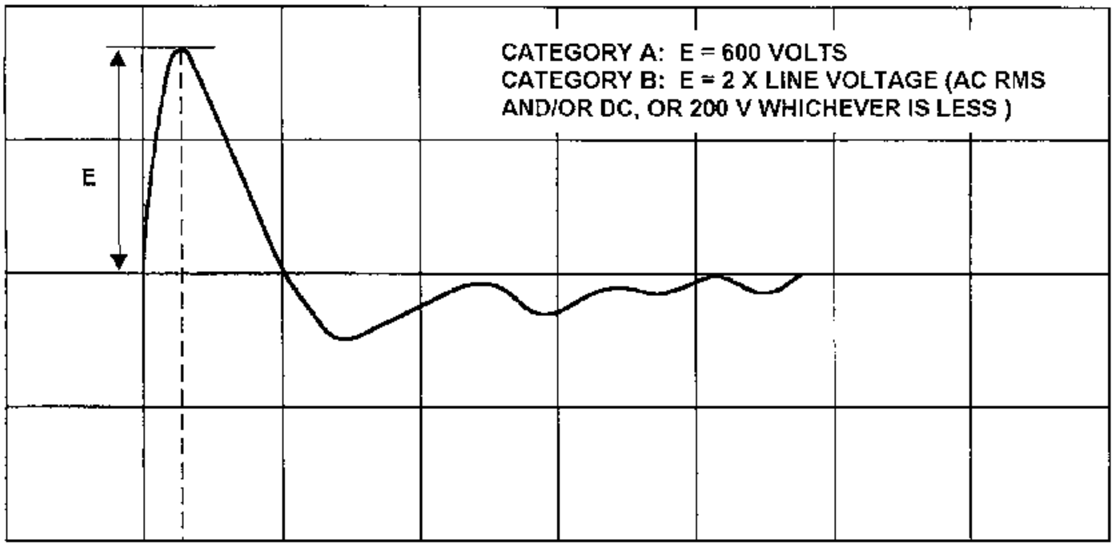
The transient wave shape shall be verified in accordance with Figure 17-1, with the equipment under test disconnected.

With the equipment operating at its design voltage(s), apply to each primary power input a series of positive and negative spikes described in Figure 17-1. Apply a minimum of 50 transients of each polarity within a period of one minute.

Repeat the test for each operating mode or function of the equipment.

After application of the spikes, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

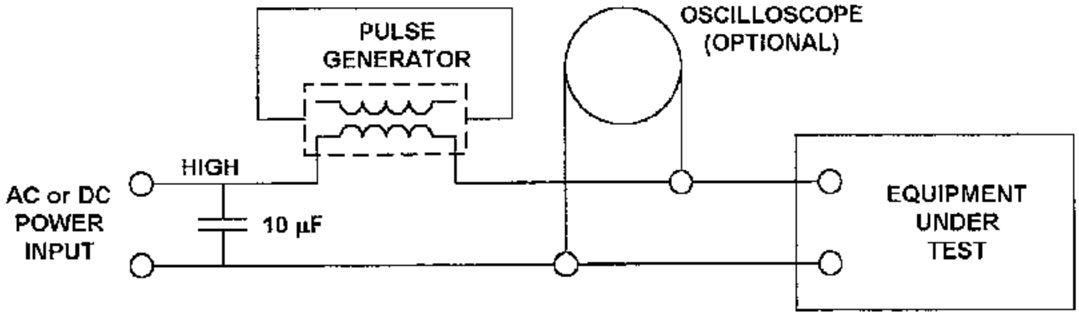
NOTE: *If performance is measured during the application of this test, then the performance requirements contained in the applicable equipment performance standard apply.*



THE WAVEFORM SOURCE IMPEDANCE SHALL BE 50Ω ±10% THE SPECIFIED VOLTAGE AND DURATIONS ARE FOR OPEN CIRCUIT CONDITIONS ONLY. THE PEAK VOLTAGE MAY BE SUBSTANTIALLY LOWER WITH THE EQUIPMENT CONNECTED. THE TESTER SOURCE IMPEDANCE CAN BE VERIFIED BY TESTING WITH A 50SΩ LOAD RESISTOR AND SHOULD PRODUCE ONE HALF OF THE SPECIFIED VOLTAGE ±10%.

<u>NOTE:</u> *The waveform shown above is typical. The waveform requirement is accomplished if the pulse risetime is less than or equal to 2μsec and the total pulse duration is at least 10μsec.*

Figure 17-1: Voltage Spike Waveform



NOTE: *For equipment drawing high currents, alternate test methods may be required (To avoid saturating transformer etc.).*

Figure 17-2: Voltage Spike Test Setup

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 18

Audio Frequency Conducted Susceptibility Power Inputs

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

18.0 AUDIO FREQUENCY CONDUCTED SUSCEPTIBILITY - POWER INPUTS (CLOSED CIRCUIT TEST)

18.1 Purpose of the Test

This test determines whether the equipment will accept frequency components of a magnitude normally expected when the equipment is installed in the aircraft. These frequency components are normally harmonically related to the power source fundamental frequency.

18.2 Equipment Categories

Category A

Equipment intended for use on aircraft electrical systems where the primary power is from a constant frequency ac system, and where the dc system is supplied from transformer-rectifier units, is identified as Category A. A battery may be floating on the dc bus.

Category B

Equipment intended for use on aircraft electrical systems supplied by engine-driven alternator/rectifiers, or dc generators where a battery of significant capacity is floating on the dc bus at all times, is identified as Category B.

Category E

When equipment requires only ac input power and is tested to the ac input parameters, the equipment is identified as Category E.

Category Z

Equipment that may be used on all other types of aircraft electrical systems applicable to these standards is identified as Category Z. Category Z shall be acceptable for use in place of Category A. Examples of this category are dc systems supplied from variable-speed generators where:

a. The dc power supply does not have a battery floating on the dc bus, or
b. Control or protective equipment may disconnect the battery from the dc bus, or
c. The battery capacity is small compared with the capacity of the dc generators.

18.3 Test Procedures

18.3.1 DC Input Power Leads

Connect the equipment under test as shown in Figure 18-1. Apply a sine wave audio frequency signal successively in series with each ungrounded dc input power lead. While varying the audio frequency of the applied signal and with the rms amplitude of this signal at the value specified in Figure 18-2 or Figure 18-3 , DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

18.3.2 AC Input Power Leads

Connect the equipment under test as shown in Figure 18-1. Apply a sine wave audio frequency signal successively in series with each ungrounded ac input power lead, while varying the frequency of the applied signal between 750 and 15,000 Hz.

Maintain the rms amplitude of this signal at not less than five percent of the nominal ac input voltage and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

18.4 General Remarks

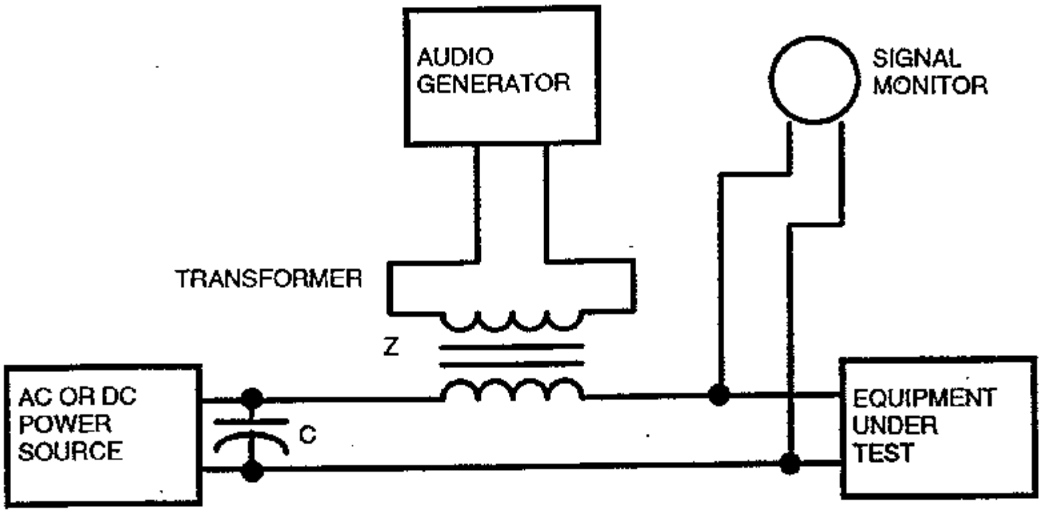
a. If the impedance of the test power leads is such that excessive power will be required to generate the specified audio signal voltage level, the test conditions will be adequately satisfied by the use of an audio amplifier with a maximum output of 30 W. The impedance of the output of the transformer shall be 0.6 ohm ±50%.

b. For dc input power leads, paragraph 18.3.1, a large capacitor (100 microfarads or more) shall be connected across the dc power source. For AC input power a 10 microfarad capacitor shall be connected across the power source.

c. When a transformer is used to couple the audio frequency energy into the power lead, it must be capable of performing adequately when the ac or dc load current drawn by the equipment under test flows through its secondary winding.

d. On ac lines, a phase shifting network may be used to eliminate the power frequency component at the signal monitor.

e. Caution must be exercised so that reflected voltages developed by input power current do not damage the audio power source generation system.



C ≥ 100 microfarads for DC power only
C = 10 microfarads for AC power only
Z = 0.6 ohms ± 50%

Figure 18-1 Test Setup For Audio Frequency Conducted Susceptibility Test (For AC And DC Power Lines)

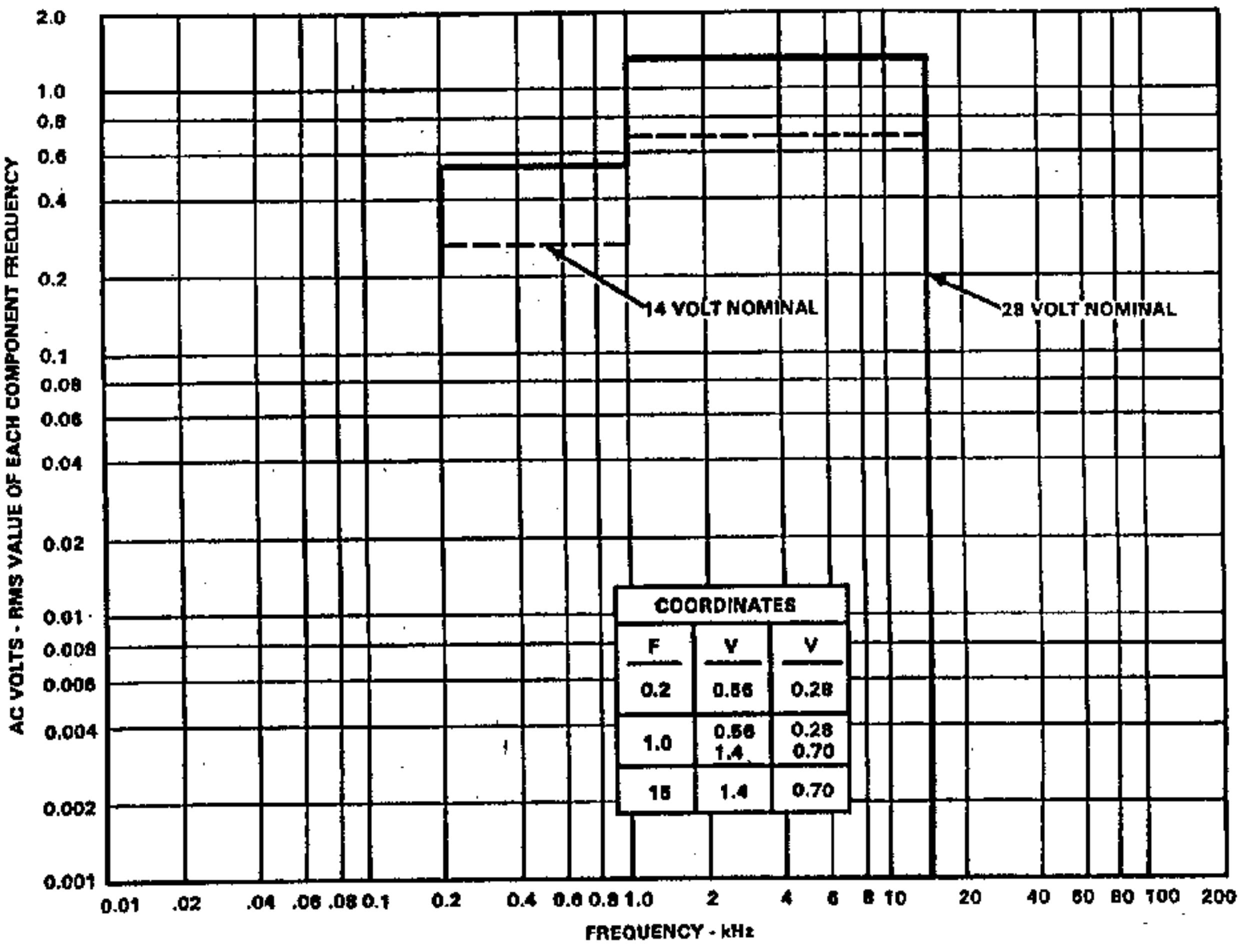
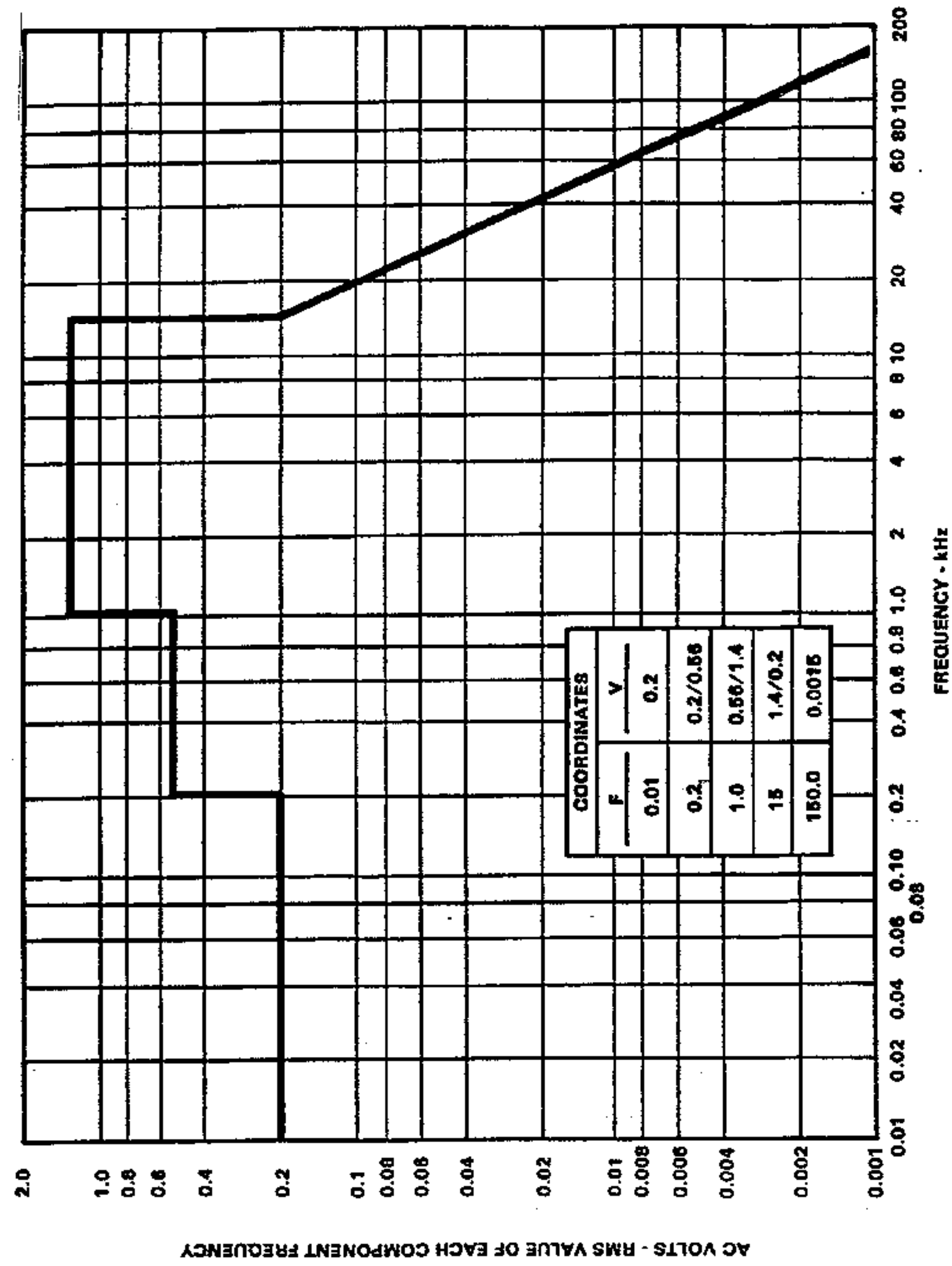


Figure 18-2 Frequency Characteristics of Ripple in 28 Volt DC Electric System – Category B



COORDINATES	
F	V
0.01	0.2
0.2	0.2/0.56
1.0	0.56/1.4
15	1.4/0.2
150.0	0.0015

Figure 18-3 Frequency Characteristics of Ripple in 28 Volt DC Electric System – Categories A & Z

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 19

Induced Signal Susceptibility

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

19.0 INDUCED SIGNAL SUSCEPTIBILITY

19.1 Purpose of the Test

This test determines whether the equipment interconnect circuit configuration will accept a level of induced voltages caused by the installation environment. This section relates specifically to interfering signals related to the power frequency and its harmonics, audio frequency signals, and electrical transients that are generated by other on-board equipment or systems and coupled to sensitive circuits within the EUT through its interconnecting wiring.

19.2 Equipment Categories

Category C

Equipment intended primarily for operation in systems where interference-free operation is required and where severe coupling occurs due to long wire runs or minimum wire separation is identified as Category C.

Category Z

Equipment intended primarily for operation in systems where interference-free operation is required is identified as Category Z.

Category A

Equipment intended primarily for operation where interference-free operation is desirable is identified as Category A.

Category B

Equipment intended primarily for operation in systems where interference would be controlled to a tolerable level is identified as Category B.

19.3 Test Procedures

19.3.1 Magnetic Fields Induced Into the Equipment

Subject the equipment under test to an audio frequency magnetic field, generated by the current specified in Table 19-1, in a straight wire radiator located within 0.15 m of the periphery of the unit of equipment under test. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

During this test, the radiator shall be oriented with respect to each external surface of each unit to cause maximum interference. The length of the radiator shall extend a distance of at least 0.6 m (laterally) beyond each extremity of the unit under test. The leads applying current to the radiator shall be routed at least 0.6 m away from any part of the unit under test and from the radiator itself. All units of the equipment under test shall be individually tested. The magnetic field power source shall not be synchronized with the power source of the equipment supply.

19.3.2 Magnetic Fields Induced Into Interconnecting Cables

Subject the interconnecting wire bundle of the equipment under test to an audio frequency magnetic field as illustrated in Figure 19-2. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS when the field is of the value specified in Table 19-1.

During this test, all equipment interconnecting cables shall be installed in accordance with the applicable installation and interface control diagrams. Any inputs or outputs from or to other equipment(s) normally associated with the equipment under test shall be adequately simulated. The magnetic field power source is not to be synchronized with the power source of the equipment power supply.

19.3.3 Electric Fields Induced Into Interconnecting Cables

Subject the interconnecting wire bundle of the equipment under test to an audio frequency electric field as illustrated by Figure 19-3. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS when the field is of the value specified in Table 19-1.

During this test, all equipment interconnecting cables shall be in accordance with the applicable installation and interface control diagrams. Shielded or twisted wires shall be used only where specified by the equipment manufacturer. Any inputs or outputs from or to other equipment(s) normally associated with the equipment under test shall be adequately simulated. The electric field power source shall not be synchronized with the power source of the equipment power supply.

19.3.4 Spikes Induced Into Interconnecting Cables

During this test, all equipment interconnecting cables shall be in accordance with the applicable installation and interface control diagrams. Shielded or twisted wires shall be used only where specified by the equipment manufacturer. Any inputs or outputs from or to other equipment normally associated with the equipment under test shall be adequately simulated.

Subject the interconnecting wire bundle of the equipment under test to both positive and negative transient fields using the test setup shown in Figure 19-4. Table 19-1 defines the desired cable lengths for Categories A, B, C and Z. The timer shown in Figure 19-4 shall be adjusted to yield a pulse repetition rate of eight to ten pulses each second. The waveform present at point A, Figure 19-4, should be similar to that described in Figure 19-5. For both positive and negative polarities of the transient, the pulsing for each polarity shall be maintained for a period of not less than two minutes or for a longer period of time if specified in the relevant equipment specification.

After exposure, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS. Any requirement for performance of the equipment during application of the tests will be specified in the equipment performance standard.

The inductive switching transient generated when the contact opens should be very similar to the illustration in Figure 19-5, when monitored at point A on Figure 19-4. When the contact opens, the voltage at Point A drives from +28 V dc to large negative voltages in about two microseconds. (The capacitance, 250 to 3,000 picofarad typically, between windings of the coil is charged negatively during this time.) When the voltage reaches the ionizing potential, arc-over occurs at the contact and the voltage drives rapidly toward 28 V dc through the ionized path at the contact. The voltage at Point A usually overshoots +28 V dc because of the wire inductance between Point A and the coil. At this time, the arc extinguishes and the cycle is repeated. In a typical case, the repetition period is 0.2 to 10 microseconds and the number of repetitions is often 5 to 1,000 before the energy of the inductive load ($E = 1/2\ LI^2$) is dissipated.

Paragraph	Test	Category Z	Category A	Category B	Category C
19.3.1	Magnetic fields induced into the equipment	20 A rms at 400 Hz	20 A rms at 400 Hz	20 A rms at 400 Hz	20 A rms at 400 Hz
19.3.2	Magnetic fields induced into interconnecting cables	I x L=30 A-m at 400 Hz reducing to 0.8 A-m at 15 kHz (as shown in Figure 19-1(a))	I x L=18 A-m from 380 to 420 Hz	Not applicable	I x L=120 A-m from 380 to 420 Hz, and 60 A-m at 400 Hz reducing to 1.6 A-m at 15 kHz (as shown in Figure 19-1(a))
19.3.3	Electric fields induced into interconnecting cables	V x L=1800 V-m from 380 to 420 Hz	V x L=360 V-m from 380 to 420 Hz	Not applicable	V x L=5400 V-m from 380 to 420 Hz, and 5400 V-m at 400 Hz reducing to 135 V-m at 15 kHz (as shown in Figure 19-1(b))
19.3.4	Spikes induced into interconnecting cables	Figure 19-4 L=3.0 m	Figure 19-4 L=3.0 m	Figure 19-4 L=1.2 m	Figure 19-4 L=3.0 m

NOTE: *When the manufacturer's installation and interface control drawings or diagrams specify a fixed length cable less than 3.3 m, the coupled length (L) of the field source wire shall be reduced to maintain the 0.15 m minimum separation distance at each end. The test level may be adjusted downward in proportion to the ratio of the reduced coupling length to the specified coupling length (L = 3.3 - (2 x 0.15) = 3 m). For example, if the manufacturer specifies a maximum cable length of 1.8 m, then L = 1.5 m. The adjusted level is then (1.5/3.0) = 0.5 times the voltage or current limits shown above. This test is not required when the manufacturer's installation and interface control drawings or diagrams specify a fixed length cable less than 1.5 m (L less than 1.2 m).*

Table 19-1 Applicability of Categories to Induced Signal Susceptibility

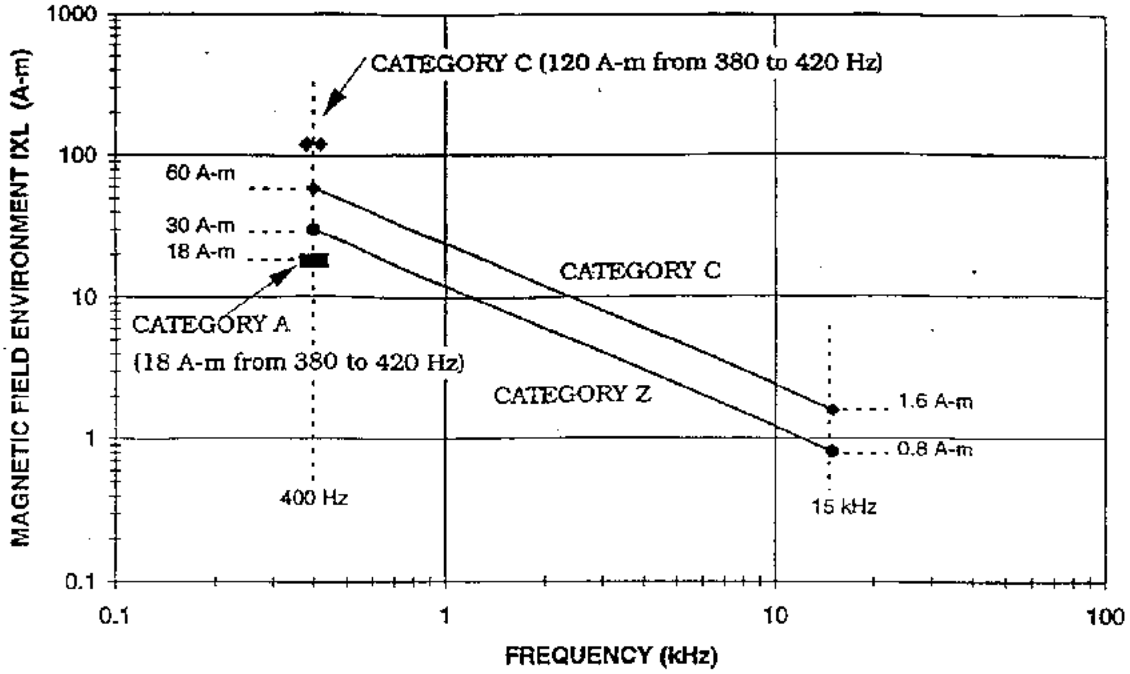


Figure 19-1(a) Audio Frequency Magnetic Field Susceptibility Test Levels

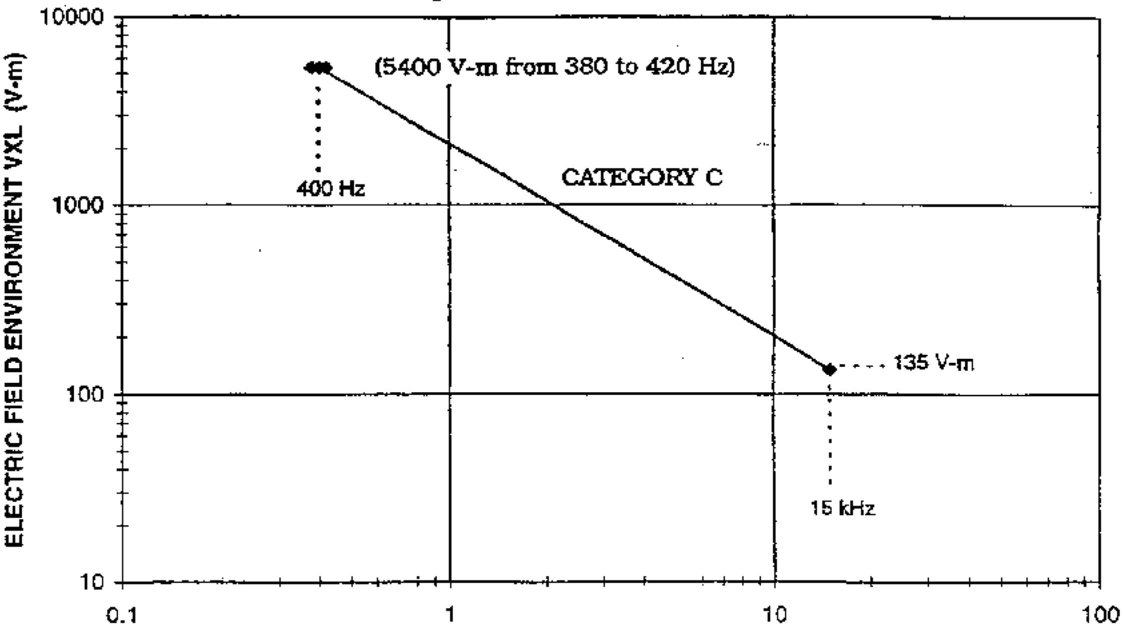
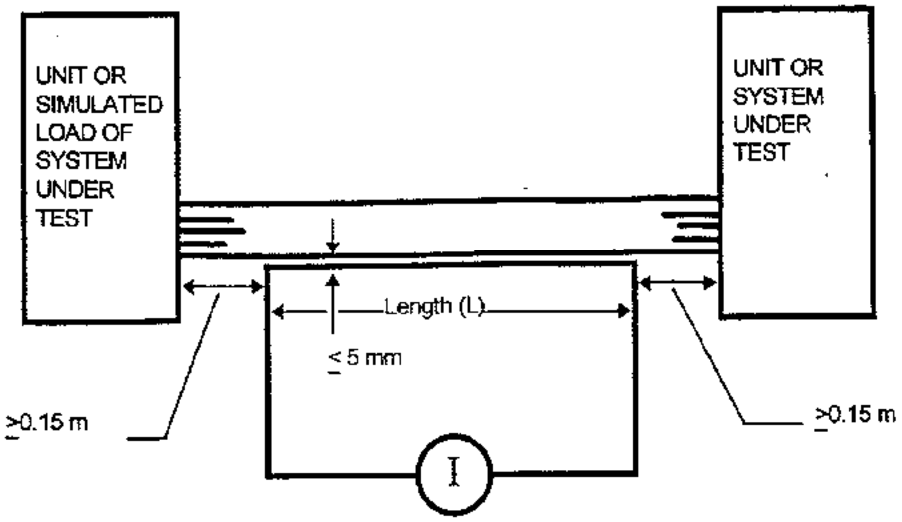


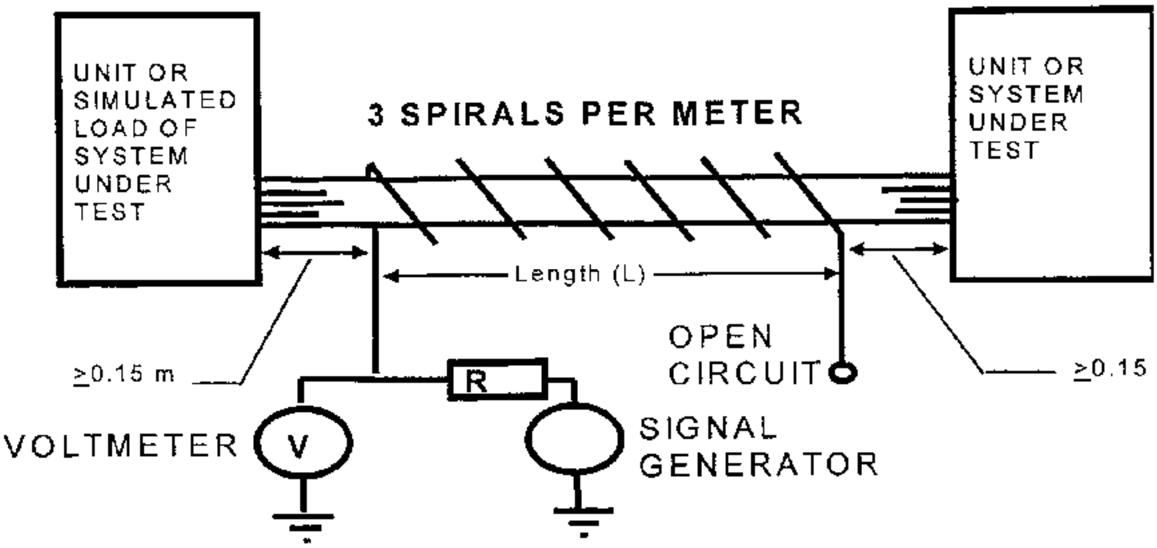
Figure 19-1(b) Audio Frequency Electric Field Susceptibility Test Level-Category C



Note 1: The interconnecting wire bundle shall be spaced a minimum of 50 mm above the ground plane.

Note 2: Magnetic Field Environment = Current (I) x Length (L) (amperes rms x meters)

Figure 19-2 Audio Frequency Magnetic Field Susceptibility Test Setup

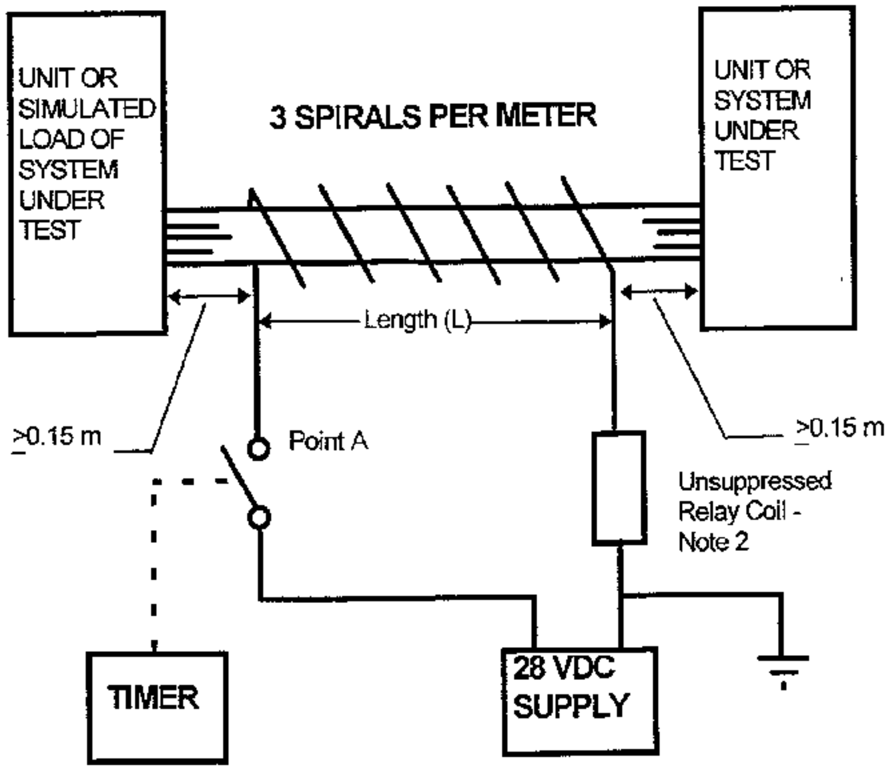


Note 1: The interconnecting wire bundle shall be spaced a minimum of 50 mm above the ground plane.

Note 2: Electric Field Environment = Voltage (V) x Length (L) (volts rms x meters)

Note 3: R sized for personnel high voltage protection

<u>Figure 19-3</u> Audio Frequency Electric Field Susceptibility Test Setup



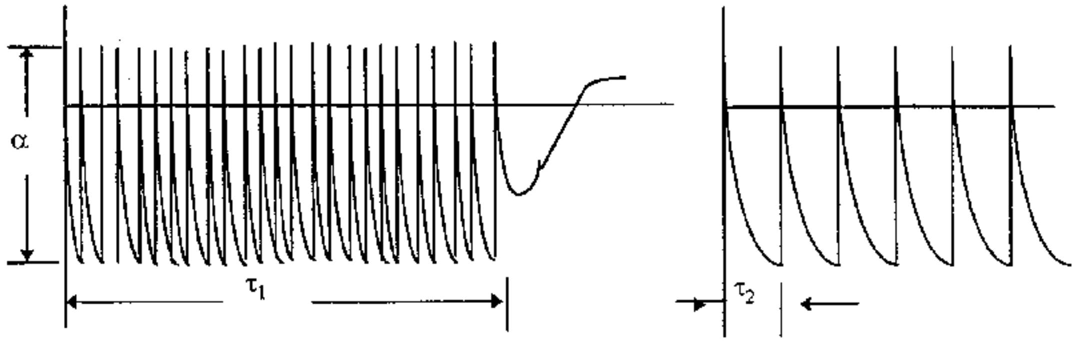
Note 1: The interconnecting wire bundle shall be spaced a minimum of 50 mm above the ground plane.

Note 2: The unsuppressed relay coil characteristics are as follows:

Voltage	=	28 volts dc
Current	=	160 mA
Resistance	=	175 ohms ± 10 %
Inductance	=	1.5 henries ± 10% in the energized position.

Note 3: 28 VDC supplied from ungrounded source with polarity reversing switch.

Figure 19-4 Interconnecting Cable Spike Test Setup



α Amplitude ≥ 600 v p-p

τ_1 Total Duration 50 to 1000 microseconds

τ_2 Repetition Period 0.2 to 10 microseconds

Note: Voltage waveforms measured between Point A of Figure 19-4 and the ground plane.

Figure 19-5 Inductive Switching Transients

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 20

Radio Frequency Susceptibility (Radiated and Conducted)

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

20.0 RADIO FREQUENCY SUSCEPTIBILITY (RADIATED AND CONDUCTED)

20.1 Purpose of the Test

These tests determine whether equipment will operate within performance specifications when the equipment and its interconnecting wiring are exposed to a level of RF modulated power, either by a radiated RF field or by injection probe induction onto the power lines and interface circuit wiring.

Two test procedures are used: 1) From 10 kHz to 400 MHz, the equipment under test (EUT) is subjected to RF signals coupled by means of injection probes into its cable bundles, and 2) for frequencies between 100 MHz and the upper frequency limit, the EUT is subjected to radiated RF fields. There is an overlap of the tests from 100 to 400 MHz.

Radiated susceptibility tests from 100 MHz to 18 GHz may be conducted using methods and materials as described within paragraph 20.5 or may be alternately conducted using methods and materiels described within paragraph 20.6. Each of these two methods are at the discretion of the applicant.

Equipment with special signal, frequency, modulation or bandpass characteristics may require test variations as specified by the applicable performance standards.

The result of these tests is to permit categories to be assigned defining the conducted and radiated RF test levels of the equipment. These tests are sufficient to obtain environmental qualification for radio frequency susceptibility of the equipment. Additional tests may be necessary to certify the installation of systems in an aircraft dependent on the functions performed.

20.2 Equipment Categories

Categories designate the RF test levels and establish the EUT minimum RF susceptibility level. The categories may be given in the applicable equipment performance standard.

The category to be applied to a system or equipment frequently must be chosen before the internal RF environment of the aircraft is known. Further, many systems or equipments are designed with the intent that they will be installed in several different types of aircraft. Therefore, if a category is not identified in the equipment specification, the equipment manufacturer should design, test and qualify the equipment to the category level consistent with expected location, exposure and use.

Category designation for equipment consists of three characters. Conducted susceptibility test levels are designated with the first category character. Continuous wave (CW) and square wave (SW) modulated radiated susceptibility test levels are designated with the second category character. Pulse modulated radiated susceptibility test levels are designated with the third category character.

To aid the equipment manufacturer in selecting appropriate test limits for the equipment and its interconnecting wiring, categories have been defined below. The descriptions are for guidance only. Equipment location, anticipated exposure and location of interconnecting wiring, aircraft size and construction determine the test level.

Categories "P", "W" and "Y" are intended for equipment and interconnecting wiring installed in severe electromagnetic environments. Such environments might be found in non metallic aircraft or exposed areas in metallic aircraft.

Category "V" is intended for equipments and interconnecting wiring installed in a moderate environment such as the more electromagnetically open areas of an aircraft composed principally of metal.

Category "U" is intended for equipment and interconnecting wiring installed in a partially protected environment such as an avionics bay in all-metallic aircraft.

Category "T" is intended for equipment and interconnecting wiring installed in a well protected environment such as an enclosed avionics bay in an all-metallic aircraft.

Category "S" is intended as a minimum test level where aircraft effects from the external electromagnetic environment are minor and where interference free operation on the aircraft is desirable but not required.

Category "R" is intended to provide test levels for equipment when bench testing is allowed to meet the high intensity radiated field (HIRF) associated with the normal environment.

20.3 General Test Requirements

a. Equipment Under Test

The EUT shall be set up on a ground plane and configured in accordance with the following criteria:

(1) Ground Plane - A copper, brass or aluminum ground plane, at least 0.25 mm thick for copper and aluminum, 0.5 mm thick for brass, 2.5 m^2 or more in area with a minimum depth (front to back) of 0.75 m shall be used. When a shielded enclosure is employed, the ground plane shall be bonded to the shielded enclosure at intervals no greater than one meter and at both ends of the ground plane. It is recommended that the DC bonding resistance should be 2.5 milliohms or less.

(2) Shock and Vibration Isolators - If specified by the equipment manufacturer, the EUT shall be secured to mounting bases incorporating shock or vibration isolators. The bonding straps furnished with the mounting bases shall be connected to the ground plane. Bonding straps shall not be used in the test setup, when they are not incorporated in the mounting bases.

(3) Electrical Bonding - Only the provisions included in the EUT design or installation instructions, e.g. bonding of enclosure, mounting base and ground plane, shall be used for bonding.

The electrical bonding of equipment, connectors, and wire bundles shall be representative of aircraft installations as specified by the applicable installation and interface control drawings or diagrams. The test report shall describe the bonding methods employed.

(4) External Ground Terminal - When an external terminal is available for a ground connection on the EUT, the terminal shall be connected to the ground plane to ensure safe operating conditions during the test. The length of the connection defined in the installation instructions shall be used; if a length is not defined, use approximately 30 cm of a representative type of wire.

(5) Interconnecting Wiring/Cables - All EUT interconnecting wiring (e.g., shielded wires, twisted wires, etc.), cable bundles and RF transmission lines shall be in accordance with the applicable installation and interface control drawings or diagrams.

Cables shall be bundled in a manner similar to that of aircraft installations and supported approximately 50 mm above the ground plane. For complex cable bundle configurations, all cable bundles and interconnected loads should be kept separated from each other as much as practical to minimize coupling effects between cables.

Unless otherwise specified, cable lengths shall be at least 3.3 m. When the length of an interconnecting cable bundle is greater than the test bench, the cable bundle should be arranged with the excess length zig-zagged at the back of the test bench approximately 50 mm above the ground plane. At least one meter of cable from the EUT must be 10 cm from the front of the test bench and parallel to the front of the test bench as shown in Figure 20-2.

Some special installations may require very long cable bundle lengths which cannot be accommodated on the test bench. Therefore, the recommended maximum length of the interconnecting cable bundles for these tests is 15 m. The exception to this limitation is where cable bundle lengths are matched or specified to a particular length for phase match or similar reasons.

Any inputs or outputs from or to other equipment or loads associated with the EUT shall be provided by an actual in-service type of device or shall be simulated taking into account the line-to-line and line-to-ground frequency dependent impedances.

(6) Power Leads - For cable bundle tests, power and return leads normally bundled with the control/signal leads shall remain in the cable bundle and only be separated from the bundle just prior to the cable bundle exiting the test area. These leads shall then be connected to Line Impedance Stabilization Networks (LISNs).
When the actual aircraft cable bundle configuration is unknown or when power and/or return leads are normally routed separately from the control/signal leads, the power and return leads should be broken out of the cable bundle near the connector of the EUT and run separately to the LISNs. Under these conditions, the length of the leads to the LISNs shall not exceed 1.0 m unless otherwise specified in the applicable equipment specification.

When the return lead is a local ground (less than 1 meter length), this lead may be grounded directly to the test bench, in accordance with the applicable installation and interface control drawings or diagrams.

(7) Dummy Antennas or Loads - For the purpose of this test, antenna cables may be terminated in a load equal to the cable characteristic impedance, or a dummy antenna. The dummy antenna, if used, shall be shielded and be designed to have electrical characteristics closely simulating the in-service antenna. It shall also contain electrical components normally used in the antenna, such as filters, crystal diodes, synchros and motors.

b. Shielded Enclosure and Test Equipment

Enclosures, test equipment and instruments shall be set up and operated in accordance with the following criteria:

(1) Bonding Test Equipment - Test equipment shall be bonded and grounded to minimize ground loops and ensure personnel safety.

(2) Line Impedance Stabilization Network (LISN) - An LISN shall be inserted in each EUT primary power line. Power return lines locally grounded in the aircraft installation do not require an LISN. The LISN case shall be bonded to the ground plane. When LISNs with self resonances above 10 kHz are used (such as standard 5µH LISNs), a 10 microfarad capacitor shall be inserted between each LISN power input terminal and the ground plane for the entire test. The RF measurement port of the LISN shall be terminated into 50 ohms for all tests. The input impedance characteristic is shown in Figure 20-1.

(3) Antenna Orientation and Positioning in Shielded Enclosures - Dipole, biconical or horn antennas shall be centered 0.3 m above the level of the ground plane and parallel to the ground plane as shown in Figure 20-2. If the transmitting antenna being used is a pyramidal horn, such as a standard gain horn or similar type radiator, as the dimensions of the antenna become small and the frequency of interest becomes higher, it is permissible to move the antenna closer to the EUT than the one meter shown in Figure 20-2. This can only be done when the far field boundary of the antenna is within this one meter distance. The position of the transmit antenna relative to the EUT must remain equal to or greater than the far field boundary of the transmitting horn antenna. If the far field boundary of the antenna extends beyond one meter then the standard one meter separation should be used.

If the transmit antenna far field boundary is less than or equal to one meter it is also allowable to move the antenna farther than one meter from the EUT. The appropriate field strength at the EUT must be maintained. Moving the transmit antenna farther away will increase the illuminated area, decreasing the number of antenna placements required for large EUT configurations.

NOTE: The far field boundary of the antenna is calculated by the following equation:

$$\frac{2 * D^2}{\lambda}$$

where D = *largest dimension of the transmitting aperture in meters, and*

λ = *wavelength of the frequency of interest in meters.*

NOTE: For typical standard gain horns, far-field boundaries less than one meter from the antenna exist only for frequencies above approximately 8 GHz.

When the beamwidth of the antenna does not totally cover the system under test, multiple area scans shall be performed. The EUT and at least one-half wavelength of wiring should be exposed during a scan. In shielded enclosure tests, the antenna shall be at least 0.3 m away from the shielded enclosure wall. Alternate antennas may be used provided the required field strengths are obtained.

NOTE: *The above does not apply if the alternate radiated susceptibility test procedure of Section 20.6 is used.*

(4) Injection Probes - Probes shall have the necessary power and range capabilities. Injection probe insertion loss limits are shown in Figure 20-3. A suggested test setup for measuring the injection probe insertion loss is shown in Figure 20-4. Support and center the probe in the fixture.

(5) Shielded Enclosure - Shield room effects on equipment and test setup shall be minimized to the greatest extent possible. RF absorber material shall be used during radiated testing inside a shielded enclosure to reduce reflections of electromagnetic energy and to improve accuracy and repeatability. As a minimum, the RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating antenna as shown in Figure 20-2. Minimum performance of the material shall be as specified in Table 20-1. The manufacturer's specification of their RF absorber material (basic material only, not installed) is acceptable.

NOTE: *The above is not applicable if the alternate radiated susceptibility test procedure of Section 20.6 is used.*

Fiber-optic interfaces may be provided for test equipment and sensors to help give susceptibility-free monitoring. The design and protection of test aids, monitors and load stimulation units should ensure appropriate simulation, isolation and immunity of test equipment interface circuits to RF currents.

c. Amplitude Measurement

The amplitudes associated with the categories are based on the peak of the rms envelope over the complete modulation period as shown in Figure 20-5. Amplitude measurements shall be made in a manner which clearly establishes the peak amplitude of the modulated waveform. This instrument must have a fast enough time response to respond to signal amplitude variations, particularly for Section 20.6. A spectrum analyzer may be used. The detection, resolution, and video bandwidths of the measuring instrument must be wider than the modulating frequency. The measurement bandwidth shall be increased until the amplitude of the measured signal does not change by more than 1 dB for a factor of three change in bandwidth. This bandwidth setting shall then be used for the test. At the proper setting, the individual modulation sidebands will not be resolved.

d. Test Frequency Exclusions

RF susceptibility tests on intentional RF transmitting or receiving equipment may exclude the transmit/receive frequency band for that equipment. Unless otherwise specified in the applicable performance standard, the exclusion band may include frequencies up to 20 percent above the highest transmit/receive frequency and frequencies within 20 percent of the lowest transmit/receive frequency. If an exclusion band is selected, the RF susceptibility tests shall be performed to Category S within the exclusion band, unless otherwise specified in the applicable performance standard.

e. Frequency Scan Rates

Sweep or step rates shall be selected with consideration of equipment under test (EUT) response time, EUT susceptibility bandwidths, and monitoring test equipment response time.

For test equipment that generate a continuous frequency sweep, the test frequencies shall be actively swept no faster than two minutes for each frequency decade.

For test equipment that generate discrete frequencies, the minimum number of test frequencies shall be 100 frequencies per decade. The test frequencies shall be logarithmically spaced. As an example, a formula which can be used to calculate these frequencies in ascending order is:

$$f_{n+1} = f_n * 10^{(1/99)}$$

where f_r is a test frequency and n = 1 to 100,
f_1 is the start frequency, and
f_{100} is the end frequency.

The dwell time at each test frequency shall be at least one second, exclusive of test equipment settling time. Additional dwell time at each test frequency may be necessary to allow the EUT to be exercised in appropriate operating modes.

NOTE: The frequencies chosen for the test should be appropriate to the equipment. Additional test frequencies should be included for known equipment response frequencies, such as image frequencies, IFs, clock frequencies, etc.

20.4 Conducted Susceptibility (CS) Test - 10 kHz to 400 MHz

a. Applicability/Intent

Subject the EUT and interconnecting cables or circuits to the appropriate category of Figure 20-6, while monitoring the induced cable bundle current. All cable bundles and appropriate branches that connect the EUT to other equipment or interfacing units in the aircraft system are subject to this test.

Interconnecting wiring can be tested as a whole or as individual wires. Simultaneous injection with separate probes on several bundles may be used, and may be required for equipment with built-in redundancy. Power return leads or ground leads that are grounded directly to the test bench, as required in Section 20.3.a.(6), shall not be included in the bundle under test and are not required to be tested.

b. Probe Calibration

Set up the signal generator, power amplifier, directional coupler, attenuator, amplitude measurement instruments, and install the injection probe in the calibration fixture per Figure 20-7. Support and center the probe in the fixture. Set the signal generator to 10kHz, unmodulated. Increase the amplifier power fed through the directional coupler to the injection probe at 10 kHz until the current or power measured on amplitude measurement instrument #1 indicates the current or power for the selected category of Figure 20-6.

CAUTION: RF fields can be hazardous. Observe appropriate RF exposure limits.

Record the signal generator/power amplifier forward power to the injection probe on amplitude measurement instrument #2.

Then scan the frequency band (unmodulated) while recording forward power on amplitude measurement instrument #2 and maintaining power amplitudes (±2 dB) on amplitude measurement instrument #1 per Figure 20-6 from 10 kHz to 400 MHz for the proper probe. The forward power plot will be used to establish the test level for the conducted susceptibility test.

The VSWR of the attenuators and loads shall be less than 1.2:1. The calibration jig VSWR without the probe installed shall not exceed the values of Figure 20-8. The amplifiers shall be capable of full power required by the probes with an individual harmonic content of less than 10 percent.

c. CS Test Setup

Set up the EUT, wiring, associated interface circuitry, and test equipment per Figure 20-9. Install the induced current monitor probe five centimeters from the EUT. If the EUT connector plus backshell length exceeds five centimeters, the probe shall be placed as close to the connector backshell as possible and the position noted. Support and center the probe. Install the injection probe five centimeters from the face of the monitor probe.

d. CS Test Procedure

Establish proper probe locations, software installation, modes of operation and stability of the EUT, test equipment and all monitoring circuits and loads.

CAUTION: RF fields can be hazardous. Observe appropriate RF exposure limits.

Set the signal generator to 10 kHz, unmodulated. Establish the forward power to the injection probe on amplitude measurement instrument #2 at 10 kHz at the power determined in the probe calibration procedure for the selected category of Figure 20-6. Slowly scan the frequency range at the proper forward power. Apply both CW and square wave modulation. Amplitude modulate the RF carrier with a 1 kHz square wave at greater than 90 percent depth, with optional 1 to 3 Hz superimposed. When modulation is applied, ensure that the peak amplitude complies with the definitions of Figure 20-5.

Also consider applying other modulations associated with the EUT, such as clock, data, IF, internal processing or moduation frequencies. Consider any possible low frequency response characteristic of the EUT, for example, a flight control equipment's response to 1 to 3 Hz modulation in the 2 to 30 MHz HF range. When using 1 Hz to 3 Hz modulation, ensure that sweeping and/or frequency stepping is suspended during the "off" period of the modulation. As an option, tests can be run using only the modulation to which the EUT is most susceptible.

Slowly scan the frequency range to 400 MHz at the forward power amplitude using the proper probes and modulations. Dwell at internal modulation, data or clock frequencies, as required.

Monitor the induced cable bundle current with the amplitude measurement instrument and data recorder to capture resonances. When necessary, adjust and control the forward power to limit induced current on the bundle:

Cat Y - 1 A;
Cat W - 500 mA;
Cat V - 250 mA;
Cat U and R - 100mA;
Cat T - 25 mA;
Cat S - 5mA.

While scanning, evaluate EUT operation and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

20.5 Radiated Susceptibility (RS) Test - 100 MHz to 18 GHz

a. Applicability/Intent

Subject the EUT and interconnecting cables to the appropriate category of RF fields for Figure 20-10.

b. Radiated Field Calibration

Perform a field calibration prior to placement of the EUT, to establish the correct field strength for the category selected.

Perform the reference CW field calibration using a three-axis omnidirectional electric field antenna (isotropic probe) or equivalent with appropriate frequency response. The isotropic probe should be centered at approximately the same location as the placement of the EUT on the groundplane, 30 cm above the groundplane. Radiate the isotropic probe, unmodulated, at the desired test frequency. Adjust the forward power to the transmit antenna to achieve the correct field strength indication from the isotropic probe for the category selected. Record the forward power and use this power setting during the EUT radiated field test. Repeat this calibration over the required frequency range.

The forward power necessary to produce the desired category field strength at the isotropic probe with a CW signal becomes the reference forward power. Square wave (SW) and pulse modulated signals should be developed in a manner which produces the same forward power, plus the appropriate scale factor if the reference CW calibration was performed at a different level than the desired square wave or pulse category field strength.

Forward power to the transmit antenna should be monitored and recorded using an amplitude measurement instrument that meets the requirements in Section 20.3.c.

Transverse electromagnetic (TEM) cell facilities may be used. TEM cell matching networks and calibration methods shall be described.

When a linearly polarized transmit antenna is used, both horizontal and vertical polarization field exposures are required. Circularly polarized transmit antennas are permitted.

c. RS Test Set-up

Set up the EUT, wiring, associated interface circuitry and test equipment per Figure 20-2.

Signal generators, amplifiers, antennas and probes shall maintain required RF field levels to properly illuminate the EUT and interconnecting wiring. Position and aim antennas to establish the RF field strengths at the EUT and interconnecting wiring. When the beamwidth of the antenna does not totally cover the EUT and wiring, perform multiple area scans. Directly expose apertures in the EUT (e.g., displays, CRTs, connectors) to the transmitting antenna, which may require additional LRU orientations. Vertical and horizontal antenna orientations are required for polarized antennas.

d. RS Test Procedure

Establish appropriate antenna and isotropic probe locations, software installation, modes of operation and stability of the EUT, test equipment and all monitoring circuits and loads.

CAUTION: RF fields can be hazardous. Observe appropriate RF exposure limits.

Use the forward power settings determined from the radiated field calibration. When modulation is applied, ensure that the peak amplitude complies with the definitions of Figure 20-5.

Scan the frequency range to the upper frequency limit using the proper antennas and modulations. Dwell at internal modulation, data and clock frequencies, as required.

While scanning, evaluate the EUT operation and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

e. RS Modulations

For category R use the following levels and modulations:

From 100 MHz to 400 MHz, use 20 v/m CW. Also use 20 v/m with 1 kHz square wave modulation with at least 90% depth.

From 400 MHz to 8 GHz, use 150 v/m pulse modulated at 0.1% duty cycle and 1 kHz pulse repetition frequency. Also, use 28 v/m with 1 kHz square wave modulation with at least 90% depth. Consider switching the signal on and off at a 1 Hz to 3 Hz rate and 50% duty cycle for an EUT which may have a low frequency response (e.g. flight control equipment). When using 1 Hz to 3 Hz modulation, ensure that sweeping and/or frequency stepping is suspended during the "off" period of the modulation.

As an alternative for category R from 400 MHz to 8 GHz, use 150 v/m pulse modulated at 4% duty cycle and 1 kHz pulse repetition frequency. Consider switching the signal on and off at a 1 Hz to 3 Hz rate and 50% duty cycle for an EUT which may have a low frequency response (e.g. flight control equipment). When using 1 Hz to 3 Hz modulation, ensure that sweeping and/or frequency stepping is suspended during the "off" period of the modulation.

For categories S, T, U, V, W and Y, use the following modulations:

From 100 MHz to the upper frequency limit in Figure 20-10 use CW as well as 1 kHz square wave modulation with at least 90% depth. Also consider using additional modulations associated with the EUT such as clock, data, IF, internal processing or modulation frequencies.

For category P, use the following modulation:

From 400 MHz to 18 GHz, use 600 v/m pulse modulated at 0.1% duty cycle (or greater) and 1 kHz pulse repetition frequency. Consider switching the signal on and off at a 1 Hz to 3 Hz rate and 50% duty cycle for an EUT which may have a low frequency response (e.g. flight control equipment). When using 1 Hz to 3 Hz modulation, ensure that sweeping and/or frequency stepping is suspended during the "off" period of the modulation.

20.6 Radiated Susceptibility (RS) Test 100 MHz - 18 GHz; Alternate Procedure - Mode-Stirred Chamber

a. Applicability/Intent

Subject the EUT and interconnecting cables to the appropriate category of RF fields for Figure 20-10.

b. Chamber Performance Requirements

The lowest useable frequency of a mode-stirred chamber is determined by its volume. For a rectangular-shaped chamber of dimensions a, b, and d, the first resonant mode occurs at a frequency of:

$f_{011}(Hz) = (c/2)*[(i/a)^2 + (j/b)^2 + (k/d)^2]^{½}$

where a is the smallest dimension (m),
i = 0, j = k = 1, and
c is the speed of light ($3x10^8$ m/s).

The lowest useable frequency for normal mode-stirred chamber operation shall be six times the first resonant frequency. The lowest useable frequency with additional power leveling can be three times the first resonant frequency. The chamber shall not be used for the mode-stirred chamber alternative procedure below three times the first resonant frequency. Mode-stirred chambers are generally useable to 18 GHz without limitations.

At frequencies greater than or equal to six times the first resonant frequency, the chamber input power (P_{input}) is equal to the forward power. If the test frequencies must extend below six times the first resonant frequency, the chamber input power (P_{input}) is equal to the net input power, which is obtained by subtracting the reflected power from the forward power at each tuner position.

The amount of power needed to generate a specific field inside a chamber can be determined from the empty chamber calibration outlined in Section 20.6.c.(1). However the EUT, the required support equipment, or added absorbing material may load the chamber, reduce the cavity Q, and hence reduce the test fields for the same input power. Therefore the fields in a loaded chamber must be monitored and input power increased, if necessary, to compensate for this loading. A receive antenna shall be used for field monitoring.

The tuner diameter and height shall be at least one-half wavelength at the lowest frequency. It should be asymmetrically shaped. It is usually most convenient to support it from the ceiling with the driver motor outside the chamber. A stepping motor with computer control is desirable. A variable speed, continuous motor is acceptable, but the time response of the EUT must be fast relative to stirrer speed for this option to be viable.

(1) The chamber time constant, as described in Section 20.6.c.(2), shall be less than 0.4 of any modulation test waveform pulse width. This will assure that the field will rise to at least 92% of the pulse maximum.

(2) The chamber performance shall be demonstrated at a number of frequencies covering the range from the lowest useable frequency to the highest frequency for the category selected by monitoring the received power while rotating the tuner. The ratio of the maximum received power to the minimum received power over one complete rotation of the tuner shall be equal to or greater than 20 dB as described in section 20.6.c.(3).

c. Calibration

(1) Chamber Power Density Calibration

As an initial guide to the chamber input power requirements, perform a one-time, empty chamber (no EUT) calibration using the following procedure:

i. Beginning at the lowest useable frequency, adjust the RF source to inject an appropriate input power, P_{input}, into the transmit antenna. For frequencies greater than six times the first resonant frequency, use the forward power. For frequencies between three and six times the first resonant frequency, use the net input power. The frequency shall be in-band for the receive antenna which shall be a high efficiency, linearly polarized antenna.

ii. Set the amplitude measurement instrument to monitor the receive antenna on the correct frequency. Adjust the resolution bandwidth and sweep time to obtain the necessary sensitivity. Set the frequency span to 0 Hz. Use the «max hold» mode of the amplitude measurement instrument to detect the peak signal.

iii. Operate the tuner continuously (mode-stirred operation) or step the tuner through 360° in at least 200 discrete steps (mode-tuned operation) so that the amplitude measurement instrument captures a full cycle of the received power over one complete tuner rotation.

iv. Record the maximum amplitude of the received signal ($P_{max\ rec}$) and the value of the input power (P_{input}) corresponding to the position of the tuner at which ($P_{max\ rec}$)was recorded. Calculate the calibration factor for the empty chamber using the following equation:

$$\text{Calibration Factor (CF)} = (8\pi/\lambda^2)(\text{Pmax rec/Pinput})$$

where λ is the free space wavelength (m), ($P_{max\ rec}$ /P_{input}) is the ratio of the maximum received power (w) over one complete tuner rotation to the input power (w), and the calibration factor is the chamber power density in w/m^2 per watt of input power at the selected frequency.

v. Repeat the above procedure for each test frequency as defined in Section 20.3(e).

(2) Q and Time Constant Calibration

In order to assure that the time response of the chamber is fast enough to accommodate pulsed waveform testing, a one-time determination of the chamber time constant shall be accomplished using the following procedure:

i. In an empty chamber, use an unmodulated (CW) signal to sample the received power over one complete tuner rotation. Calculate the average value of these received power samples. Record the input power. A suggested frequency set for these measurements is the lowest useable frequency or 0.1 GHz, which ever is greater, and 0.5, 1, 2, 4, 6, 8, 10, 12, 15, 18 GHz.

ii. Calculate Q using:

$$Q = (16\pi^2 V / \lambda^3)(P_{ave\ rec}/P_{input})$$

where V is the chamber volume (m^3), λ is the free space wavelength (m) at the specific frequency, and ($P_{ave\ rec}$ /P_{input}) is the ratio of the average received power (w) over one complete tuner rotation to the input power (w).

iii. Calculate the chamber time constant, t, using:

$$t = Q/2\pi f$$

where Q is the value calculated in ii. above, and f is the frequency (Hz).

iv. If the chamber time constant is greater than 0.4 of any modulation test waveform pulse width, absorber must be added to the chamber. Repeat the Q measurement and the calculation until the time constant requirement is satisfied with the least possible absorber. Perform a power density recalibration if absorber material is required.

(3) Stirring Ratio Determination

i. Using a constant input power and an UNMODULATED (CW) signal, sample the received power over one complete tuner rotation.

ii. Calculate the difference in dB between the maximum received signal and the minimum received signal, or the noise floor, whichever is highest.

iii. Repeat the measurement at representative frequencies. A suggested frequency set is the lowest useable frequency or 0.1 GHz, whichever is greater, and 0.5, 1, 2, 4, 6, 8, 10, 12, 15, and 18 GHz.

iv. The ratio of the maximum received power to the minimum received power over one complete rotation of the tuner shall be equal to or greater than 20 dB. If not, then adjust the tuner size/shape to improve tuning and repeat the Stirring Ratio Determination.

d. RS Test Setup

Except as specifically noted in this Section, the requirements of Section 20.3 apply to the mode-stirred chamber tests.

The typical test setup should be as shown in Figures 20-11 and 20-12. The equipment layout should be representative of the actual installation as specified in Section 20.3.a(5). The EUT shall be at least one-third wavelength from the chamber wall at the lowest test frequency.

The transmit and receive antennas shall not directly illuminate the EUT or each other. Directing the antennas into the corners of the chamber is an optimum configuration. Establish software installation, modes of operation and stability of the EUT, test equipment, and all monitoring circuits and loads.

e. RS Test Procedures

CAUTION: RF fields can be hazardous. Observe appropriate RF exposure limits.

Determine the chamber input power for the test from the electric field intensity category level in Figure 20-10 using the following equation:

$$P_{input} = (E(v/m))^2 / (377 * CF)$$

Perform the test using either mode-tuned or mode-stirred procedures. For mode-tuned operation use a minimum of 200 discrete steps per one complete tuner rotation. Assure that for either procedure the EUT is exposed to the field level for the appropriate dwell time. Limit the mode-stirrer tuner speed to a maximum of 1 revolution in 5 seconds (12 rpm). Expose the EUT to the field for one revolution of the tuner.

Monitor P_{input} and $P_{max\ rec}$ with the receive antenna used in the calibration of each frequency band, and calculate the chamber Calibration Factor (CF) throughout the test. If the Calibration Factor (CF) decreases by a factor of two (2) or more, increase the input power to compensate for this reduction.

Modulate the carrier as specified in Section 20.5. When modulation is applied, ensure that the peak amplitude complies with the definitions of Figure 20-5.

Scan the frequency range to the upper frequency limit using the appropriate in-band antennas and modulations. The scan time for this procedure should be as specified in Section 20.3.e. Dwell at internal modulation, data and clock frequencies, as required.

While scanning, evaluate the EUT operation and DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

Frequency	Minimum Absorption
100 to 250 MHz	6 dB
Above 250 MHz	10 dB

Table 20-1 RF Absorption at Normal Incidence

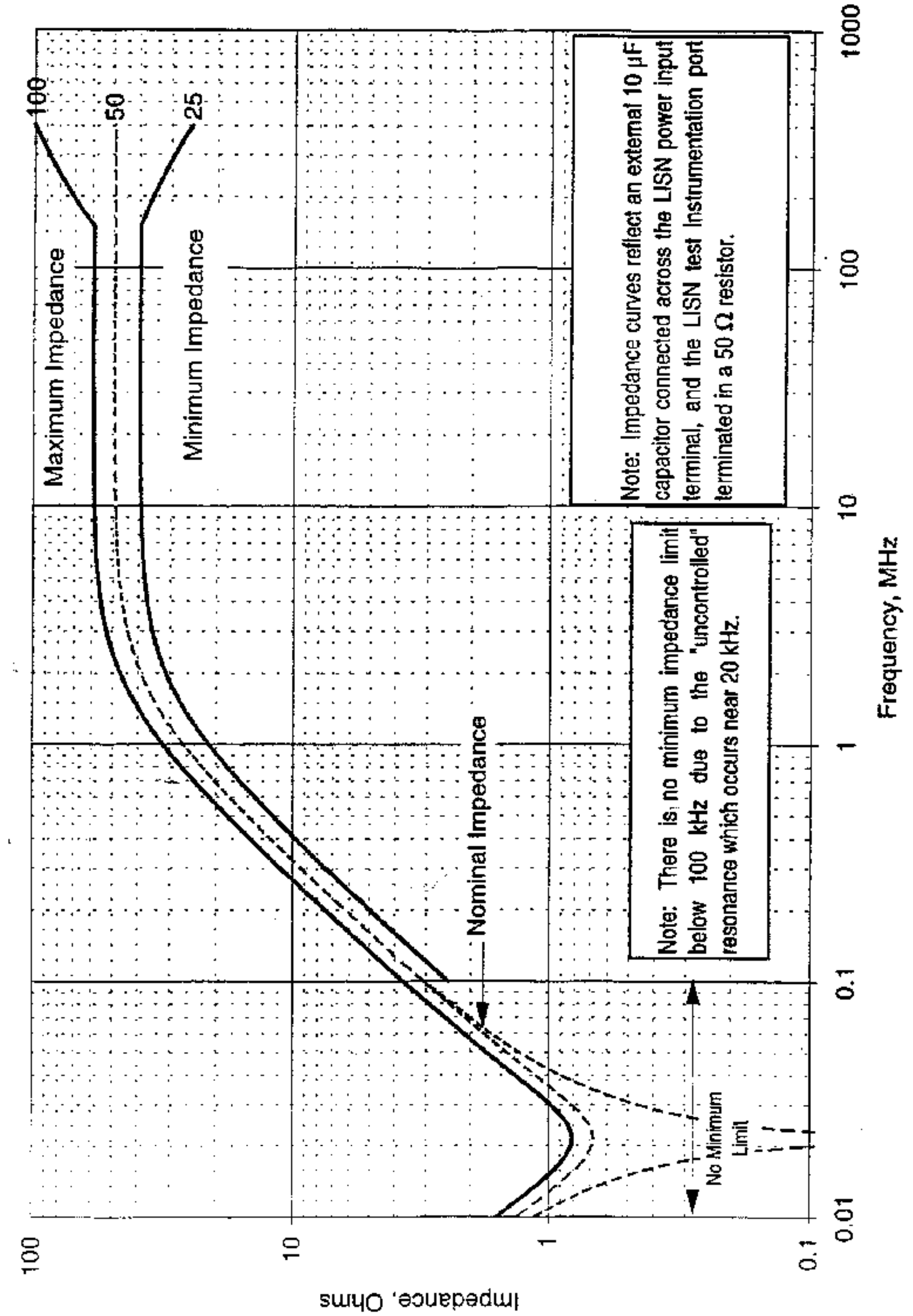
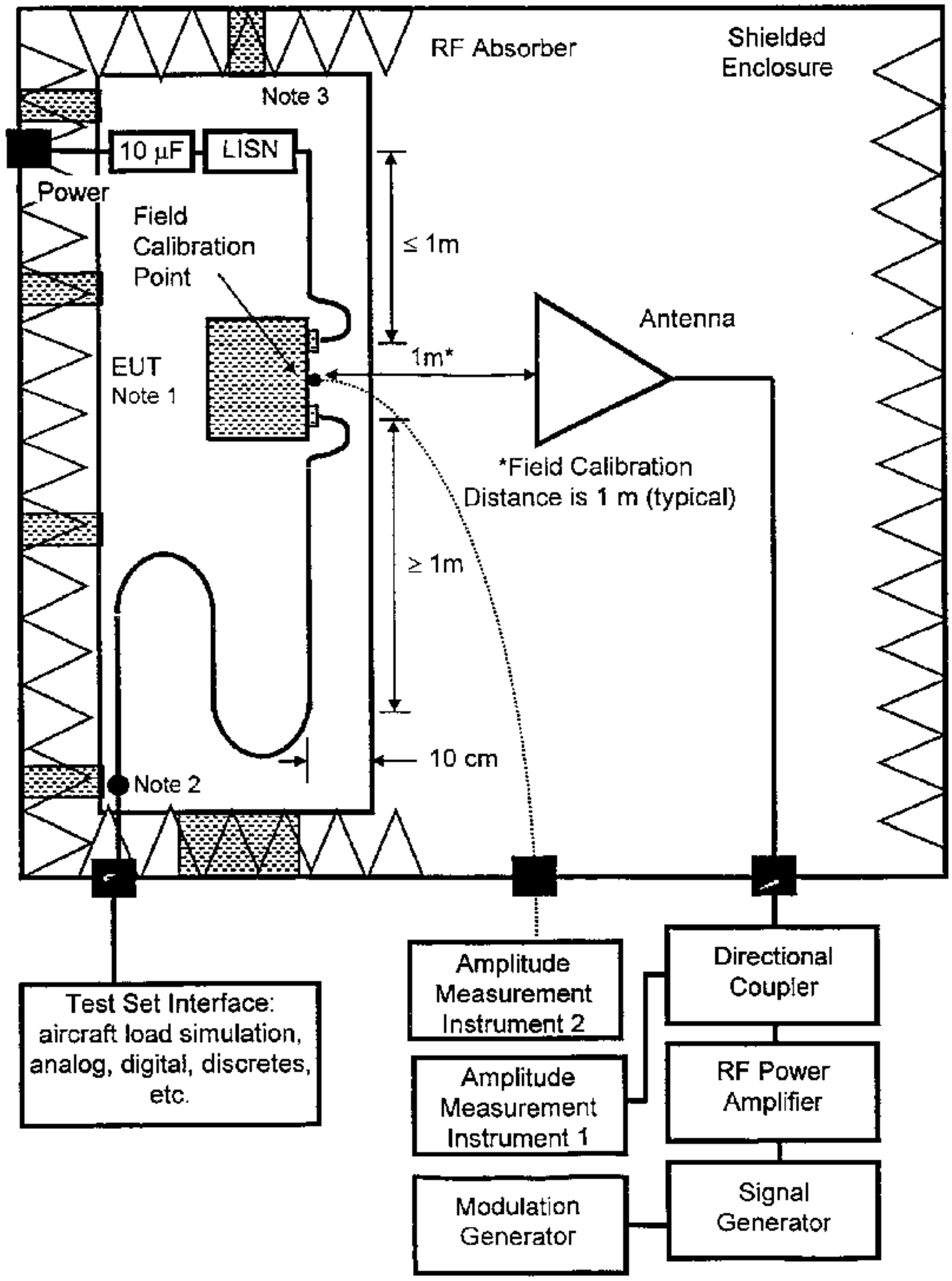


Figure 20-1 Line Impedance Stabilization Network Input Impedance



Note 1 See Section 20.3 for EUT general requirements.
Note 2 End of exposed cable. Unshielded cable may be shielded from here to the wall.
Note 3 Bonding strap.

Figure 20-2 Radiated Susceptibility Test Setup

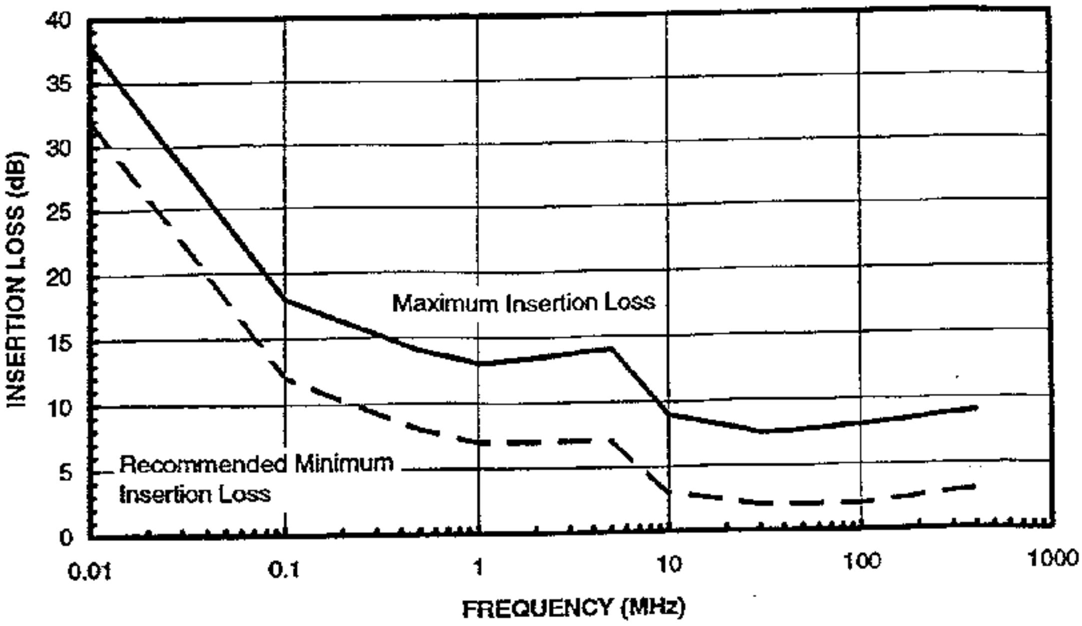


Figure 20-3 Injection Probe Insertion Loss Limits

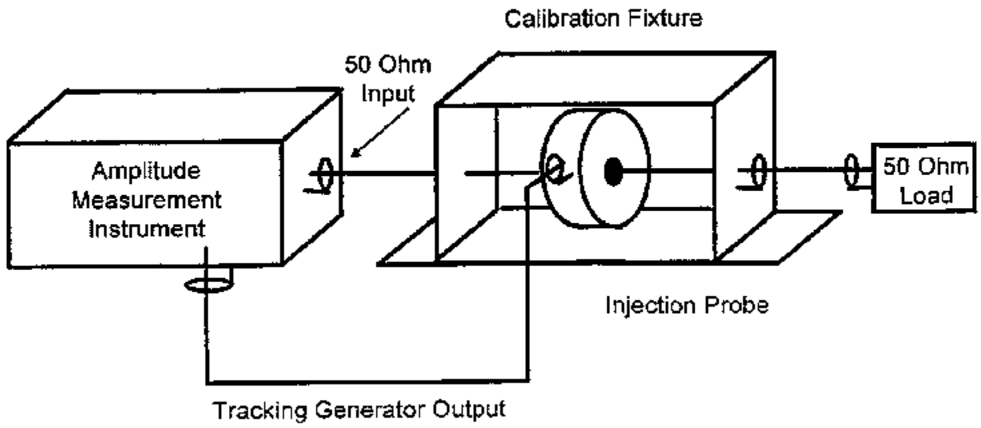


Figure 20-4 Injection Probe Insertion Loss Test

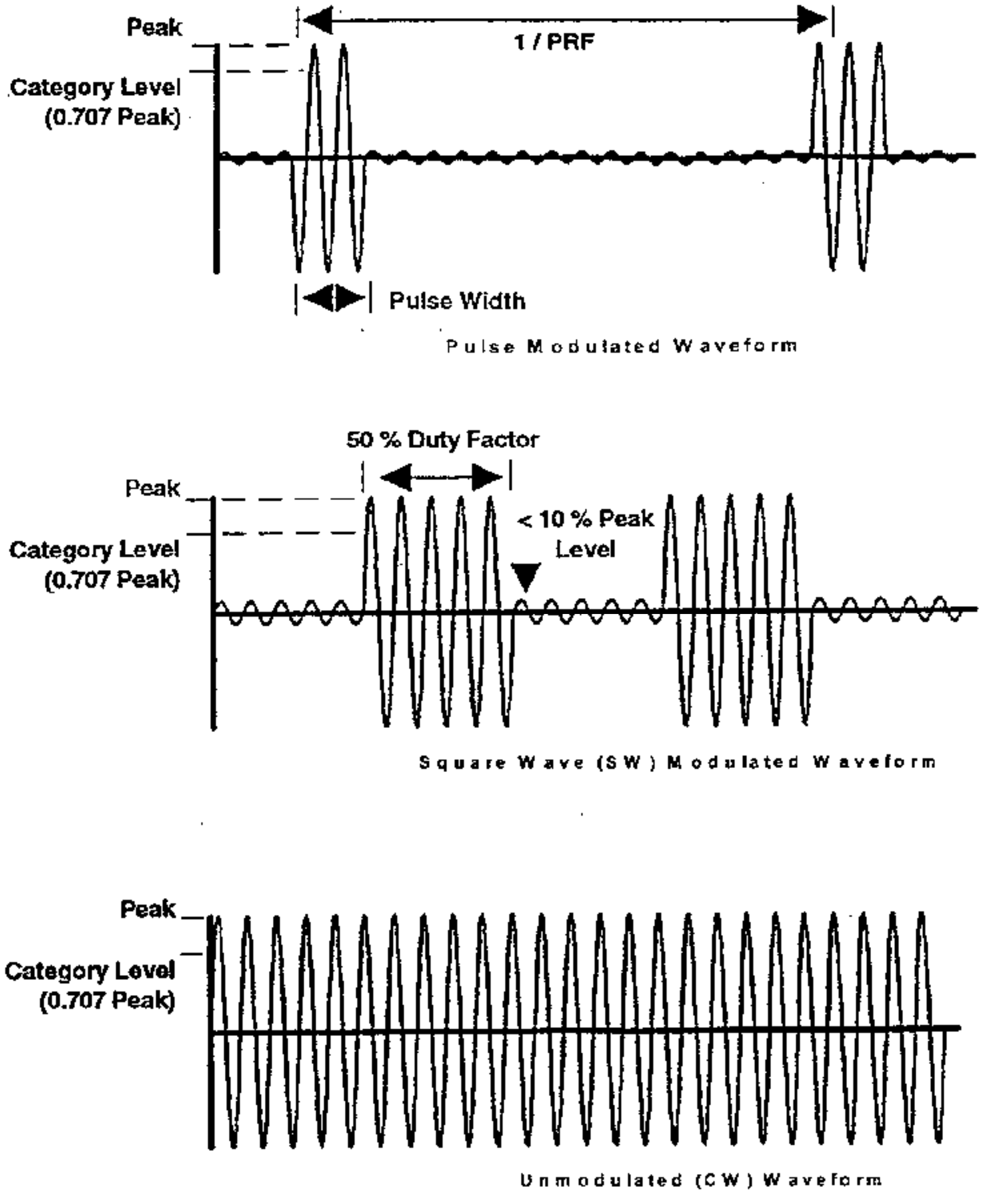


Figure 20-5 Amplitude Measurement

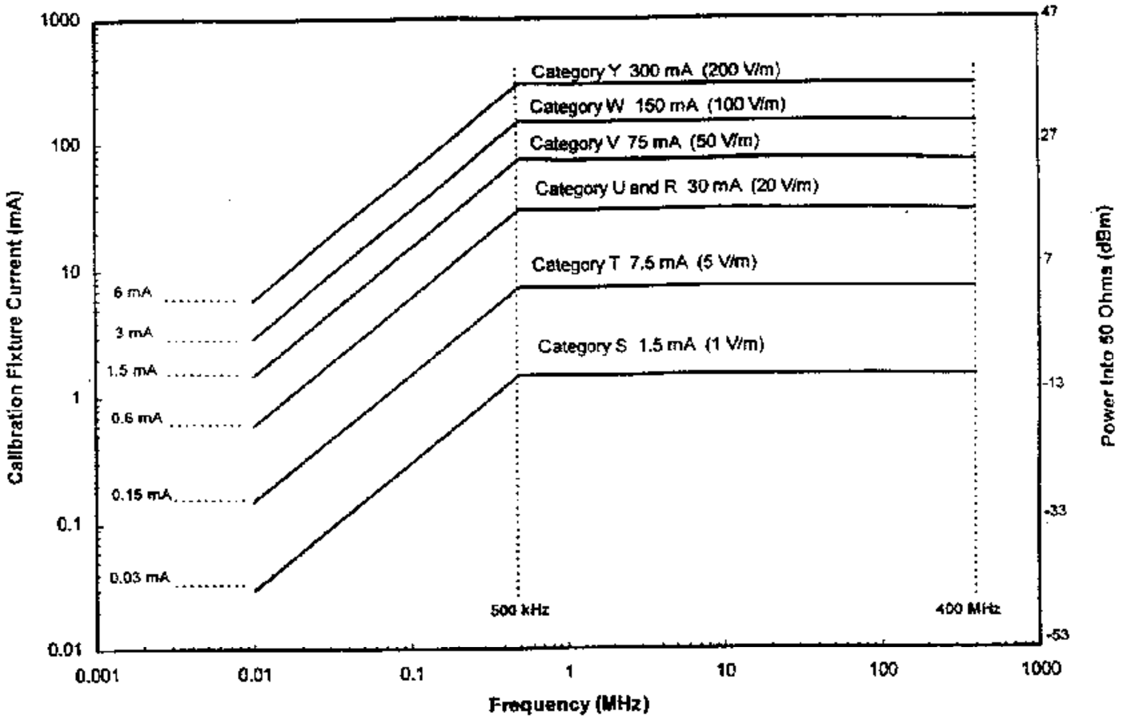


Figure 20-6 Conducted Susceptibility Test Levels

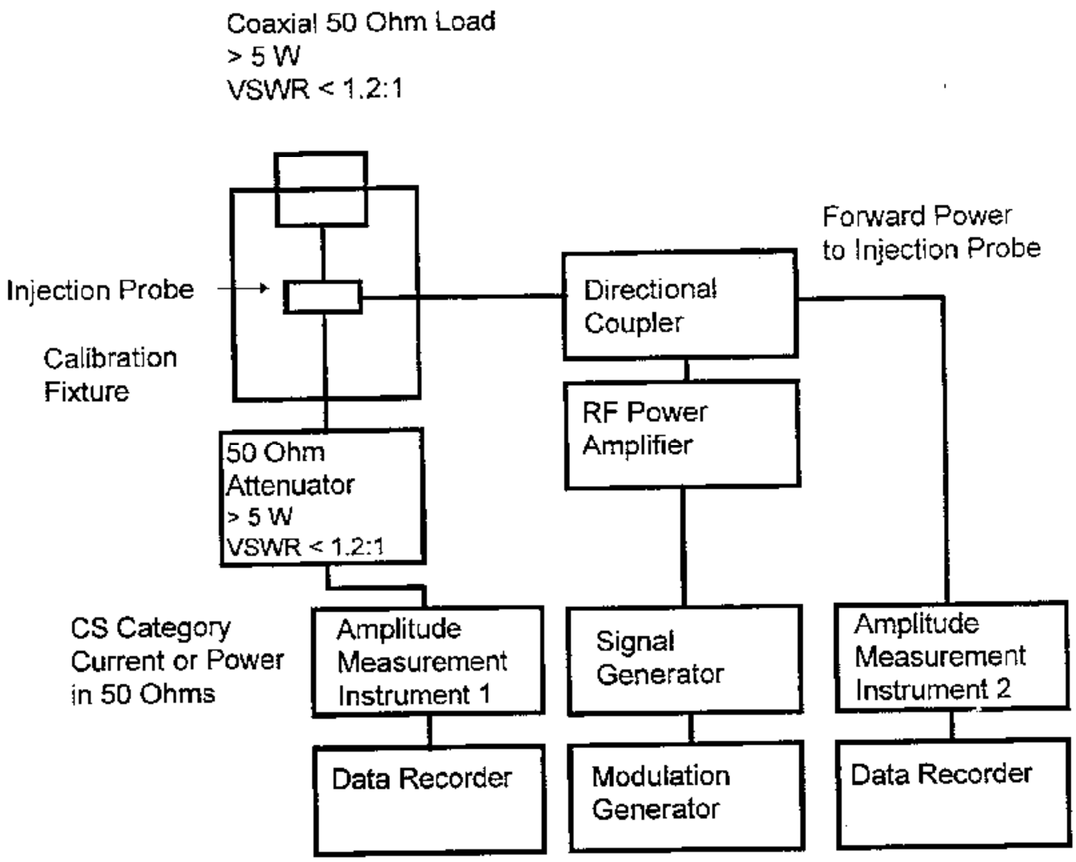


Figure 20-7 Conducted Susceptibility Calibration Setup

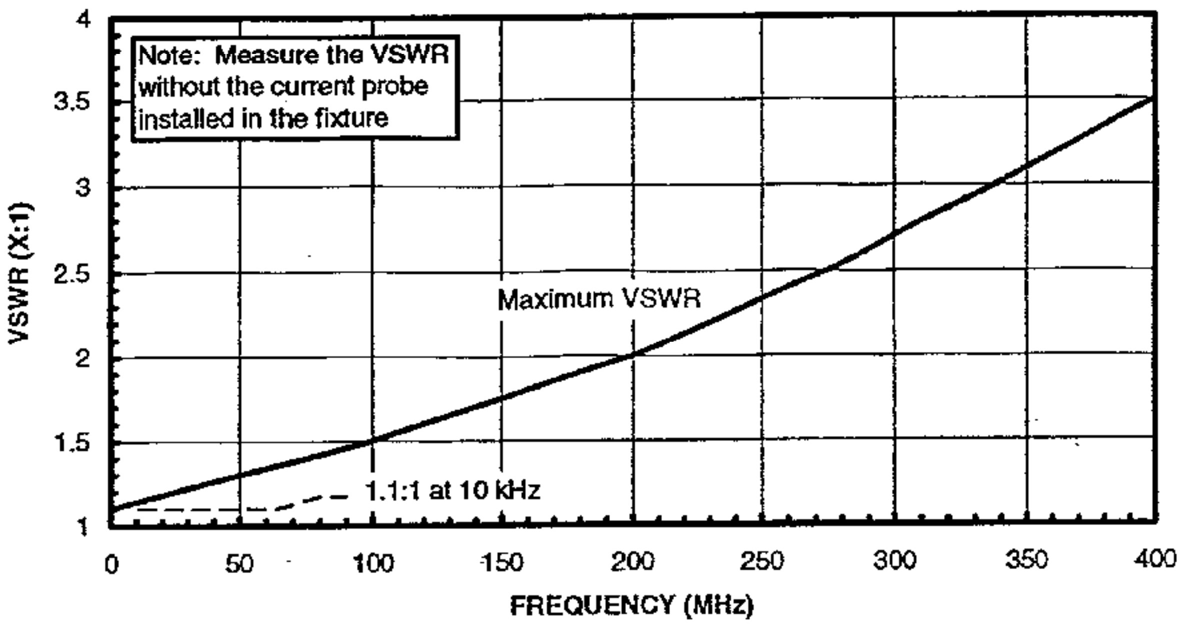
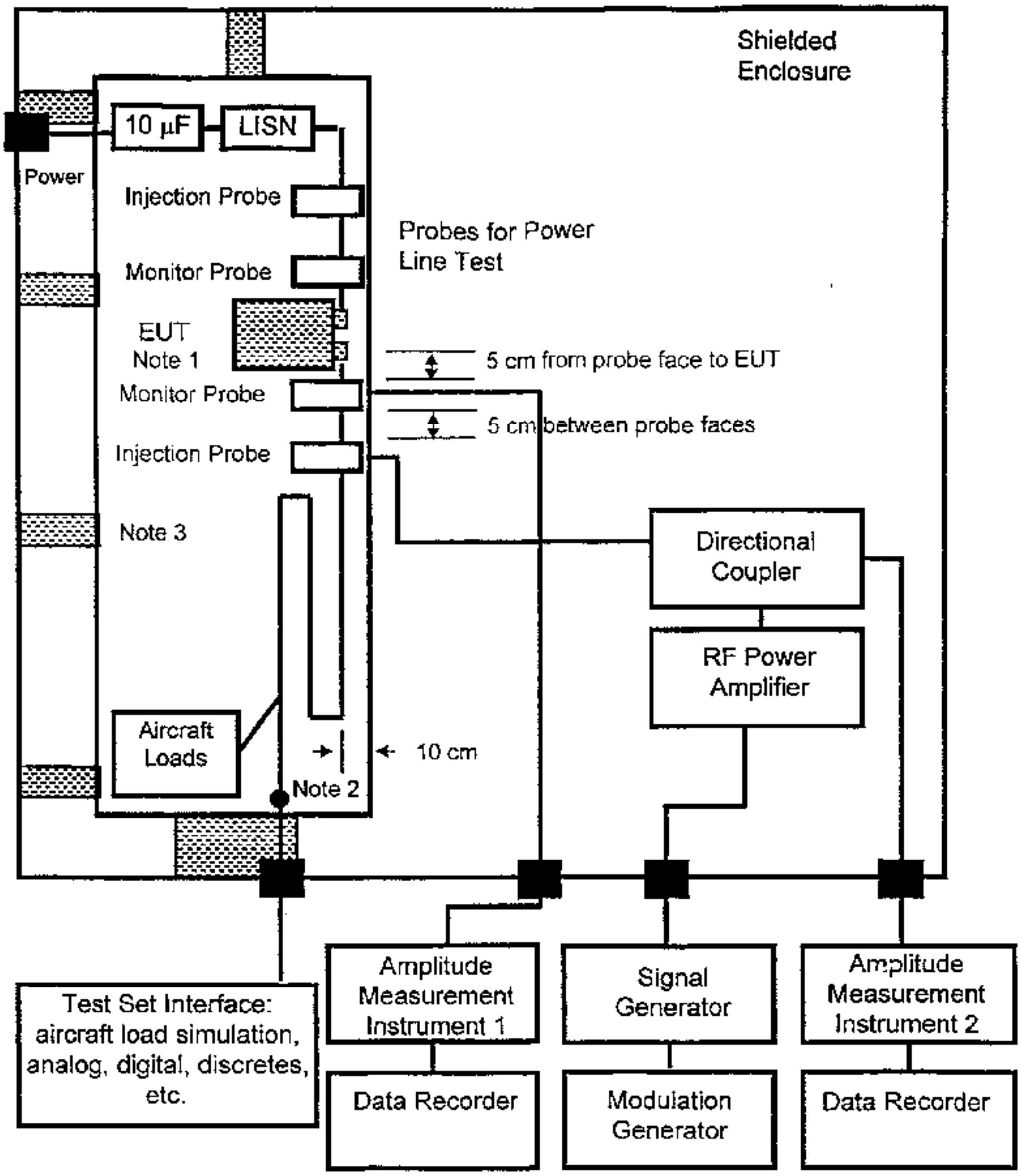
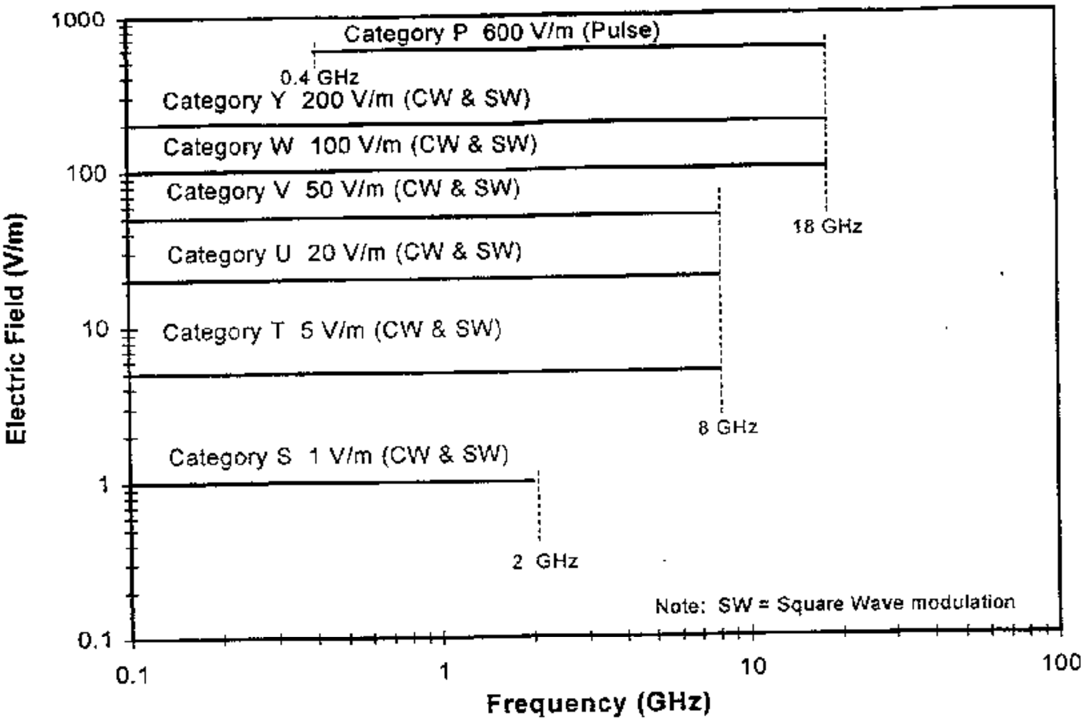


Figure 20-8 Calibration Fixture Maximum VSWR Limits



Note 1 See Section 20.3 for EUT general requirements.
Note 2 End of exposed cable. Unshielded cable may be shielded from here to the wall.
Note 3 Bonding strap.

Figure 20-9 Conducted Susceptibility Test Setup



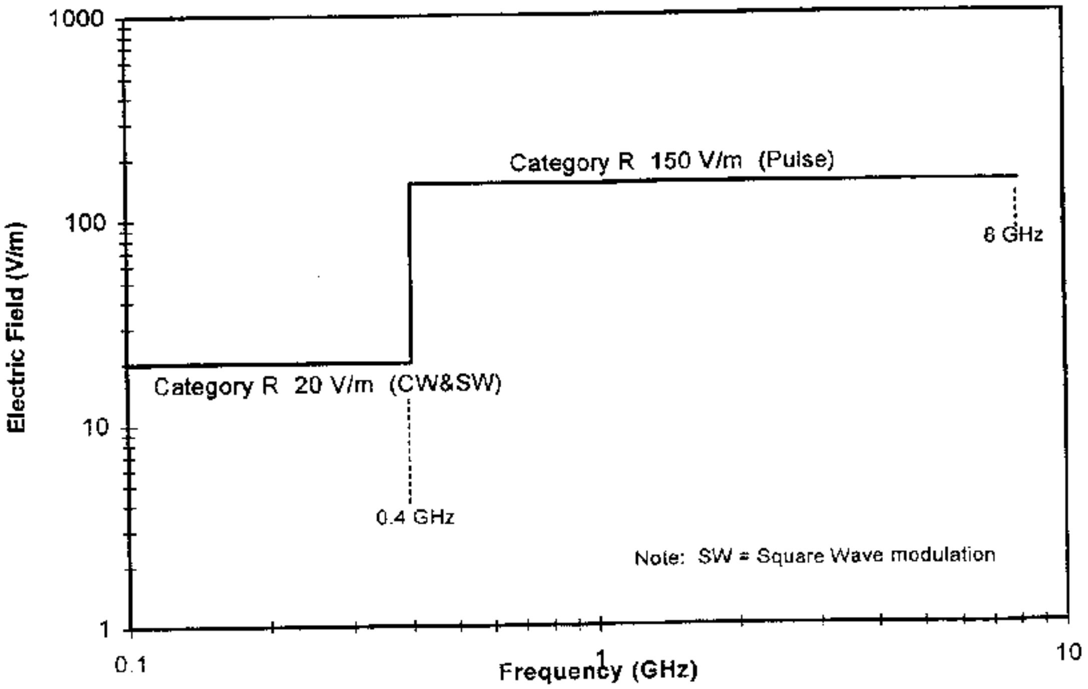
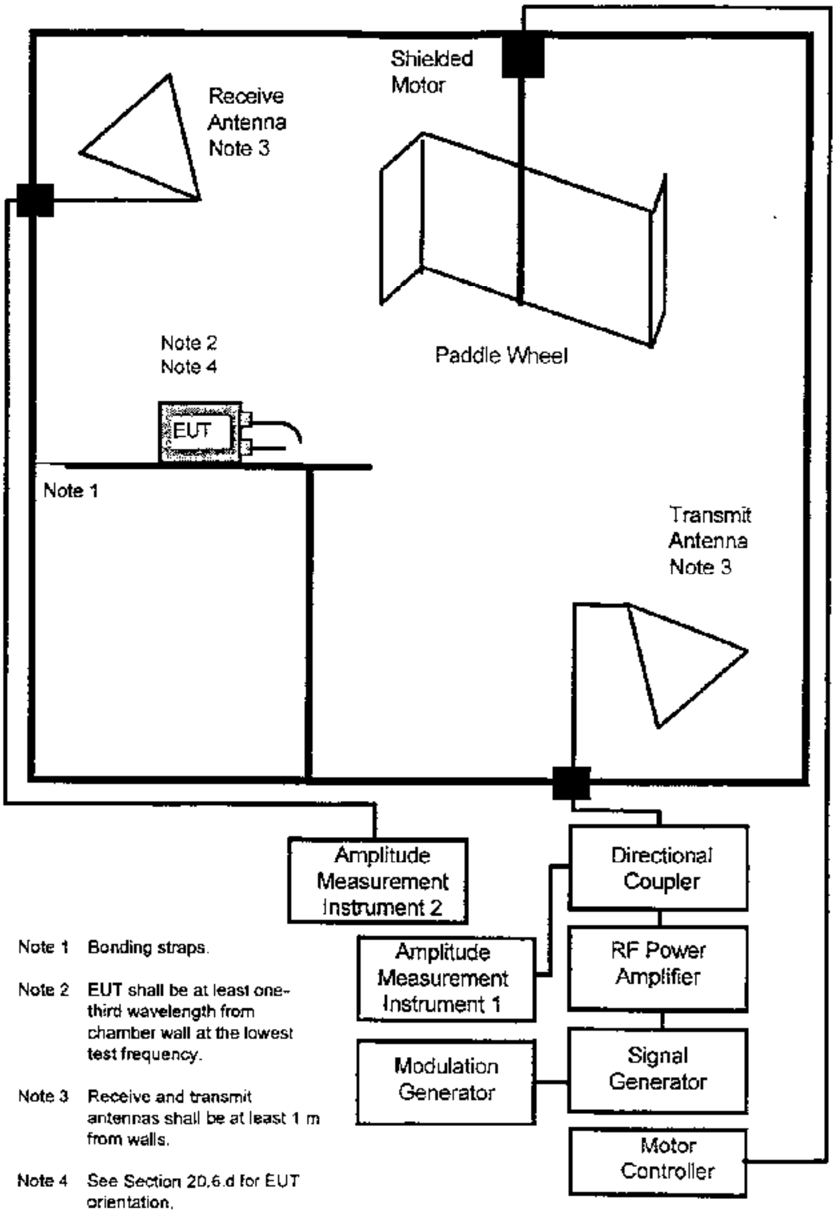


Figure 20-10 Radiated Susceptibility Test Levels



Note 1 Bonding straps.

Note 2 EUT shall be at least one-third wavelength from chamber wall at the lowest test frequency.

Note 3 Receive and transmit antennas shall be at least 1 m from walls.

Note 4 See Section 20.6.d for EUT orientation.

Figure 20-11 Typical Mode-Stirred Chamber - Side View

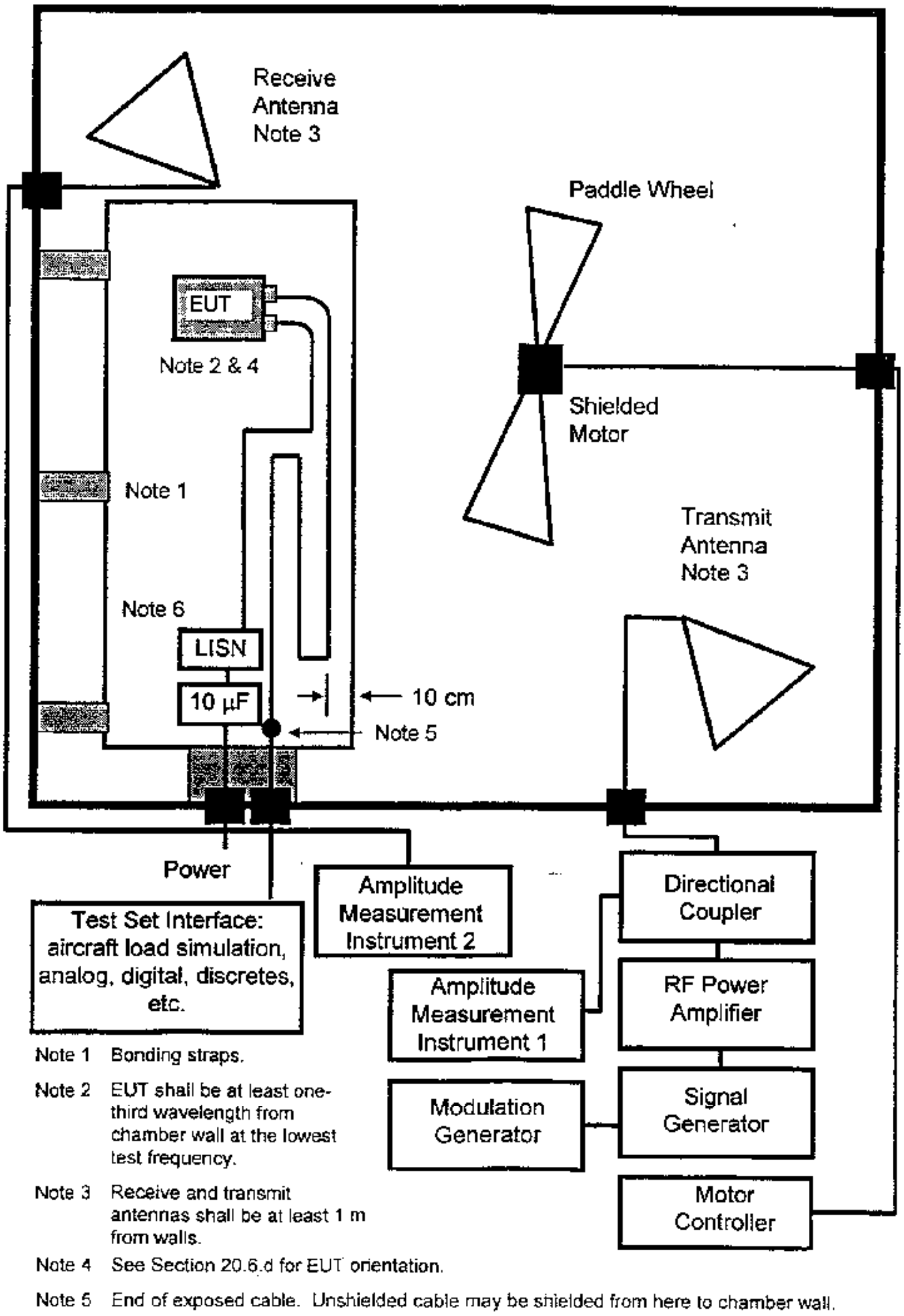


Figure 20-12 Typical Mode-Stirred Chamber - Plan View

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 21

Emission of Radio Frequency Energy

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2, 3, and 20. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

21.0 EMISSION OF RADIO FREQUENCY ENERGY

21.1 Purpose of the Test 21.1

These tests determine that the equipment does not emit undesired RF noise in excess of the levels specified below. The notches specified in the radiated emissions limits are included to protect aircraft RF sensors operating frequencies.

21.2 Equipment Categories

Categories are defined in terms of location and separation between the equipment and aircraft radio antennas. As these parameters are widely linked to aircraft type and size, some examples are given with each category definition.

Category B

This category is intended primarily for equipment where interference should be controlled to tolerable levels.

Category L

This category is defined for equipment and interconnected wiring located in areas far from apertures of the aircraft (such as windows) and far from radio receivers antenna. This category may be suitable for equipment and associated interconnecting wiring located in the electronic bay of an aircraft.

Category M

This category is defined for equipment and interconnected wiring located in areas where apertures are em significant and not directly in view of radio receiver's antenna. This category may be suitable for equipment and associated interconnecting wiring located in the passenger cabin or in the cockpit of a transport aircraft.

Category H

This category is defined for equipment located in areas which are in direct view of radio receiver›s antenna. This category is typically applicable for equipment located outside of the aircraft.

21.3 Conducted RF Emission

a. Interference currents generated by the equipment and measured by using a clamp-on interference measuring device within the frequency ranges and in excess of the values given in Figure 21-1 (a) shall not appear on any power line normally connected to an aircraft bus.

   Line Impedance Stabilization Networks (LISNs) shall be used as shown in Figure 21-3. Figure 20-1 provides technical data for a LISN. Power return wires tied locally to the ground plane as noted in Section 20.3.a (6) are not tested.

b. Interference currents on interconnecting cable bundles other than antenna feed cables and primary power lines shall be measured by using a clamp-on interference measuring device. The limits and frequency ranges are as shown in Figure 21-2.

Figure 21-3 shows a simplified test arrangement for the use of the current probe.

Install the current probe five centimeters from the EUT. If the EUT connector plus backshell length exceeds five centimeters the probe shall be placed as close to the connector backshell as possible and the position noted.

21.4 Radiated RF Emission

Radiated interference fields generated by the equipment within the frequency ranges, and in excess of the values shown in Figures 21-4, 21-5 and 21-6 for the appropriate categories, shall not be radiated from any unit, cable or interconnecting wiring. This does not include radiation emanating from antennas or, in the case of transmitters, any radiation on the selected frequency ∀+50% of the band of frequencies between adjacent channels; when the transmitter is keyed and supplying RF to the load. Radio transmitters or receiver/transmitters must meet specified emissions requirements (including the selected frequency ± 50% of the band of frequencies between adjacent channels) while in an unkeyed or receive mode. A typical arrangement of equipment for conducting the radiated RF emission test is shown in Figure 21-7.

NOTE: *Subsection 21.4 does not measure or control spurious signals conducted out of the antenna terminals of receivers and transmitters. That control should be specified in the equipment performance standard for that receiver or transmitter.*

21.5 General Requirements

The equipment under test shall be set up on a ground plane and operated in accordance with the criteria in Subsection 20.3 subparagraph a and parts 1, 2 and 5 of subparagraph b, with the following additions:

a. Interference shall be measured using the peak detector function of the interference measuring equipment. Interference measuring instruments with selectable IF bandwidths (BWI) may be used, and the selected BWI must be the values given in the following table.

The time constant of the peak detector must be lower or equal to 1/BWI. Where applicable, video bandwidths shall be selected to be greater than or equal to the resolution bandwidth.

Frequency Bands	BWI
0.15-30 MHz	1 kHz
30-400 MHz	10 kHz
400-1000 MHz	100 kHz
1000-6000 MHz	1 MHz

NOTE: *During radiated tests the above bandwidths may not provide a low enough noise floor to make proper measurements in the notches defined for categories M & H. In that case, a 10 kHz BWI shall be used for measurements in the notches with no correction factor being applied.*

b. Field strength units are obtained by using any appropriate antenna and adding the appropriate antenna factor to the measured voltage in dB microvolts. Appropriate correction factor for cable losses and matching networks must also be applied.

c. When linearly polarized antennas are used for radiated tests above 25 MHz, measure radiated emissions using both vertically and horizontally polarized orientations.

d. For EUT with multiple apertures and sensors such as displays, several different orientations may be required, for example connector side and aperture side(s) facing the antenna.

e. Consider EUT realistic operating modes which produce maximum emission.

f. Radiated ambient data (EUT "off" and test support equipment "on") is required only if EUT emissions are greater than 3 dB below the selected category limit. It is good engineering practice to check ambient radiated emissions prior to a radiated emissions test, and it is desirable that the ambient emissions be at least 6 dB below the selected limit line.

g. Measure and record the EUT emissions conditions and apply the appropriate limit from Figures 21-4, 21-5 or 21-6 for the selected category.

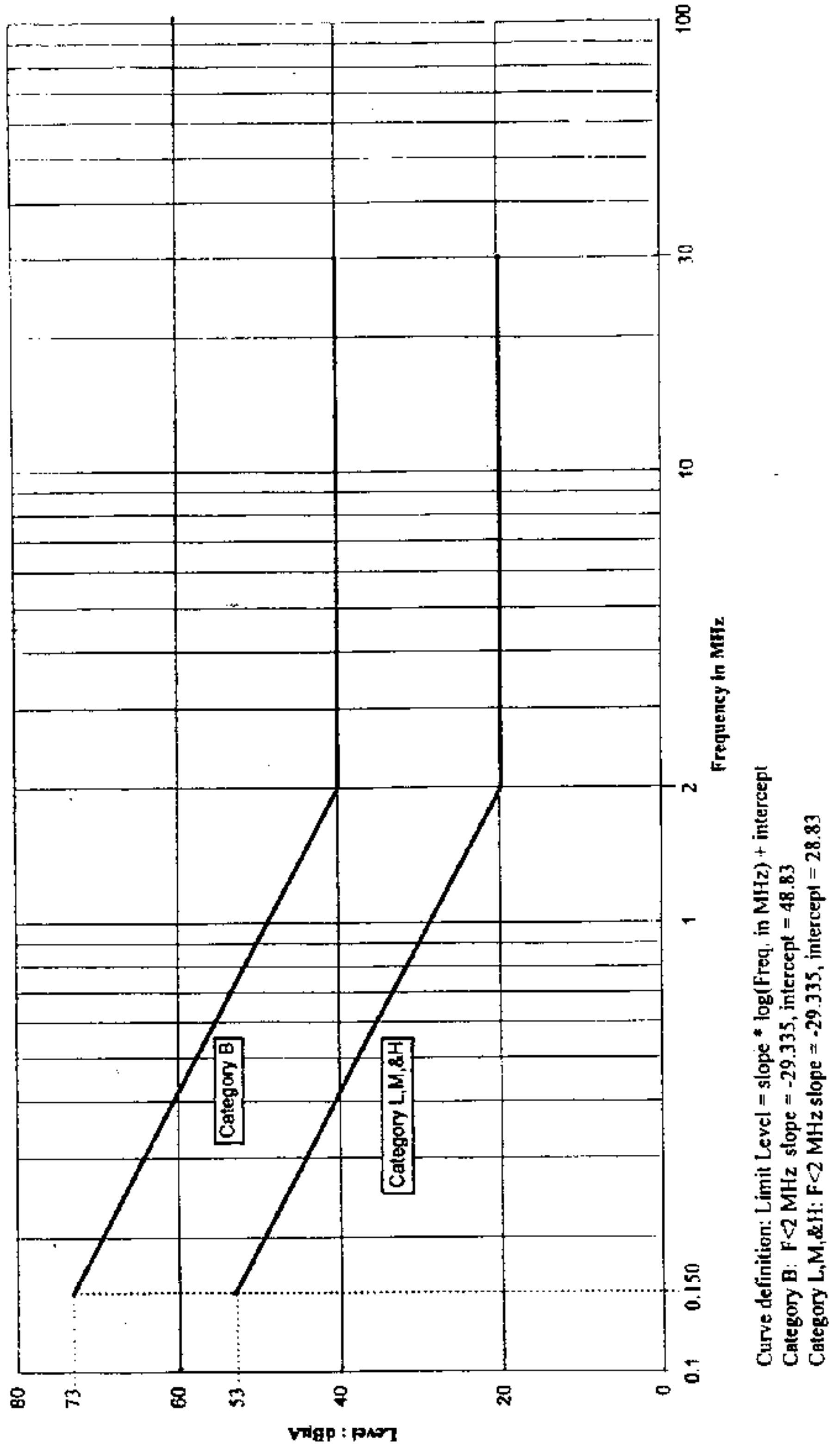
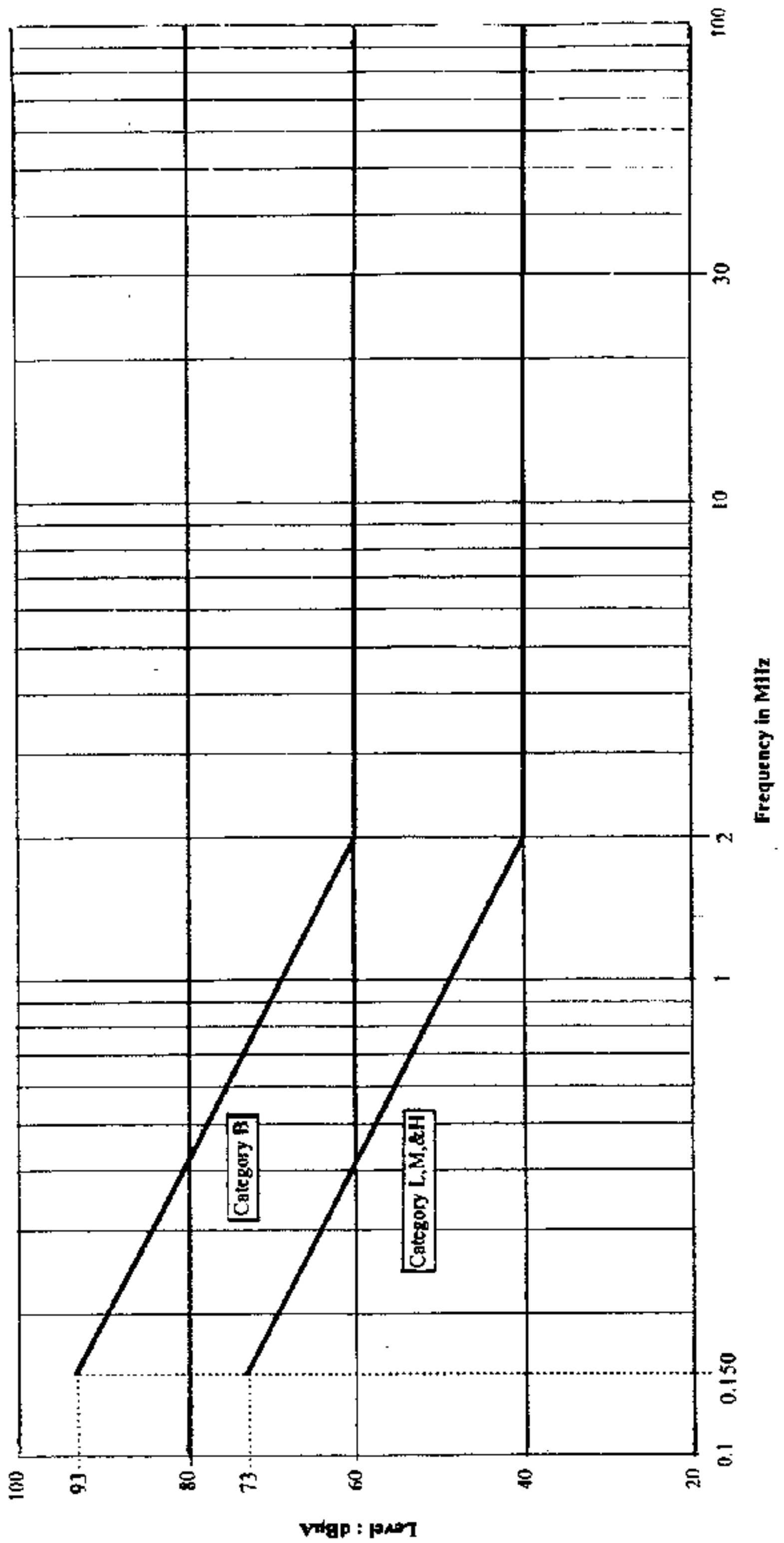


Figure 21-1 Maximum Level of Conducted RF Interference - Power Lines



Curve definition: Limit Level = slope * log(Freq. in MHz) + intercept
Category B: F<2 MHz slope = -29.335, intercept = 68.83
Category L,M,&H: F<2 MHz slope = -29.335, intercept = 48.83

Figure 21-2 Maximum Level of Conducted RF Interference - Interconnecting Cables

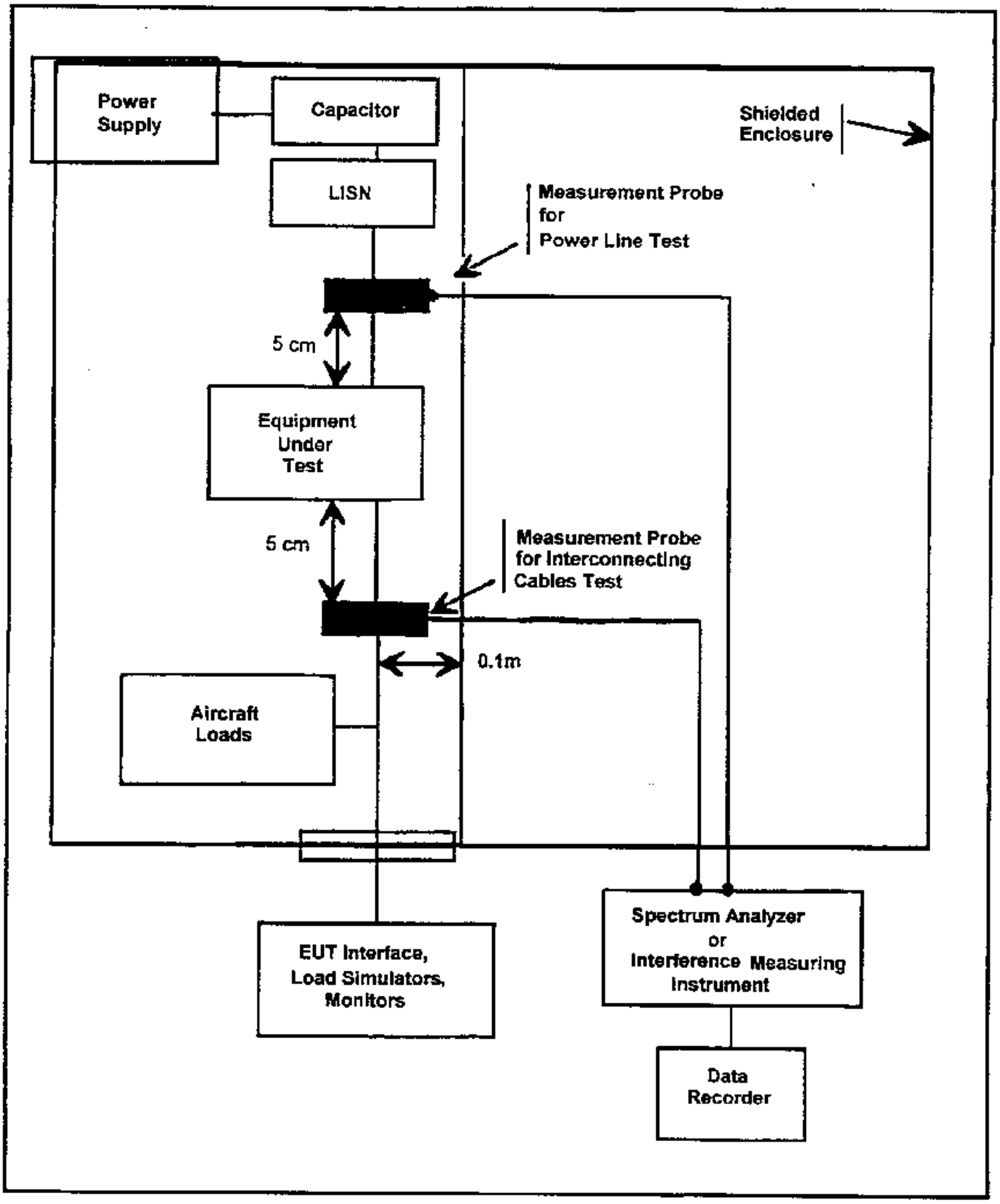
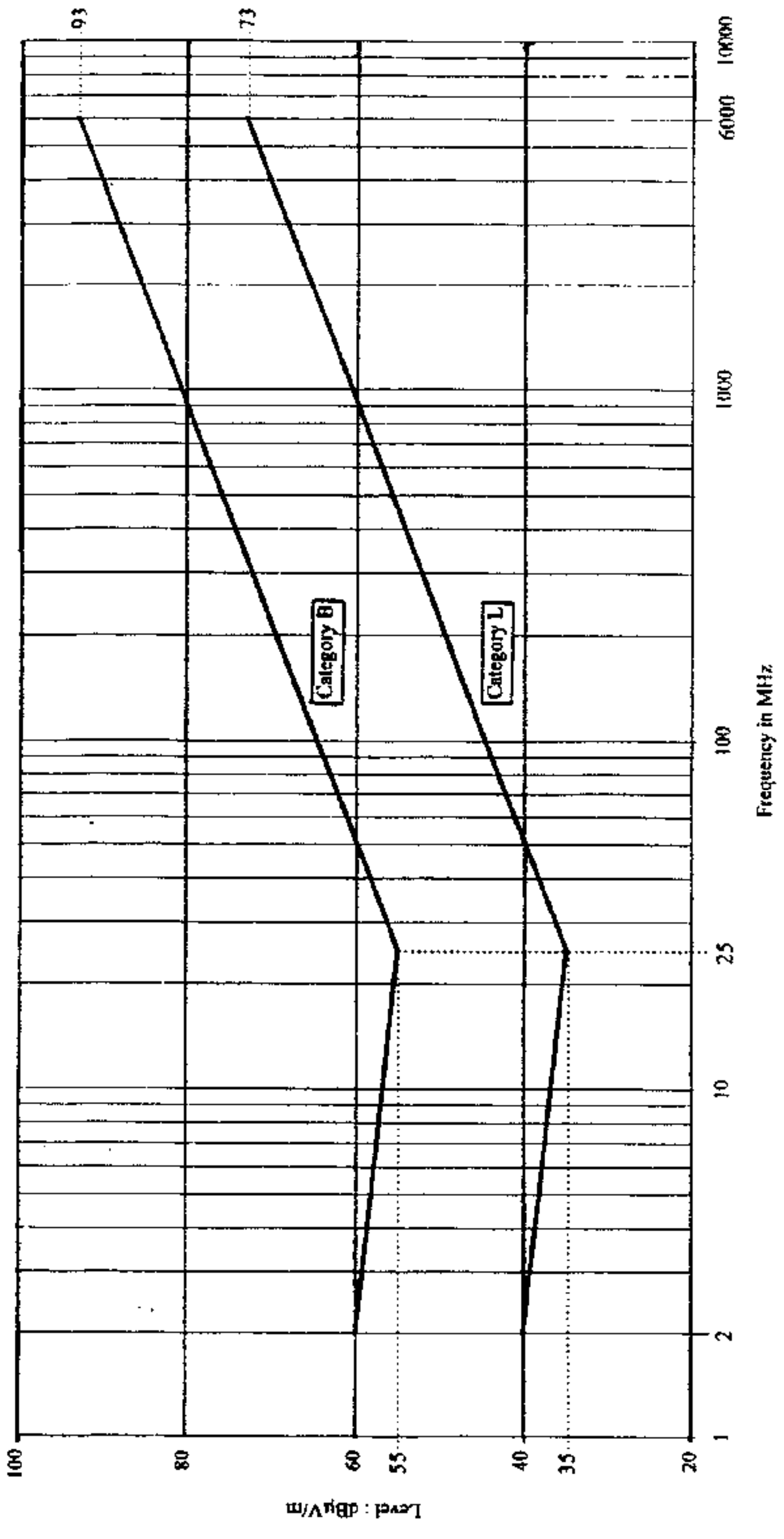
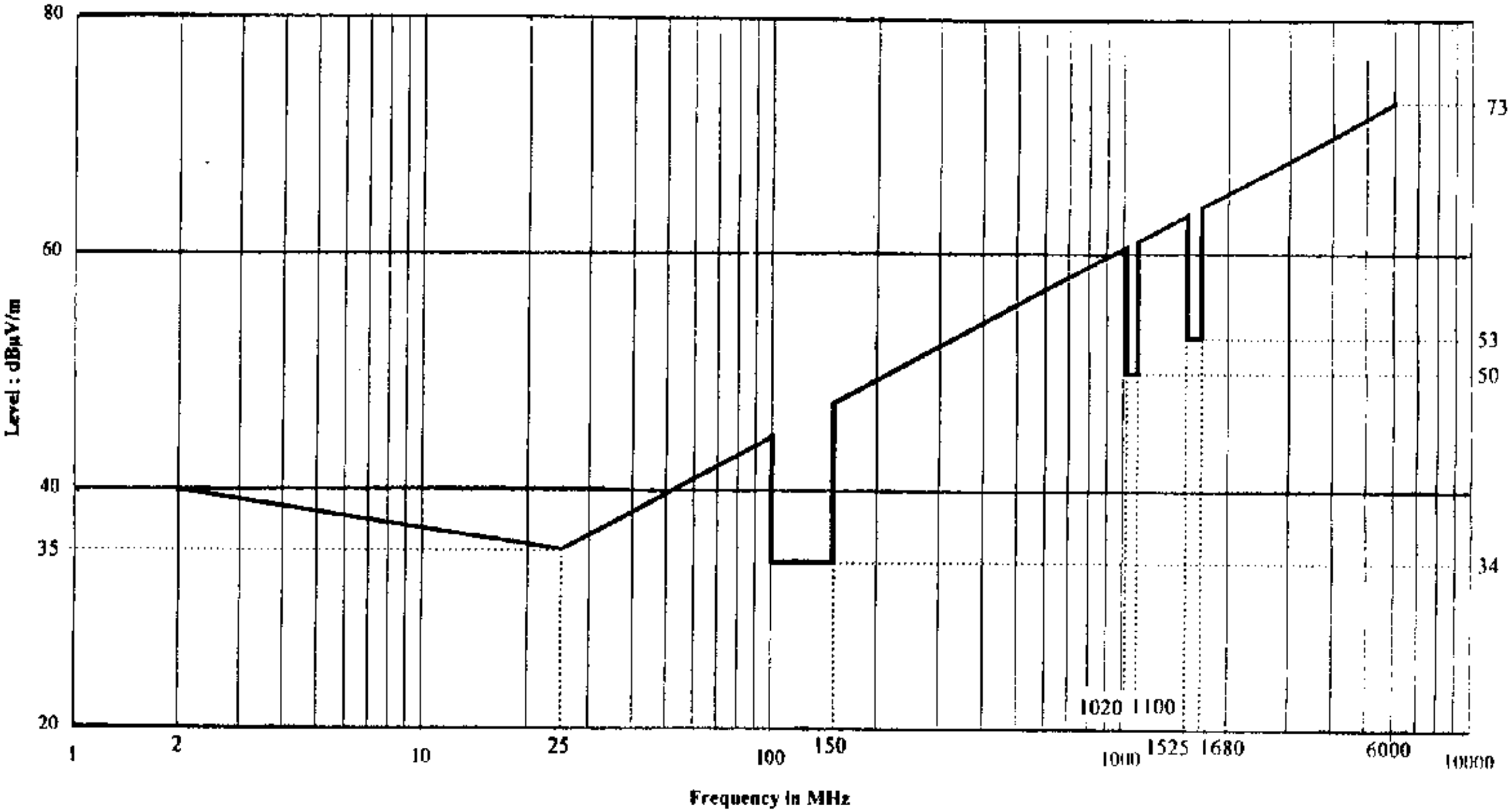


Figure 21-3 Typical Setup for Conducted RF Interference Test



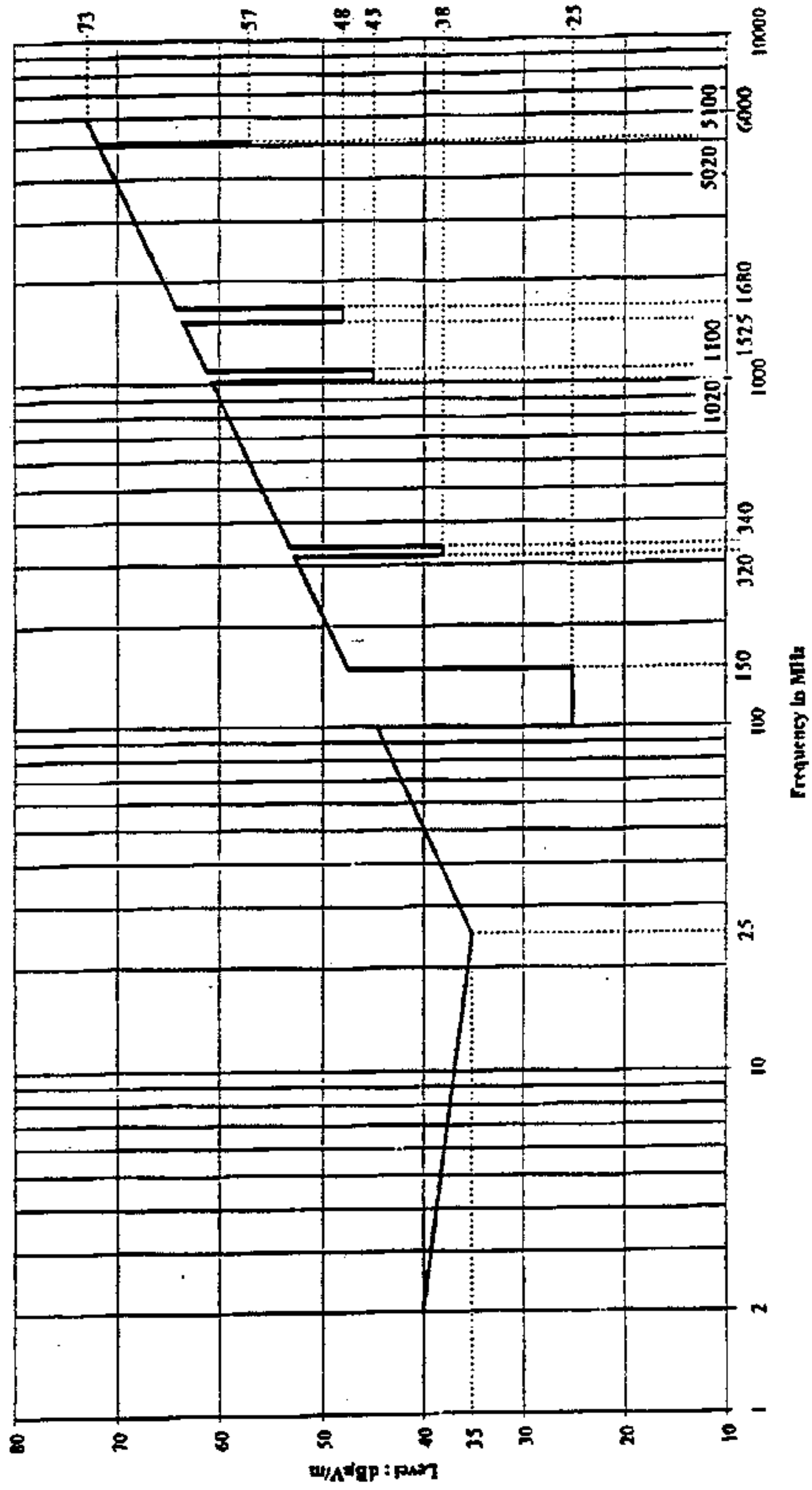
Curve definition: Limit Level = slope * log(Freq. in MHz) + intercept
Category B: F<25 MHz slope = -4.558, intercept = 61.372 F>25 MHz slope = 15.965, intercept = 32.682
Category L: F<25 MHz slope = -4.558, intercept = 41.372 F>25 MHz slope = 15.965, intercept = 12.682

Figure 21-4 Maximum Level of Radiated RF Interference - Categories B & L



Curve definition outside of notches: Limit Level = slope * log(Freq. in MHz) + intercept
Category M: F<25 MHz slope = -4.558, intercept = 41.372 F>25 MHz slope = 15.965, intercept = 12.682

Figure 21-5 Maximum Level of Radiated RF Interference - Category M



Curve definition outside of notches: Limit Level = slope * log(Freq. in MHz) + intercept
Category H: F<25 MHz slope = -4.558, intercept = 41.372 F>25 MHz slope = 15.965, intercept = 12.682

Figure 21-6 Maximum Level of Radiated RF Interference - Category H

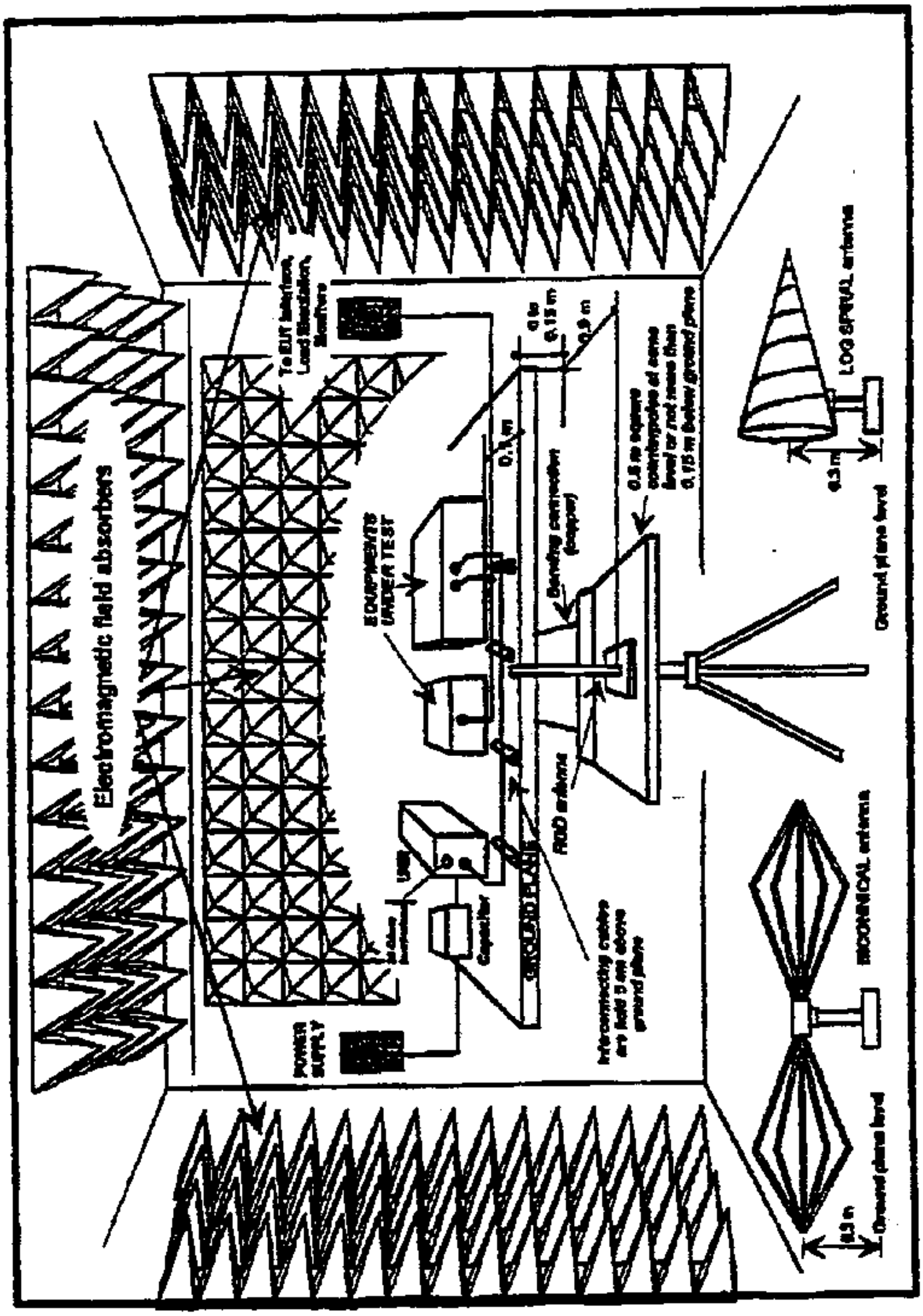


Figure 21-7 Typical Setup for Radiated RF Interference Test

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Section 22

Lightning Induced Transient Susceptibility

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

22.0 LIGHTNING INDUCED TRANSIENT SUSCEPTIBILITY

22.1 Purpose of Tests

These test methods and procedures apply idealized waveforms to verify the capability of equipment to withstand effects of lightning induced electrical transients. The criteria for equipment performance in the presence of lightning transients shall be defined in the applicable equipment specification.

Two groups of tests may be used for equipment qualification. The first is a damage tolerance test performed using pin injection as described in paragraph 22.5.1. The second group, as described in paragraphs 22.5.2.1 and 22.5.2.2, evaluates the functional upset tolerance of equipment when transients are applied to interconnecting cable bundles. Cable bundle tests can also provide an indication of damage tolerance. The appropriate test group or groups will be defined in the applicable equipment specifications.

NOTE: *These tests may not cover all aspects of lightning induced interaction and effects on equipment, particularly when incorporated into a system. Additional tests, such as simultaneous cable bundle injection, multiple stroke, multiple burst and/or multiple frequency, may be required to achieve system certification. Tests for the direct effects of lightning on equipment are covered in Section 23.0 of this document.*

22.2 Definitions

Cable Bundle
A group of wires and/or cables bound or routed together that connect two pieces of equipment.

Calibration Loop
A heavy duty, low self-inductance, low resistance, single turn wire loop passed through the injection transformer to form an insulated secondary winding. It should be low enough in impedance to achieve the test level and waveform.

Generator
A set of equipment (waveform synthesizer, amplifiers, couplers, etc.) that delivers a voltage or current waveform, via direct or indirect coupling to the equipment under test (EUT).

Local Ground
Any ground strap or conductor that is connected to the equipment and the same part of airframe structure to which that equipment is installed. The ground strap or conductor would therefore be bonded to the same ground plane that the equipment is mounted to and, during a lightning strike, would be at the same potential as the equipment.

Monitor Loop
A close fitting, single turn, wire loop wound through the injection transformer to form an insulated secondary winding. It is used to monitor the induced cable bundle or calibration loop voltage.

Shield
A conductor which is grounded to an equipment case or aircraft structure at both ends and is routed in parallel with and bound within a cable bundle. It usually is a wire braid around some of the wires or cables in the cable bundle or may be a metallic conduit, channel or wire grounded at both ends within the cable bundle. The effect of the shield is to provide a low resistance path between equipment so connected.

Shielded Cable Bundle
A cable bundle that contains one or more shields. Such cable bundles may include some unshielded wires.

Unshielded Cable Bundle
A cable bundle that contains no shields.

22.3 Categories

The equipment manufacturer must test the equipment to the test levels and waveforms consistent with its expected use and aircraft installation.

Category designation for equipment shall consist of four characters:

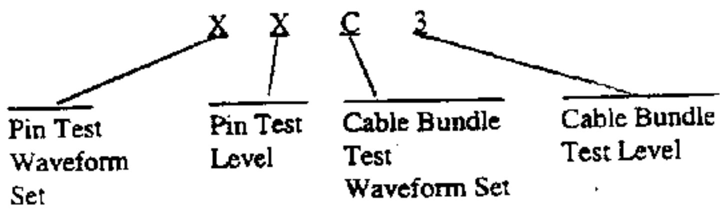
a. Pin test waveform set letter (A or B) as designated in Table 22-1 or Z or X,

b. Pin test level (1 to 5) as designated in Table 22-2 or Z or X,

c. Cable bundle test waveform set letter (C through F) as designated in Table 22-1 or Z or X,

d. Cable bundle test level (1 to 5) as designated in Table 22-3 or Z or X.

Category designation should, therefore, appear as follows:



In the above example, Category XXC3 identifies an equipment cable bundle test with waveform set C to level 3 in Table 22-3. In another example, Category B3XX would identify an equipment pin test with waveform set B at level 3 in Table 22-2. The third and fourth designators in this example indicate that no cable bundle tests were performed. When no tests are performed, the category designation is XXXX.

A general installation case for cable bundles is illustrated in Figure 22-1. Figures 22-2 through 22-6 define the individual waveforms associated with waveform sets A through F.

The use of Z in either of the waveform set designator positions indicates that either the waveform set or the test configuration (i.e., shielding, grounding) was different from that designated in Table 22-1. Similarly, a Z in either test level position indicates that test levels different than those designated in Tables 22-2 or 22-3 were applied. For example, AZZ3 indicates that pin tests were conducted at level(s) other than those designated, and that an alternate waveform set or configuration was used for cable bundle tests at level 3. The specific test conditions and test levels shall be described in the test report.

22.3.1 Waveform Set Designators (First and Third Characters)

Waveform sets A, C, and E are applicable to equipment interconnected with wiring installed within airframes or airframe sections where apertures, not structural resistance, are the main source of induced transients as would be the case in an all-metal airframe. For the same reasons, these waveform sets can also apply to equipment in airframes composed of metal framework and composite skin panels, and to equipment in carbon fiber composite (CFC) airframes whose major surface areas have been protected with metal meshes or foils.

Waveform sets B, D, and F are applicable for equipment interconnected with wiring installed within any airframe or airframe section when structural resistance is also a significant source of induced transients, (i.e., carbon fiber composite structures). In these cases the wiring is exposed to high structural voltages and redistributed lightning currents which are represented by Waveform 5A.

A and B are for pin injection tests.

C through F are for cable bundle tests.

Z indicates tests other than those specified in Table 22-1 were conducted, such as the use of waveform set C or D with shielded cables.

22.3.2 Test Level Designators (Second and Fourth Characters)

Test level descriptions for internal aircraft environments are provided below with specific levels for each test waveform listed in Tables 22-2 and 22-3. Levels 1 through 5 allow flexibility in the protection of an equipment. The descriptions are for guidance only. Anticipated exposure of interconnecting wiring and equipment location determines the test level.

Level 1 is intended for equipment and interconnecting wiring installed in a well-protected environment.

Level 2 is intended for equipment and interconnecting wiring installed in a partially protected environment.

Level 3 is intended for equipment and interconnecting wiring installed in a moderately exposed environment.

Levels 4 and 5 are intended for equipment and interconnecting wiring installed in severe electromagnetic environments.

Z indicates tests conducted at voltage and/or current levels other than those specified in Tables 22-2 and 22-3.

22.4 General Test Requirements

a. Equipment Under Test - The EUT shall be set up on a ground plane and configured in accordance with the following criteria unless otherwise specified by the individual equipment specification:

(1) Ground Plane - A copper, brass or aluminum ground plane, at least 0.25 mm thick for copper and aluminum, 0.5 mm thick for brass, 2.5 m^2 or more in area with a minimum depth (front to back) of 0.75 m shall be used. When a shielded enclosure is employed, the ground plane shall be bonded to the shielded enclosure at intervals no greater than one meter and at both ends of the ground plane. It is recommended that the dc bonding resistance should be 2.5 milliohms or less.

(2) Shock and Vibration Isolators - If specified by the equipment manufacturer, the EUT shall be secured to mounting bases incorporating shock or vibration isolators. The bonding straps furnished with the mounting bases shall be connected to the ground plane. When mounting bases do not incorporate bonding straps, they shall not be used in the test setup.

(3) Electrical Bonding - Only the provisions included in the EUT design or installation instructions (e.g., bonding of enclosure, mounting base and ground plane) shall be used for bonding. The electrical bonding of equipment, connectors and wire bundles shall be representative of aircraft installations and in accordance with the equipment manufacturers' requirements for minimum performance.

Equipment intended to be grounded by means other than the bonding supplied by the installation method should be placed on an insulating mat. The test report shall describe the bonding methods employed.

(4) External Ground Terminal - When an external terminal is available for a ground connection on the EUT, the terminal shall be connected to the ground plane to ensure safe operating conditions during the test, unless otherwise specified for these tests. The length of the connection defined in the installation instructions shall be used; if a length is not defined, use approximately 30 cm of a representative wire or strap.

(5) Interconnecting Wiring/Cable Bundles - For cable bundle tests, all EUT interconnecting wiring (e.g., shielded wires, twisted wires, etc.), cable bundles and RF transmission lines shall be in accordance with the applicable installation and interface control drawings or diagrams.

Cables shall be bundled in a manner similar to that of aircraft installations and supported approximately 50 mm above the ground plane. For complex cable bundle configurations, all cable bundles and interconnected loads should be kept separated from each other as much as practical to minimize coupling effects between cables.

Unless otherwise specified, the cable bundle shall be at least 3.3 m. When the length of an interconnecting cable bundle is greater than the test bench, the cable bundle should be arranged with the excess length zig-zagged at the back of the test bench approximately 50 mm above the ground plane.

Some special installations may require very long cable bundle lengths which cannot be accommodated on the test bench; therefore, the recommended maximum length of the interconnecting cable bundles for these tests should not exceed 15 m. The exception to this limitation is where cable bundle lengths are matched or specified to a particular length for phase match or similar reasons.

(6) Power Leads - For cable bundle tests, power and return leads normally bundled with the control/signal leads shall remain in the cable bundle and only be separated from the bundle just prior to the cable bundle exiting the test area. These leads shall then be connected to Line Impedance Stabilization Networks (LISNs). See paragraph 22.4b (2).

When the actual aircraft cable bundle configuration is unknown or when power and/or return leads are normally routed separately from the control/signal leads, the power and return leads should be broken out of the cable bundle near the connector of the EUT and run separately to the LISNs. Under these conditions, the length of the leads to the LISNs shall not exceed 1.0 m unless otherwise specified in the applicable equipment specification.

When the return lead is a local ground (less than 1 meters length), this lead may be grounded directly to the test bench, in accordance with the applicable installation and interface control drawings or diagrams.

(7) Interface Loads and Support Equipment - Cable bundle tests ideally should be performed on fully functioning equipment. EUTs should be suitably loaded with actual interface equipment.

Where the interface equipment must be simulated, the simulated electrical, electronic and/or electromechanical characteristics of the loads should be representative of the aircraft installation. To avoid altering the voltage and current distributions in the cable bundles, the electrical/electronic loads should simulate the actual load line-to-line and line-to-ground impedances (including stray capacitances) as far as is pracical.

Care should be taken that any test configuration, simulated load or monitoring equipment does not alter the susceptibility or immunity of the EUT. The support equipment may require protection from the effects of the applied transients in order to avoid upset or damage.

(8) Dummy Antennas or Loads - For the purpose of this test, antenna cables may be terminated in a load equal to the cable characteristic impedance, or a dummy antenna. The dummy antenna, if used, shall be shielded and be designed to have electrical characteristics closely simulating the in-service antenna. It shall also contain electrical components normally used in the antenna, such as filters, crystal diodes, synchros and motors.

b. Test equipment - These shall be set up and configured in accordance with the following criteria:

(1) Bonding - Test equipment shall be bonded and grounded to minimize ground loops and ensure personnel safety. When high current levels are to be applied to cable bundles, care shall be exercised to ensure that these currents are safely transferred from the shields to the wall of the shielded enclosure or that adequate bonding and shielding is provided

outside the shielded enclosure to minimize risk to personnel.

(2) Line Impedance Stabilization Network - A LISN shall be inserted in each primary power input and return line. Power return lines locally grounded in the aircraft installation do not require a LISN. The LISN case shall be bonded to the ground plane. When LISNs with self resonances above 10KHz are used (such as standard 5uH LISN), capacitors shall be inserted at each LISN power input terminal as shown in Figures 22-11 and 22-13 for the entire test. The RF measurement port of the LISN shall be terminated into 50 ohms for all tests. The input impedance characteristic of the LISN is shown in Figure 22-7.

(3) Measurement and Injection Probes - Probes shall have the necessary power and range capabilities to reproduce the test waveform(s). Waveform 3 tests shall use probes with electrostatic shielding.

c. Data to Assist in Interpretation of Test Results - The test report should include the following test setup and data items.

(1) Cable Configuration(s) - The length of each cable bundle, types of wiring, shielding and shield terminations (including individual as well as overall shields).

(2) Test Setups - Schematic or block diagrams or photographs of each test setup including layout of cable bundles and placement of transient injection probes and measurement probes.

(3) EUT Operating Mode(s) - The mode(s) of operation used during cable bundle tests.

(4) Load(s) - A description of all loads, either actual or simulated. Simulated loads shall identify the extent of impedance simulation both line-to-line and line-to-case (ground).

(5) Test Waveforms and Levels - Calibration/verification oscillograms of each test waveform and level.

(6) Applied Transients - Oscillograms of representative test currents and voltages measured on interconnecting cable bundle(s) or pin(s) as applicable to each test setup.

(7) Pass/Fail Criteria - A description of the pass/fail criteria.

(8) Test Results - The results of the test and any responses that do not meet the pass/fail criteria.

22.5 Test Procedures

Pin injection tests are primarily for damage assessment and involve the injection of transients directly into EUT interface circuits.

Cable bundle tests determine whether functioning equipment will experience upset or component damage when the equipment and its interconnecting wiring are exposed to the applied transients. The test methods and procedures are applicable to configurations composed of the EUT, interconnecting cable bundle(s) and load(s) tested to a common level (see Figure 22-1).

EUT's included in complex systems where various cable bundles are exposed to widely different environments may require different test levels on different cable bundles, requiring a Z category designator (see Subsection 22.3).

WARNING

The transient generators used in these tests produce lethal voltage and current levels. Exercise all operational safety precautions to prevent injury or death of test and support personnel.

22.5.1 Pin Injection Tests

Pin injection testing is a technique whereby the chosen transient waveform(s) is applied directly to the designated pins of the EUT connector, usually between each pin and case ground. This method is used for assessing the dielectric withstand voltage or damage tolerance of equipment interface circuits. For equipment that is electrically isolated from case and local airframe grounds, a dielectric withstand or hi-pot test to the peak amplitude of a level in Table 22-2 is adequate to satisfy pin test requirements.

Testing of simple equipment such as electromechanical devices or temperature probes does not require that operating voltages be applied, provided the presence of such voltages and associated currents is not a factor in component failure.

Testing more complex equipment may require that power be applied. When testing a unit with power applied, a suitable means must be used to ensure that the transient generator does not produce excessive loading of power supply or signal lines. Isolation must be provided to ensure that the applied transients will be directed to the interface of the equipment and not into the power supply or any other load.

Groups (three or more) of EUT circuits (pins) with identical interfaces may be qualified by testing three representative pins of each group. The remaining pins in the group are qualified by similarity.

22.5.1.1 Procedures - Generator Calibration

a. Adjust the transient generator such that the applicable open circuit voltage (Voc) waveform parameters identified in Figures 22-4 to 22-6 and level of Table 22-2 are attained at the calibration point shown in Figure 22-8.

b. Record the Voc, and verify that the applicable waveform parameters have been satisfied. Note the waveform polarity.

c. Record the generator setting so that the test level can be repeated during testing.

d. As illustrated in Figure 22-8, connect a non-inductive resistor equal in value to the test waveform source impedance (see Table 22-2, Note 4).

e. With the generator set as previously determined, record the voltage across the non-inductive resistor and verify that the voltage amplitude reduces to one half of Voc (±10%). The waveform shall retain its general shape. This verifies that the generator source impedance is correct.

f. Remove the non-inductive resistor.

NOTE: The generator source impedance can also be verified by recording the short circuit current (Isc) for the previously determined generator setting.

22.5.1.2 Procedures - Test Sequence

a. As illustrated in Figure 22-9, connect the transient generator between a designated pin and case ground of the EUT by means of a short, low inductance lead.

b. At the generator setting previously established in subparagraph 22.5.1.1 apply ten individual transients to the selected pin. Monitor the waveform of each applied transient for signs of unexpected changes in the waveshape.

c. Repeat step b for each designated pin in each connector of the EUT.

d. Reverse the transient generator polarity; repeat the generator calibration, and repeat steps a through c.

e. Repeat the generator calibration and test sequence for each test waveform.

f. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

22.5.2 Cable Bundle Tests

Cable bundle testing is a technique where transients are applied by cable induction or ground injection. These methods are used to verify that aircraft equipment can withstand the internal electromagnetic effects produced by the external lightning environment without experiencing functional upset or component damage. In either method, the test must be performed on fully configured and functioning equipment complete with interconnecting cable bundles and interface loads. This test requirement is satisfied by applying the specified waveforms and limits to interconnecting cable bundle(s) individually or simultaneously.

22.5.2.1 Cable Induction Tests

The procedures outlined in the following paragraphs are applicable primarily to waveforms 1, 2 and 3.

22.5.2.1.1 Procedures - Generator Performance

a. Connect the transient generator to the primary inputs of the injection transformer (see Figure 22-10).

b. For each generator, record the voltage waveform with the calibration loop open and the current waveform with the calibration loop shorted. Verify the relevant waveshape parameters identified in Figures 22-2 to 22-4, and verify that the maximum designated test level (V_T or I_T) of Table 22-3 can be achieved.

22.5.2.1.2 Procedures - Test Sequence

a. Configure the EUT, support equipment and interconnecting cable bundles as shown in Figure 22-11 with the injection transformer around the cable bundle under test.

b. Connect the current and voltage monitoring probes to an oscilloscope. For uniformity of test results, the probe positions should be as close as possible to those shown.

c. Apply power to the EUT and configure it in the selected operating mode(s). Verify proper system operation as described in the applicable equipment specification.

d. While applying transients, increase the generator setting until the designated test level (V_T or I_T) or the limit level (V_L or I_L) is reached. Record the waveforms. If V_L or I_L is reached before V_T or I_T, the test shall be reevaluated to determine if another generator and/or waveform set is required.

e. At the generator setting established in step d, apply a minimum of ten transients while monitoring the operation of the EUT.

f. Repeat steps d and e for each mode of EUT operation to be tested.

g. Reverse the transient generator polarity; repeat the generator performance verification, and repeat steps a through f.

h. Repeat steps a through g for each interconnecting cable bundle.

i. Repeat the generator performance verification and steps a through h for each waveform applied.

j. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

22.5.2.2 Ground Injection

The procedures outlined in the following paragraphs are applicable primarily to waveforms 4 and 5A.

22.5.2.2.1 Procedures - Generator Performance Verification

For each generator, record the voltage waveform across an open circuit and the current waveform through a shorted calibration loop as shown in Figure 22-12. Verify the relevant waveshape parameters identified in Figures 22-5 or 22-6, and verify that the maximum designated test level (V_T or I_T) of Table 22-3 can be achieved.

22.5.2.2.2 Procedures - Test Sequence

a. The general requirements of Subsection 22.4 shall apply to this test setup except that the case and all local grounds or returns at the transient injection point (EUT or a load) shall be insulated from the ground plane and connected to the equipment case. The insulator used between the case and ground plane must be capable of withstanding the maximum applied test voltage.

b. Configure the EUT, support equipment and interconnecting cable bundles as shown in Figure 22-13 with the transient generator connected between the EUT case and ground plane.

c. Connect the applicable current and voltage monitoring probes to an oscilloscope.

d. Apply power to the EUT and configure it in the proper operating mode(s). Verify proper system operation as described in the applicable equipment specification.

e. While applying transients, increase the generator setting until the designated test level (V_T or I_T) or the limit level (V_L or I_L) is reached. Record the waveforms. If V_L or I_L is reached before V_T or I_T, the test shall be reevaluated to determine if another generator and/or waveform set is required.

f. At the generator setting established in step e, apply a minimum of ten transients while monitoring the operation of the EUT.

g. Repeat steps e and f for each mode of EUT operation to be tested.

h. Reverse the transient generator polarity; repeat the generator performance verification, and repeat steps b through g.

i. Repeat steps b through h for each designated injection location.

j. Repeat the generator performance verification and steps b through i for each designated waveform.

k. DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

Waveform Set	Test Type	Test Levels	Waveform Nos.	Test Method	Notes
A	Pin	Table 22-2	3, 4	22.5.1	1
B	Pin	Table 22-2	3, 5A	22.5.1	1
C	Cable Bundle (Unshielded)	Table 22-3	2, 3	22.5.2.1	2, 5
			4	22.5.2.2	
D	Cable Bundle (Unshielded)	Table 22-3	2, 3	22.5.2.1	2, 3, 5
			5A	22.5.2.2	
E	Cable Bundle (Shielded)	Table 22-3	1, 3	22.5.2.1	2, 4, 5
F	Cable Bundle (Shielded)	Table 22-3	3	22.5.2.1	2, 5
			5A	22.5.2.2	

Table 22-1 Test Requirements

NOTES:

1. *For pin injection tests, waveform 3 is applied at the primary aircraft installation resonance or 1.0 MHz (±20%) if the resonance is unknown.*

2. *For cable bundle tests, waveform 3 is applied at the primary aircraft installation resonances or 1.0 MHz (±20%) and 10 MHz (±20%) if the resonances are unknown.*

3. *Waveform 5A occurs as a voltage waveform if unshielded harnesses are routed in metallic trays, conduits or have overbraids when installed in the aircraft. In this case, the appropriate test level (V_T) is the waveform 5A voltage limit (V_L) of Table 22-3.*

4. *Waveform 1 may be applied by using either test method in paragraph 22.5.2.1 or 22.5.2.2.*

5. *The criterion for deciding whether or not another generator or waveform set has to be used is whether or not the measured shapes of the current and voltage waveforms are appropriate for the waveform set under consideration. For example, waveform set E is applicable to shielded cables which would usually result in a loop under test behaving as an inductive load. In this case, a generator capable of delivering current waveforms is required. If the inductance is high, then the voltage limit could be reached first; but the waveform shapes will be correct, and the test need not be redone.*

   If the load is predominantly resistive, the voltage limit will be reached first, but the monitored voltage waveform shape will be incorrect; another test with another generator/waveform set should be selected and the test redone.

   Waveform set C is applicable to unshielded cables which would usually result in a loop under test behaving as a resistive load. In this case, a generator capable of delivering voltage waveforms is required. If the resistance and inductance are low, the current limit would be reached first, and depending on the impedance of the generator, the waveform shapes could be incorrect. In this case, reevaluation would indicate waveform set E should be used.

   It should be noted that if a low impedance source generator is available, the appropriate response will be achieved, and in this case, the test will be completed when either a test level or limit is reached.

   The category put on the label applies to the class of tests that were passed.

Level	Waveforms		
	3	4	5A
	Voc/Isc	Voc/Isc	Voc/Isc
1	100/4	50/10	50/50
2	250/10	125/25	125/125
3	600/24	300/60	300/300
4	1500/60	750/150	750/750
5	3200/128	1600/320	1600/1600

Table 22-2 Test Levels for Pin Injection

NOTES:

1. *Voc = Peak Open Circuit Voltage (volts) available at the calibration point shown in Figure 22-8.*
2. *Isc = Peak Short Circuit Current (amps) available at the calibration point shown in Figure 22-8.*
3. *Amplitude Tolerances +10%, -0%.*
4. *The ratio of Voc to Isc is the generator source impedance to be used for generator calibration purposes.*
5. *Waveforms 3, 4 and 5A are identified in Figures 22-4, 22-5 and 22-6.*
6. *When the load impedance characteristic for the pin under test is specified in the equipment installation requirements, that impedance characteristic may be inserted in series with the generator and EUT. To account for cable frequency effects the maximum inserted series impedance shall be limited to 75 Ω during Waveform 3 tests, thereby resulting in a maximum source impedance of 100 ohms. When the specified load impedance is inserted in the test circuit, and this is the only change in test conditions, the category Z designator is not to be used. The equipment is to be labeled in accordance with the waveform set and level designators utilized.*
7. *Voltage Waveform 4 should produce current Waveform 5A when the tested interface impedance is low, such as when a protective device is present.*
8. *In certain situations related to airframe design and wiring layout, equipment may be exposed to higher levels of Waveform 5A or to the longer duration waveform designated as 5B (see Figure 22-6). Tests conducted under these conditions should be given designator Z.*

Waveforms					
	1	2	3	4	5A
Level	V_L/I_T	V_T/I_L	V_T/I_L	V_T/I_L	V_L/I_T
1	50/100	50/100	100/20	50/100	50/150
2	125/250	125/250	250/50	125/250	125/400
3	300/600	300/600	600/120	300/600	300/1000
4	750/1500	750/1500	1500/300	750/1500	750/2000
5	1600/3200	1600/3200	3200/640	1600/3200	1600/5000

Table 22-3 Test Levels for Cable Bundles

NOTES:

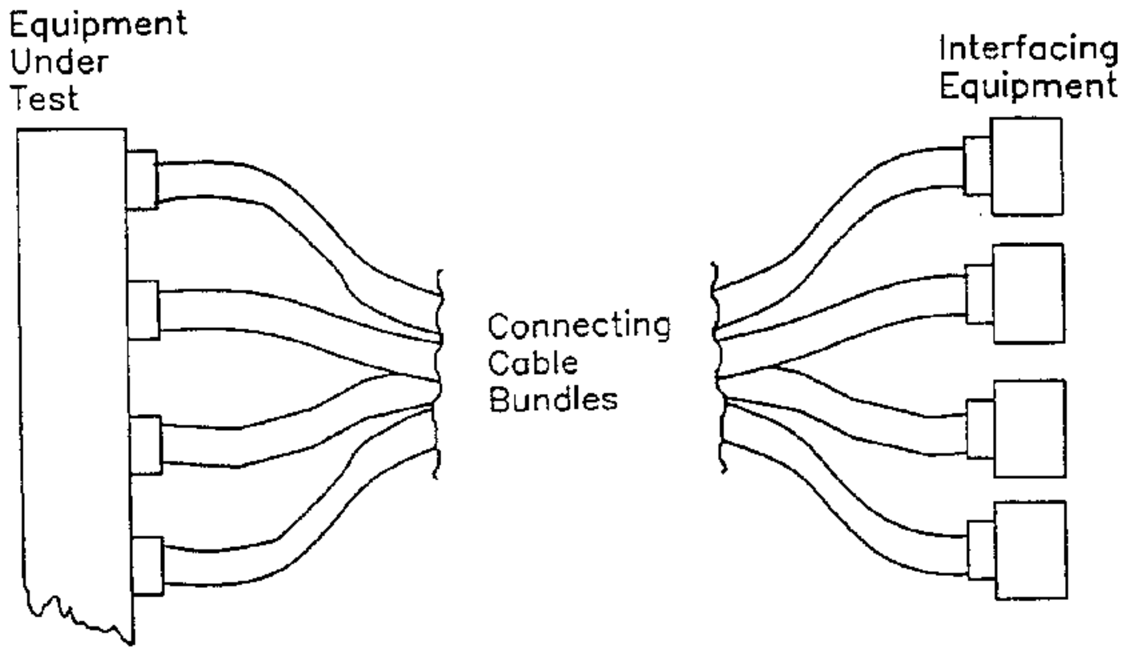
1. *Amplitude tolerances are +10%, -0%.*

2. *Waveforms 1, 2, 3, 4 and 5A are identified in Figures 22-2, 22-3, 22-4, 22-5 and 22-6, respectively.*

3. *Under each waveform, V_T represents the test voltage level in volts, and I_T represents the test current level in amperes. V_L (volts) and I_L (amperes) represent limits intended to prevent over-stressing the EUT beyond requirements.*

4. *For tests with current Waveform 5A, the test generator open circuit voltage rise and decay times should be similar to voltage Waveform 4. The measured voltage waveshape and amplitude used to determine V_L during the test may vary from this open circuit waveform. Care should be taken to insure that initial transients such as noise produced by test generator switching to the test circuit should be ignored. Normally, such noise occurs during the first one or two microseconds.*

5. *In certain situations related to airframe design and wiring layout, equipment may be exposed to higher levels of Waveform 5A (i.e., up to 10kA) or to the longer duration waveform designated as 5B (see Figure 22-6) up to 5kA. Tests conducted under these conditions should be given designator Z.*



NOTES:

1. *When each cable bundle is tested to the same level, that level is marked in the cable bundle test designator.*

2. *When interfacing equipment is co-located and their associated cable bundles are routed together, the cables can be tested as one bundle.*

3. *When cable bundles are tested to different levels, the cable bundle test designator is marked with a Z.*

Figure 22-1 Installation Configuration - General Case

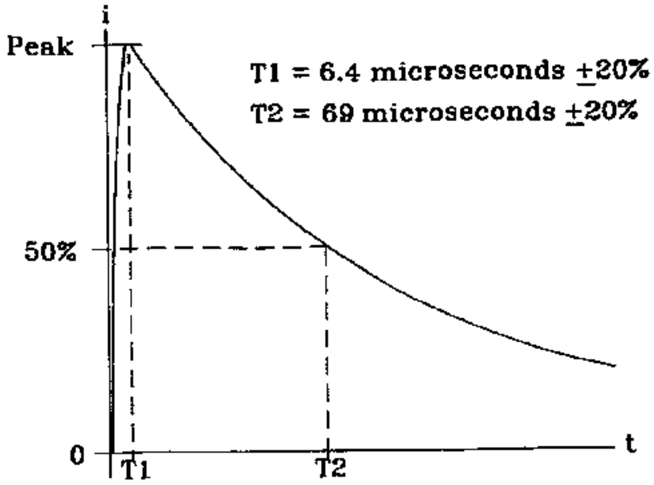
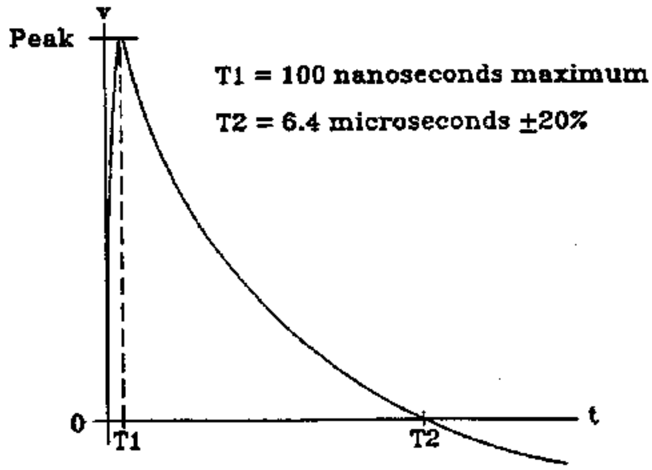
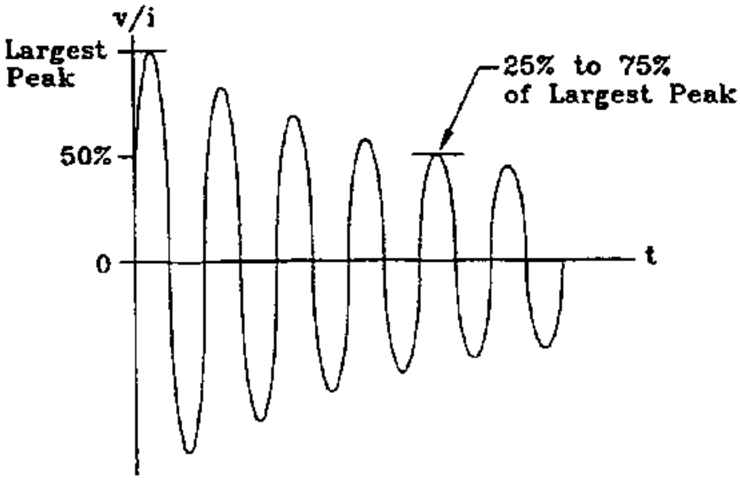


Figure 22-2 Current Waveform 1



NOTE: *Ideally, the waveform 2 generator will produce waveform 1 in the shorted calibration loop of Figure 22-10.*

Figure 22-3 Voltage Waveform 2



NOTE: Voltage and current are not necessarily in phase.

Figure 22-4 Voltage/Current Waveform 3

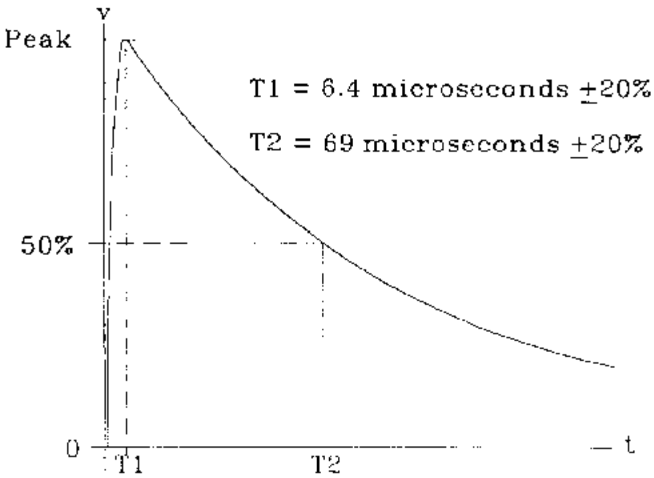


Figure 22-5 Voltage Waveform 4

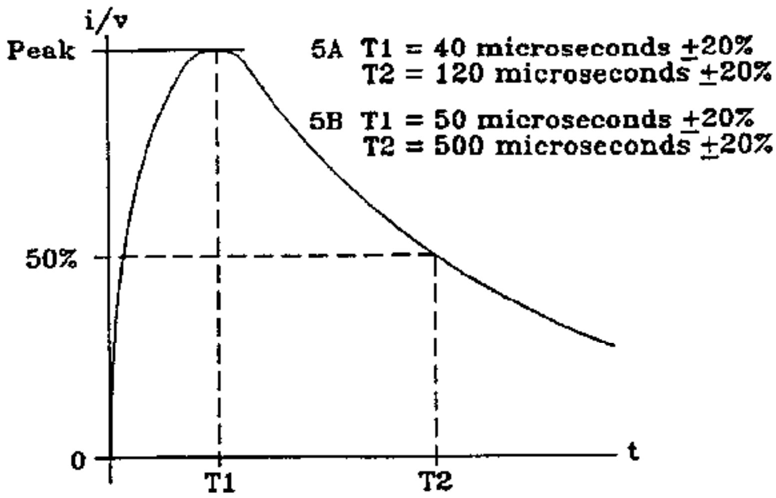


Figure 22-6 Current/Voltage Waveform 5

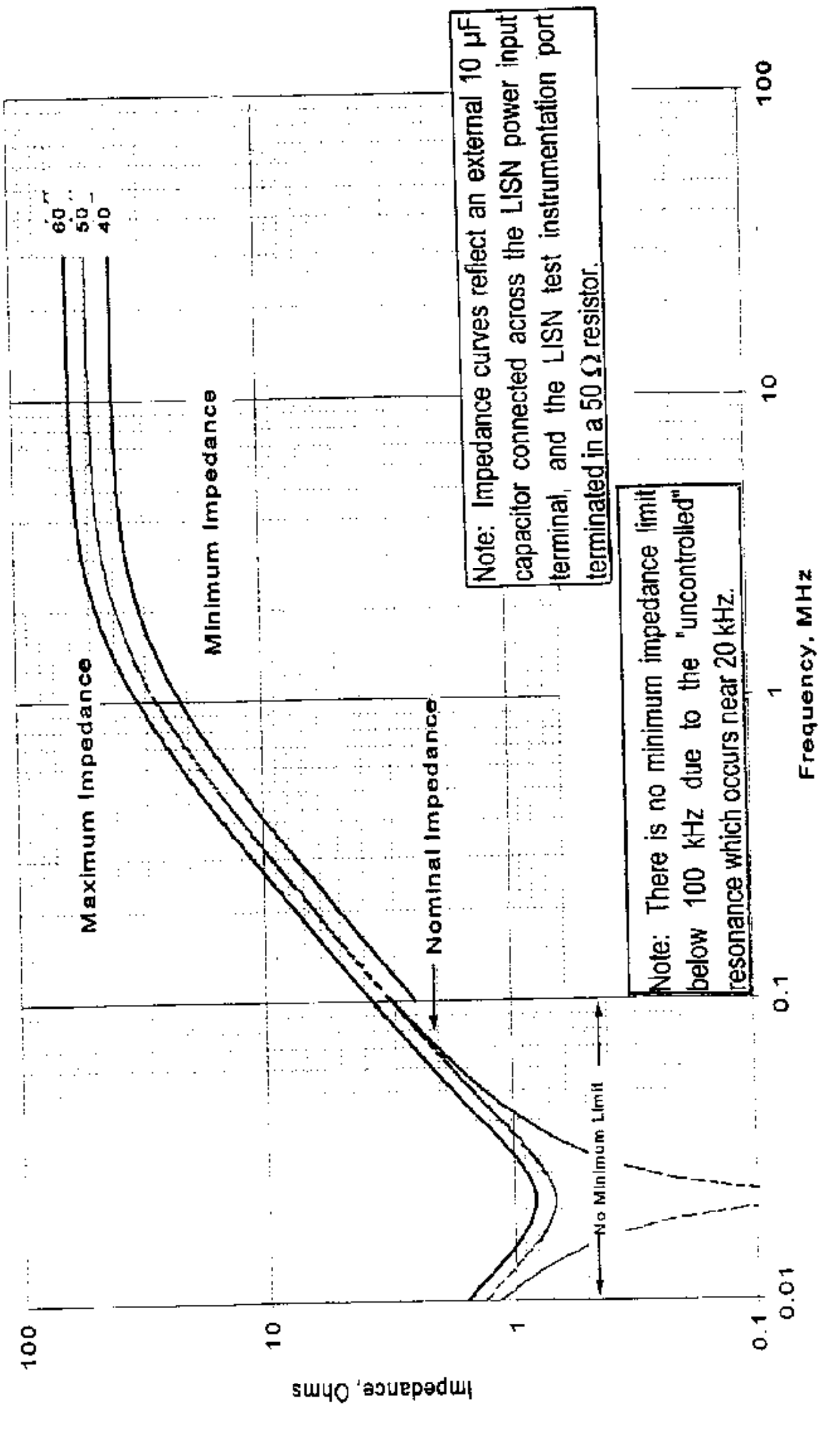
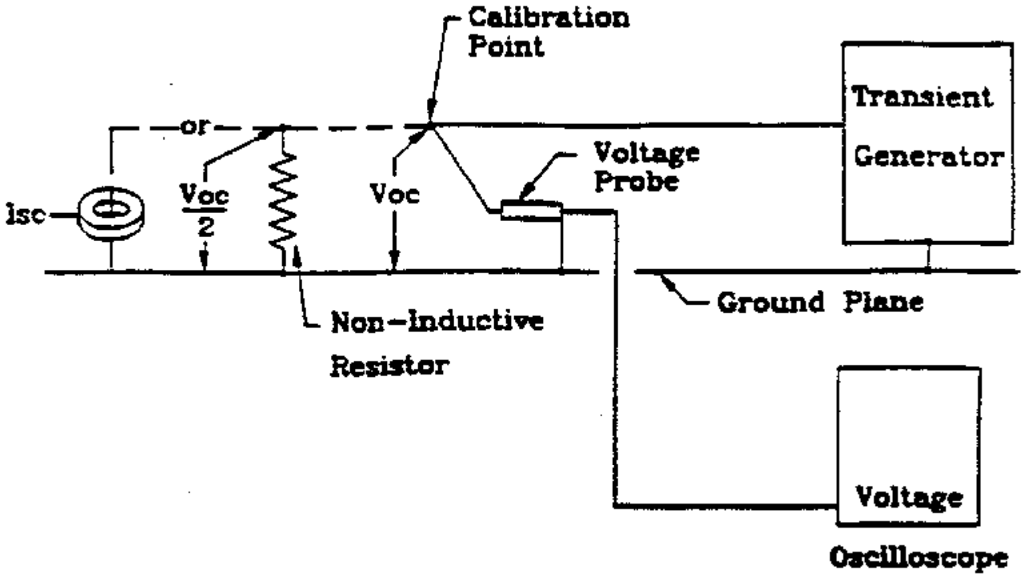


Figure 22-7 LISN Input Impedance Characteristic

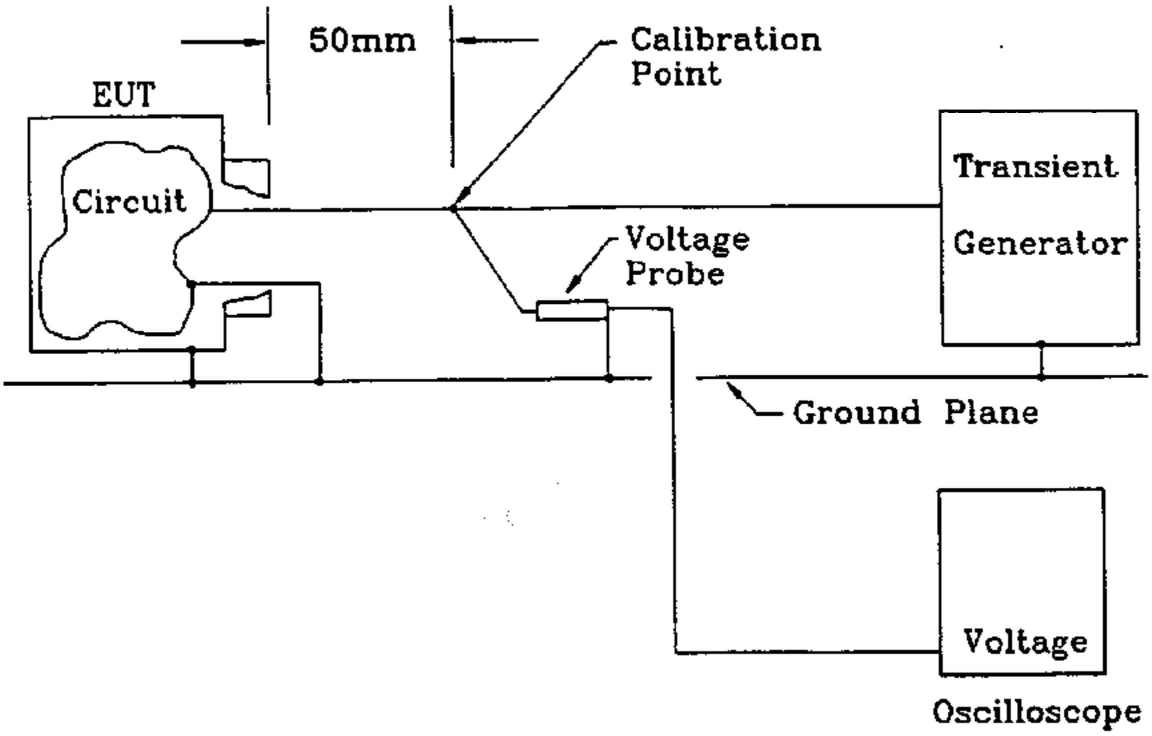


NOTES:

1. *A non-inductive or low-inductance resistor equal to the generator source impedance should be used for verifying the generator impedance. A carbon composition resistor(s) of appropriate wattage and short lead length is sufficient for the pin test waveforms.*

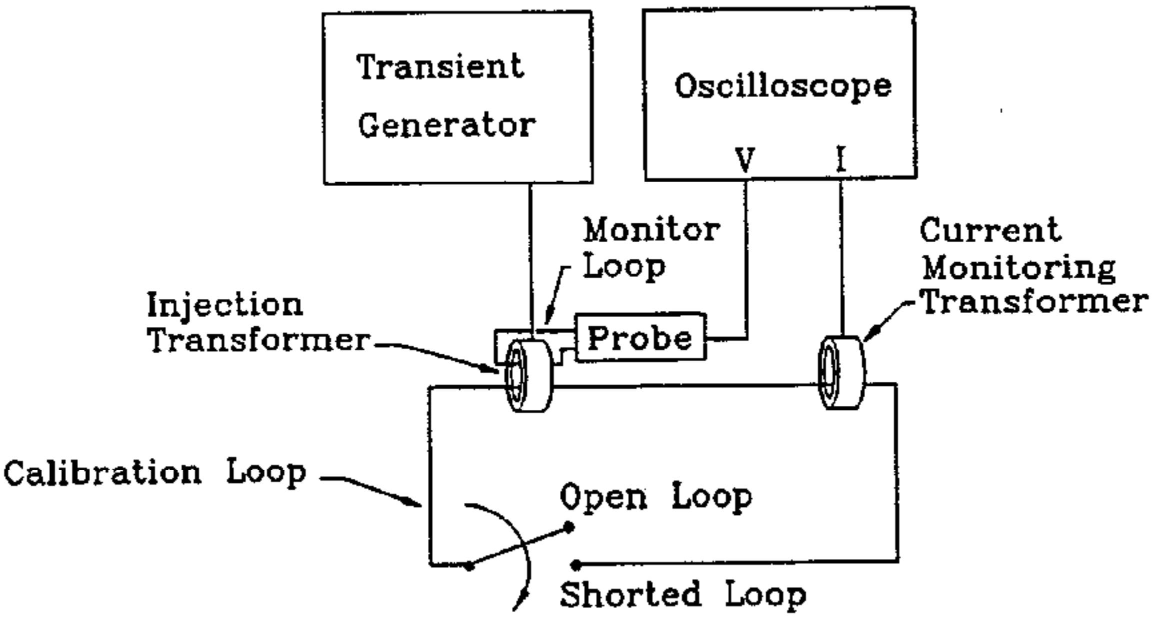
2. *Tests of active ac power circuits may require transformer coupling of the applied transients to the power lines, and transients should be synchronized to the peak of the ac waveform.*

Figure 22-8 Typical Pin Injection Calibration Setup



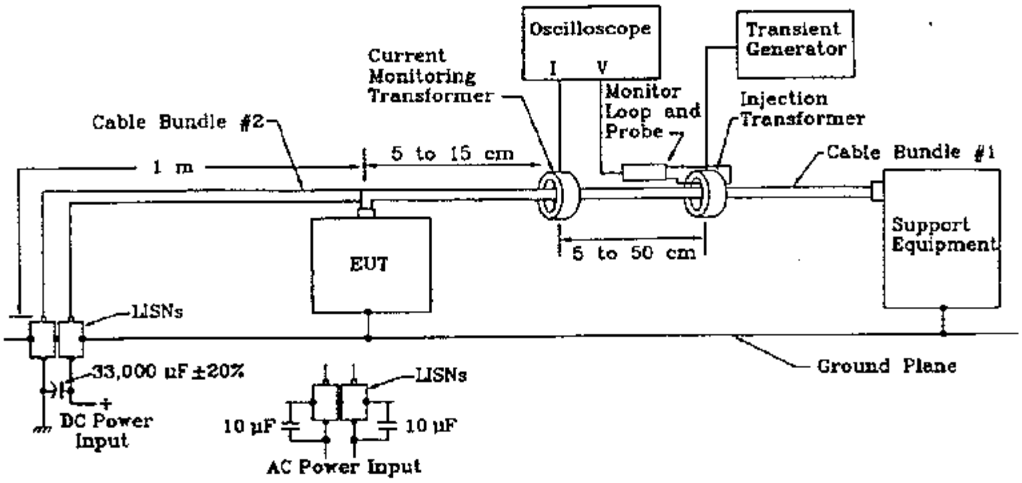
NOTE: *Test procedures assume lightning transients appear common-mode between all pins and case. If the expected installation utilizes local power and/or signal returns tied either internaly or externally to case or aircraft structure, tests shall be performed with the return(s) tied to the case.*

Figure 22-9 Typical Pin Injection Test Setup



NOTE: A series current-monitoring resistor may be used instead of the current-monitoring transformer.

Figure 22-10 Typical Generator Performance Verification Setup for Cable Induction Tests



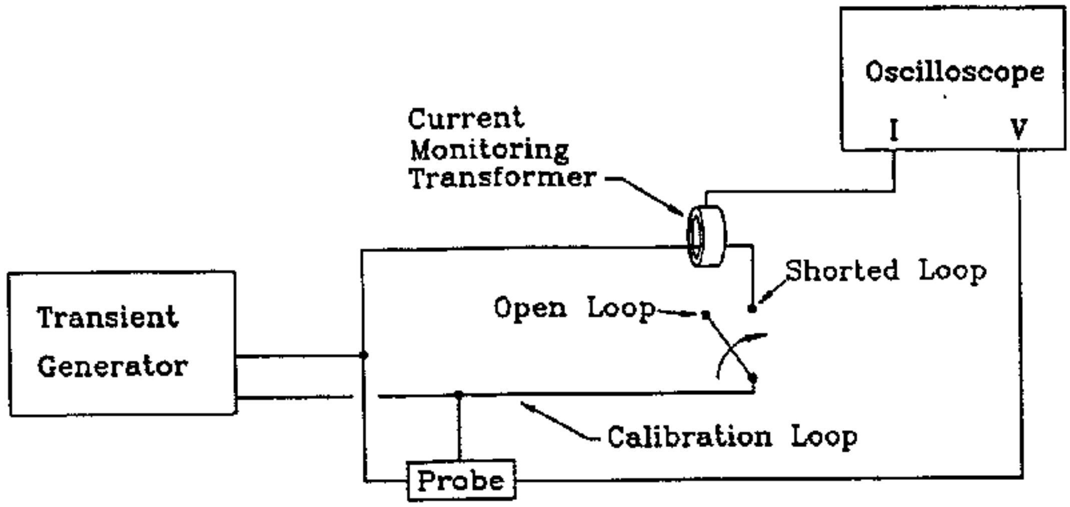
NOTES:

1) *Capacitor(s) shall be applied on power inputs to provide a low impedance to ground, as shown.*

2) *A series current-monitoring resistor may be used instead of the current-monitoring transformer.*

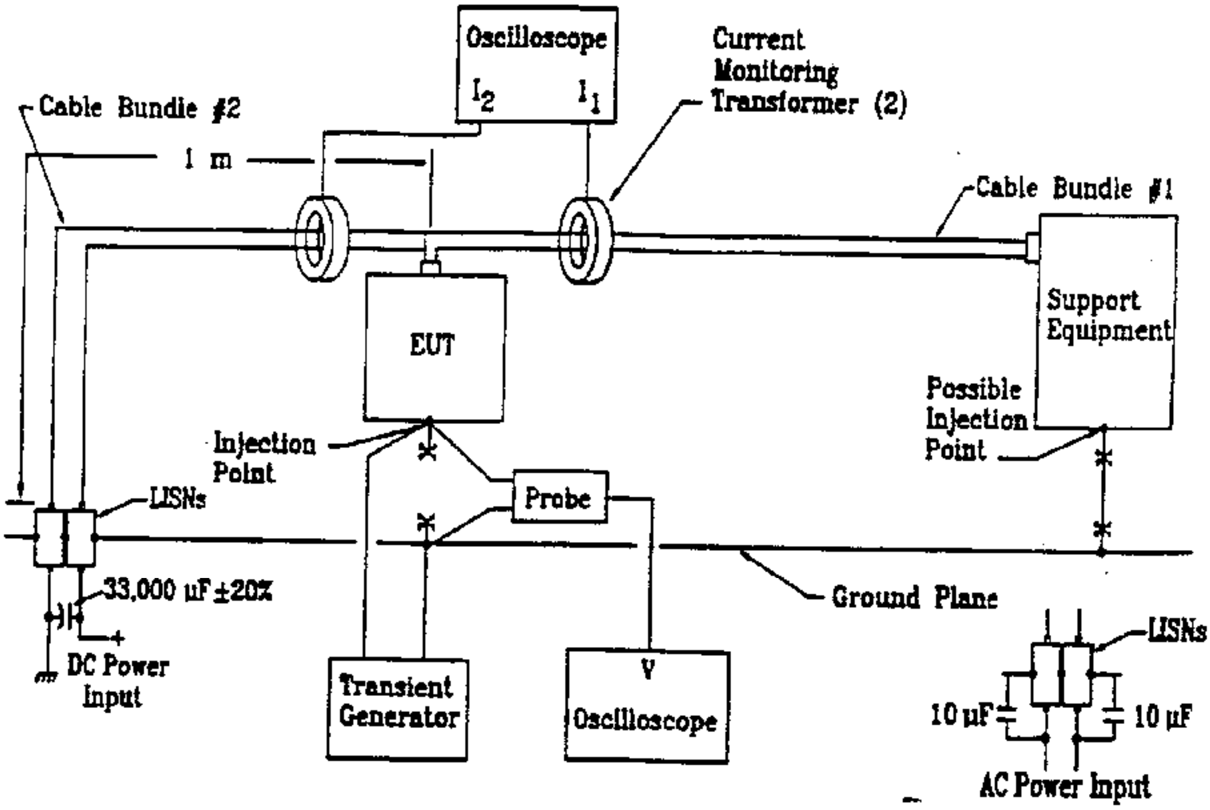
3) *When testing power leads (Cable Bundle #2), care should be taken to ensure that individual conductor currents do not exceed the corresponding pin test current level as presented in Table 22-2.*

Figure 22-11 Typical Cable Induction Test Setup



NOTE: A series current-monitoring resistor may be used instead of the current-measuring transformer.

Figure 22-12 Typical Generator Performance Verification Setup for Ground Injection Tests



NOTES:

1. *Capacitor(s) shall be applied on power inputs to provide a low impedance to ground as shown.*
2. *A series current-monitoring resistor may be used instead of the current-monitoring transformer.*
3. *At the transient injection point, all chassis, local power and local signal grounds shall be isolated from the ground plane and terminated to the equipment chassis.*
4. *When ground injection tests are performed at an EUT with multiple cable bundles, current must be measured in each cable bundle to ensure that the current limit is not exceeded in any one cable bundle. The intent of the test is to achieve the applicable test level in each cable bundle; therefore, tests may need to be repeated at other injection points.*
5. *When testing power leads (Cable bundle #2), care should be taken to ensure that individual conductor currents do not exceed the corresponding pin test current level as presented in Table 22-2.*

Figure 22-13 Typical Ground Injection Test Set-Up

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 23

Lightning Direct Effects

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2, and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

23.0 LIGHTNING DIRECT EFFECTS

23.1 Purpose of Tests

The tests described in this section are intended to determine the ability of externally mounted electrical and electronic equipment to withstand the direct effects of a severe lightning strike. The term «externally mounted equipment» refers to all electrical and electronic equipment mounted externally to the main skin of the aircraft and includes all such equipment that is covered only by a dielectric skin or fairing that is an integral part of the equipment. It also includes connecting cables and associated terminal equipment furnished by the equipment manufacturer as a part of the equipment. The tests described herein specifically exclude the effects of voltages and currents induced into the externally mounted equipment and its associated circuitry by means of magnetic or electric field coupling. These indirect effects are covered in Section 22.0.

Examples of equipment covered by this section are antennae, exterior lights, air data probes, external sensors, and anti-ice and de-ice equipment which is mounted external to the structure, i.e. electrically heated anti-ice boots. Electrical and electronic equipment such as lights and fuel quantity probes mounted on fuel tanks and exposed to direct or swept lightning strikes is also covered by this section.

Examples of equipment not covered by this section are mechanical devices such as fuel filler caps, equipment that is an integral part of the aircraft structure (i.e., heated or unheated windshields, electrically de-iced leading edges where the de-ice system is an integral part of the leading edge structure or is enclosed by the leading edge structure), and externally mounted equipment that is protected by aircraft nose radomes or dielectric coverings which are specific to the aircraft structure and are not integral with the equipment itself. Components such as these are to be addressed and/or tested as a part of the airframe lighting certification program specified by the aircraft manufacturer, or by other test method(s) appropriate to the component being qualified.

Normally the equipment will not be powered up or operating during the tests described herein. In situations where a power-on condition could change the susceptibility or vulnerability of the equipment to the direct effects of lightning, the equipment will have to be powered up or, alternatively, means employed to simulate the powered up condition. The need to do this should be defined in the test plan.

23.2 Definitions

23.2.1 Lightning Definitions

Arc Root

The location on the surface of a conducting body at which the lightning channel is attached while high current flows.

Continuing Current

A low level long duration current pulse that might occur between or after the high current strokes.

Direct Effects

Any physical damage to the aircraft and/or equipment due to direct attachment of the lightning channel and/or conduction of lightning current. This includes dielectric puncture, blasting, bending, melting, burning and vaporization of aircraft or equipment surfaces and structures. It also includes directly injected voltages and currents in associated wiring and plumbing.

First Return Stroke

The high current surge that occurs when the leader completes the circuit between the two charge centers. The current surge has a high peak current, high rate of change of current with respect to time (di/dt) and a high action integral.

Flash Hang-on

During the period of the lightning flash, the lightning channel may be swept backwards from one part of the aircraft to another as a result of the forward movement of the aircraft, attaching at various points along the surface of the aircraft. When the attachment point reaches the last point where attachment to the aircraft is possible, it stays with that point for the remaining duration of the flash.

Intermediate Current

After the initial decay following the peak current of some strokes, there is often a low level current of a few kiloamperes that persists for several milliseconds. This current is termed the intermediate current.

Leader

The low luminosity, low current precursor of a lightning return stroke, accompanied by an intense electric field.

Lightning Flash

The total lightning event in which charge is transferred from one charge center to another. It may occur within a cloud, between two clouds, or between cloud and ground. It consists of a leader and a first return stroke. It may also include an intermediate current, a continuing current and one or more restrikes.

Restrike

A subsequent high current surge during the lightning flash, which has a lower peak current, a lower action integral, but a higher di/dt than the first return stroke. This normally follows the same path as the first return stroke, but may reattach to a new location further aft on the aircraft.

Slow Components

This term is used to refer to the intermediate current and the continuing current collectively.

Swept Leader

A lightning leader that has moved its position relative to an aircraft, subsequent to initial leader attachment, and prior to first return stroke arrival, by virtue of aircraft movement during continued leader propagation.

23.2.2 General Definitions

Action Integral

The action integral of a current waveform is the integral of the square of the time varying current over its time of duration. It is usually expressed in units of ampere-squared seconds (A^2s).

Discharge

When used to refer to discharge of High Voltage (HV) or High Current (HC) impulse generators, the term «discharge» shall mean the discharge of the storage capacitors. This may or may not cause an electrical breakdown of the gap between the electrodes connected to the output terminals of the generator.

Flashover

This term is used when the arc produced by a gap breakdown passes over or close to a dielectric surface without puncture.

Fuel Vapor Regions

A fuel vapor region is a region in the aircraft that may have fuel or fuel vapor present.

Gap Breakdown

This term is used when the discharge of the capacitors of an HV or HC impulse generator results in the electrical breakdown of the gap between the electrodes connected to the generator output terminals.

V_{90}

This is nominally the voltage to which an HV impulse generator must be erected in order that 90 percent of all discharges will result in gap breakdown. For test purposes, a notional V_{90} is used as described in paragraph 23.5.1.

23.2.3 Zoning Definitions

The following text defines the various lightning zones. The areas appropriate to these zones on any particular aircraft shall be agreed between the airframe manufacturer and the appropriate certifying authority.

Zone 1A

All areas of the aircraft surfaces where there is a high possibility of an initial lightning attachment with a low possibility of flash hang-on are designated Zone 1A. For the purposes of this document, swept leader attachment areas are also included in Zone 1A. (In the future, those surfaces where first return strokes may only arrive by sweeping of the leader may be separately designated.)

Zone 1B

All areas of the aircraft surface where there is a high possibility of an initial lightning attachment and a high possibility of flash hang-on are designated Zone 1B.

Zone 2A

All areas of the aircraft surface where there is a high possibility of a lightning attachment being swept onto it from a Zone 1A, but having a low possibility of flash hang-on, are designated Zone 2A.

Zone 2B

All areas of the aircraft surface where there is a high possibility of a lightning attachment being swept onto it from a Zone 1A or 2A, but having a high possibility of flash hang-on, are designated Zone 2B.

Zone 3

All areas of the aircraft surface not covered by all Zones 1 and 2 are designated Zone 3. In Zone 3, there is a low possibility of a direct lightning attachment.

NOTE: *All zones of the aircraft (including Zone 3) may be required to carry part or the whole of the total lightning flash currents flowing between two attachment points.*

23.3 Equipment Categories

The nature and severity level of the tests to be applied to externally mounted equipment will depend upon the designated category of that equipment.

Category 1A

Equipment externally mounted in those areas of the aircraft identified as Zone 1A is designated Category 1A, unless otherwise designated as Category X.

NOTE: *Equipment intended for use in areas where the first return stroke attachment can only arrive by sweeping of a leader must qualify as Category 1A unless otherwise designated as Category X.*

Category 1B

Equipment externally mounted in those areas of the aircraft identified as Zone 1B is designated Category 1B, unless otherwise designated as Category X.

Category 2A

Equipment externally mounted in those areas of the aircraft identified as Zone 2A is designated Category 2A, unless otherwise designated as Category X.

Category 2B

Equipment externally mounted in those areas of the aircraft identified as Zone 2B is designated Category 2B, unless otherwise designated as Category X.

Category 3

Equipment externally mounted in those areas of the aircraft identified as Zone 3 is designated Category 3, unless otherwise designated as Category X.

Equipment classified as suitable for use in fuel vapor regions

Equipment intended for use in fuel vapor regions must have additional test requirements over and above those applicable to the appropriate zone for non-fuel vapor region equipment. Equipment so tested will have the additional classification «F» after the zone classification, which will indicate that the equipment may be used in a fuel vapor region, e.g., classification 2AF will clear the equipment for use in fuel vapor regions in zone 2A. When qualified to obtain the «F» classification for a particular zone/category, the configuration tested should be clearly defined. Comparison between this and the final aircraft installation may indicate that further tests are not required. Equipment not having the additional «F» classification may not be used in fuel vapor regions without further testing.

23.4 Lightning Direct Effects and Associated Parameters

This Subsection lists and describes the various direct effects failure mechanisms that can affect externally mounted equipment during a lightning strike to an aircraft. It also identifies the lightning current parameters and thereby the phase of the lightning flash associated with specific failure mechanisms.

23.4.1 Ohmic Heating

The instantaneous power dissipated as heat in a conductor due to an electrical current is i^2R watts. The ohmic heating generated by the complete lightning pulse is therefore the ohmic resistance of the lightning path through the aircraft multiplied by the action integral of the pulse and is expressed in Joules or watt seconds. In a lightning discharge, the high action integral phases of the lightning flash are of too short a duration for any heat generated in an aircraft structure by ohmic heating to disperse significantly. The phases of the lightning flash relevant to this failure mechanism are the first return stroke and any restrike.

23.4.2 Exploding Conductors (Disruptive Forces)

Where conductors having a very small cross sectional area are required to carry a substantial part of the lightning current, they may vaporize explosively. The associated shock wave can give rise to severe damage particularly in confined spaces. This failure mechanism is particularly significant in electric wiring connected to external equipment, e.g., navigation lights, antennae, pitot heaters, etc. If these are not adequately protected and are confined in or pass through closed compartments in the aircraft, they can present a significant hazard. In addition, small cross section metal foils etc. encapsulated in a dielectric, such as in an externally mounted blade antenna, or high energy internal arcs such as may result from the penetration of a non-conductive cover, can present a hazard from disruptive forces. The relevant current parameter is action integral, and the relevant phases of the lightning flash are the initial return stroke and restrikes.

23.4.3 Arc Root Thermal Damage

Burn through and material erosion can occur at the arc root. In metal, this is mainly a complex function of current and time. In the arc root area, there is a large thermal input from the arc root itself, as well as a concentration of ohmic heating due to the high current densities. Most of the energy is generated at or very close to the surface of the metal, and must therefore be dissipated by conduction. The heat generated in the immediate arc root area is in excess of that which can be absorbed into the metal by conduction, and the excess is either lost in melting and vaporizing the metal, or reradiated. There is minimum current and a minimum time for any given thickness of any given material below which burn through cannot occur. It is only the slow components phase of the lightning flash that can exceed the minimum requirements of both current and duration for metal burn through or severe erosion of any practical thickness of metal.

In carbon fiber composites the thermal effects are more pronounced, but the lower thermal conductance and higher electrical resistance affects the proportions of vaporizing and propagation processes. This leads to an increase in area in relation to the depth of damage. The arc root burning voltage of carbon is higher than that of metals. This effect, plus the high bulk resistivity, generates more heat in the immediate arc root area and the hot spot remains for a longer period than for most metals. Thus, short duration high action integral pulses as well as low current long duration pulses produce high thermal inputs, and so all phases of the lightning flash are significant in producing arc root damage in carbon fiber composites.

23.4.4 Hot Spot Formation

Hot spot formation may occur on the inner surface of the aircraft skin as a result of one of two processes: first on an inner surface under an arc root, and second from local high current densities. The effects of hot spots are usually only significant with regard to ignition in fuel and other highly flammable substances. All phases of the lightning flash are significant to the first process, while the high peak current phases are significant to the second process.

23.4.5 Acoustic Shock Wave Damage

At the commencement of the first return stroke, there is a rapid pinching of the arc channel due to the increase in the magnetic field surrounding the channel. This produces a radial acoustic shock wave. At the same time, the rapid heating of the arc channel itself produces an axial shock wave. The latter is probably the most significant in its reaction with the aircraft. The severity of the shock is dependant upon both the peak current value and rate of rise of the current. It is therefore related to the first return stroke and in some instances to restrikes.

In general, the damage due to acoustic shock wave is insignificant on metal skins, but less malleable composite skins can rupture.

23.4.6 Magnetic Pressure

This pressure is only significant when the surface current density is greater than several kiloamperes per millimeter. For example, a conductor of five millimeters diameter carrying a pulse of 200 kA peak current would experience a surface pressure of 1000 atmospheres. The pressure is proportional to the square of the current (i^2) and the inverse square of the diameter. Thus, doubling the diameter or halving the current would reduce the pressure to 250 atmospheres.

In some cases, however, even relatively small pressures can be significant, such as the case of metal braid bonding strips. These can be compressed to near solid conductors leading to metal embrittlement and subsequent mechanical failure.

The relevant current phase is the first return stroke.

23.4.7 Magnetic Interaction

Considerable magnetic forces can exist from the interaction of the magnetic fields of two current carrying conductors or from two separate sections of the same conductor where the lightning current is forced to change direction. This force can also exist between current in the aircraft and the arc channel. This force is usually only of significance where the lightning current is confined to small cross-section conductors as might occur in some externally mounted equipment. The peak value of the force is proportional to the square of the peak current (I^2). The ultimate effect on the test object concerned can be a complex function of I^2, rise time, decay time, action integral and the mechanical response of the test object. The failure mechanism is therefore related to the first return stroke and in some cases to the restrikes.

23.4.8 Direct Effects Sparking

Direct effects sparking occurs when very high currents are forced to cross a joint between two conducting materials, or forced to take very convoluted paths. Two different types of sparking can occur: thermal sparking and voltage sparking.

Most thermal sparking occurs near the edges of high spots on the mating surfaces where the interface pressure is at or close to zero. The primary causes are high current density and inadequate interface pressure. Thermal sparks are burning particles of material ejected from the contact area by vaporization pressures occurring after the contact point melts. The ejected particle sizes cover the range from non-incendiary (<20 µm dia. Al.) to incendiary and move at various velocities. Ignition of a flammable mixture is the best detection method to evaluate ignition hazards. The relevant current parameter is peak current and the appropriate lightning current phase is the first return stroke and restrikes.

Voltage sparking occurs where the current is forced to take a convoluted path through the joint. The gap geometry and spacing has a significant effect on the energy necessary for ignition. Close spacings act more like thermal sparks. Ignition of a flammable mixture is the best detection method to evaluate ignition hazards. The significant current parameter is di/dt and the appropriate phase is the first return stroke and restrikes.

23.4.9 Dielectric Puncture

The puncture of any dielectric skin covering any externally mounted equipment could permit the direct attachment of lightning to that equipment. The probability of puncture of a dielectric will be a function of the presence of any conductor underneath the dielectric that raises the electric field stress, the thickness and strength of the dielectric, the condition of the dielectric surface, and the proximity of other conducting surfaces. As a general guide, puncture of the dielectric must be considered possible unless the voltage required to puncture the dielectric at any point is significantly greater than the voltage required to cause flashover to the nearest conducting point of the airframe. The conditions for dielectric puncture are generated in the pre-discharge phase and at the onset of the first return stroke phase of the lightning flash. Puncture might also occur as a result of a restrike, or a swept stroke reattachment.

23.5 Test Parameters

23.5.1 Voltage Waveforms and Levels

High Voltage tests shall be conducted using a high voltage pulse generator capable of delivering a 1.2/50 μs open circuit output voltage waveform (risetime from zero to peak voltage in 1.2 μs ±20 percent and decaying from peak voltage to half peak voltage in 50 μs ±20 percent; see Figure 23-l.). This waveform shall be used in conjunction with the «Up-down Voltage Transfer Method» (UDVTM) for testing. This method defines a notional V_{90} level.

The UDVTM is a technique first proposed by Bakken for testing with breakdowns at or about the V_{90} level in which the level is formed during testing. To find the V_{90} level would otherwise require a very large number of tests to raise confidence through a statistically significant sample. UDVTM involves varying the generator voltage by increments in accordance with a set procedure as the gap breakdown occurs or fails to occur. The formula for incremental changes is as follows:

a. Start at a voltage slightly below gap breakdown voltage.

b. Whenever gap breakdown fails to occur, raise the voltage by five percent.

c. After three consecutive gap breakdowns at the same voltage, lower the voltage by five percent.

d. If breakdown still occurs after lowering the voltage then lower the voltage by an additional five percent.

Each gap breakdown that occurs should be counted towards the number required to complete the test. Each failure to break down should be discounted.

Alternative waveforms and tests may be used as follows:

a. A voltage rising at the rate of 1000 kV/μs ±50 percent may be applied. See Figure 23-2. This voltage is applied across the gap and allowed to rise until gap breakdown occurs.

b. A voltage rising to peak in between 50 μs and 250 μs. See Figure 23-3. This voltage is applied across the gap and the peak voltage adjusted to a value where gap breakdown occurs at or just after peak voltage.

23.5.2 Current Waveforms and Levels

For verification purposes, the natural lightning environment is represented by current test components A, B, C and D in Figure 23-4. Each component simulates a different characteristic of the current in a lightning flash. When testing is carried out, the application of these waveforms to the appropriate category is obtained from the table associated with Figure 23-4. They shall be applied individually or as a composite of two or more components together in one test.

a. Component A - First Return Stroke Current

Component A has a peak amplitude of 200 kA ±10 percent and an action integral of $2 \times 10^6 A^2s$ ± 20 percent with a total time duration not exceeding 500 μs. This component may be unidirectional or oscillatory. The rise time (make consistent with component D) from 10 to 90 percent peak current shall be less than 50 μs.

NOTE: For magnetic forces tests, a unidirectional pulse is preferred. When an oscillatory pulse is used, account must be taken of the mechanical response of the system under test.

b. Component B - Intermediate Current

Component B has an average amplitude of two kA ±20 percent and charge transfer of 10 coulombs ±10 percent in five milliseconds ±10 percent. The waveform shall be unidirectional and may be rectangular, exponential or linearly decaying.

c. Component C - Continuing Current

Component C transfers a charge of 200 coulombs ±20 percent in a time of between 0.25 s and 1.0 s. The waveform shall be unidirectional, may be rectangular, exponent or linearly decaying, and its amplitude shall be between 200 and 800A.

d. Component D - Re-strike Current

Component D has a peak amplitude of 100 kA ±10 percent and an action integral of 0.25×10^6 A^2s ±20 percent. This component may be either unidirectional or oscillatory with a total time duration not exceeding 500 µs. The time from 10 percent peak current to 90 percent peak current shall be less than 25 µs.

NOTE: For magnetic forces tests, a unidirectional pulse is preferred. Where an oscillatory pulse is used, account must be taken of the mechanical response of the system under test.

The current components applicable to each category shall be as shown in Figure 23-4.

23.6 Test Procedures and Levels

WARNING

Lightning simulation tests require high energy electrical equipment which may be charged to very high voltages during their operation. Therefore, all safety precautions relevant to this type of test apparatus should be complied with. All tests should be conducted in a controlled access area by personnel experienced in high voltage/high current testing.

23.6.1 General

This paragraph contains scope and descriptions of high voltage and high current tests for externally mounted equipment. Equipment that has an integral dielectric covering should first be tested with high voltage as defined in paragraph 23.6.2 to establish surface flashover or puncture paths. If the protecting insulation of an equipment, such as a blade antenna, does not puncture during high voltage tests, then normally a high current test will be required to demonstrate survival of the equipment from thermal and acoustic effects arising from proximity to the high current arc following the flashover paths indicated during the high voltage tests.

If puncture of the protecting dielectric does occur, and this does not in itself constitute failure of the equipment, high current tests shall be carried out at the level of the category chosen with the arc directed along the path(s) of the puncture(s) caused during the high voltage tests.

All equipment that has no dielectric covering must be subjected to high current tests using the current waveforms appropriate to the category chosen, as defined in Subsection 23.3 and Figure 23-4 to determine the ability to transfer these currents to the airframe safely, and to assure that excessive currents or voltages are not conducted into the aircraft on associated interconnections and interconnected equipment.

Equipment that is partially covered by a dielectric shall be subjected first to high voltage tests for those parts covered by the dielectric as defined in paragraph 23.6.2, and also subjected to high current tests to all exposed conducting parts including fasteners, using the current waveforms appropriate to the category chosen as defined in Subsection 23.3 and Figure 23-4.

A flow chart giving the sequence of testing is shown in Figure 23-5.

23.6.2 High Voltage Tests

23.6.2.1 Applicability and General Requirements

The HV tests are applicable to all categories where the equipment is covered by a dielectric that is integral to the equipment, except for category 3. In all cases where HV tests are applied, they will be flashover versus puncture tests.

The specimen shall be fully representative of the production standard, and all installation requirements that could affect the test results, such as electrical bonding, shall be addressed.

The equipment under test should be mounted in accordance with the installation requirement onto a conducting ground plane as indicated in Figure 23-6. All conducting parts of the equipment normally bonded to the airframe shall be bonded to the ground plane and to one terminal of the pulse generator. The other terminal of the generator shall be connected to a large plate electrode as shown in Figure 23-6. The ground plane and the electrode shall be stress relieved on all edges and corners. They may be either square or circular in plan view.

All dimensions of the ground, the electrode, and the test gap shall be related to the dimensions of the test object as defined in Figure 23-6 and quantified in the associated table.

The Environmental Qualification Form (Appendix A), or DDP Form, if appropriate, should identify equipment that has been subjected to the high voltage tests.

23.6.2.2 Test Set-up and Procedures

The tests shall be conducted by using either the notional V_{90} method as defined by paragraph 23.5.1 and Figure 23-l, or one of the two alternative methods as defined in paragraph 23.5.1 and Figures 23-2 and 23-3. The tests shall continue until the gap breakdown requirements have been met.

Whichever method is chosen, a total of five discharges resulting in gap breakdown shall be applied at each polarity on each specimen tested. Discharges that do not result in gap breakdown shall be discounted.

During each discharge the voltage waveform shall be recorded, and a photograph of the test article shall be taken to record all gap breakdowns. After any suspected puncture, and at the completion of the test series, inspection of the recorded data, with any other diagnostics used, and a visual inspection of the equipment under test shall be done to establish if surface flashover or puncture has occurred.

If dielectric puncture occurs and the damage associated with the puncture does not exceed the damage criteria, then the appropriate high current tests should follow using the puncture already created or a deliberately drilled hole at the same location as the puncture.

If puncture does not occur, then high current tests will normally be conducted to demonstrate the ability of the test object to survive the normal thermal effects and acoustic shock wave effects of a surface flashover. These tests will be conducted as described in paragraph 23.6.3.

In the event that high voltage tests performed in accordance with Sections 23.6.2.1 and 23.6.2.2 using the high voltage electrode configuration described in Figure 23-6 do not result in flashovers to the test object, the high voltage test should be repeated with a spherical electrode with a minimum diameter of 10 ±1 cm and be positioned at distance ℓ_2 from the surface of the test object as illustrated in Figure 23-6.

Other aspects of this high voltage test should be the same as those described in paragraphs 23.6.2.1 and 23.6.2.2.

In cases where the large flat electrode is not likely to produce flashovers to the test object, tests with this electrode may be omitted and the high voltage tests begun with the spherical electrode.

In all cases, the procedures as shown in the flow chart of Figure 23-5 shall be followed.

23.6.3 High Current Tests

23.6.3.1 General Requirements

The current components (A,B,C and D) applicable to each category depend upon the zone appropriate to the category, as defined in Subsection 23.3. The current components applicable to each zone are specified in paragraph 23.5.2. If a specific category is not identified in the individual specification, the equipment manufacturer should design and qualify the equipment to the category consistent with the expected lightning zone in which it will be installed and state the category.

a. Test Specimen

The test specimen shall be fully representative of the production standard and all installation requirements which could affect the test results, such as electrical bonding, shall be addressed.

b. Test Electrode and Arc Root Wander Limitation

For arc entry tests (Categories 1A, 1B, 2A and 2B), the electrode material shall be a good electrical conductor. It may be a plain rod or, preferably, a «jet diverting electrode.» The jet diverting electrode has an insulating material covering all surfaces that face the test object, thus forcing the arc to originate from a surface which faces away from the test object. The area close to the point of entry on the test object shall be protected by a thin dielectric shield to prevent excessive wander of the arc root. The arc shall be directed to the surface of the test object through a circular hole in the protecting dielectric of between 10 mm and 12 mm radius.

c. Electrode Gap

The electrode gap is the distance between the electrode and the attachment point to a conductor on or in the test specimen. To prevent arc jet and blast pressure effects from influencing the test results, it is recommended that a spacing of not less than 50 mm, measured from the conducting surface of the electrode to the surface of the test object, be employed if a jet diverting electrode is used and not less than 150 mm with a plain electrode. Spacings less than the above would constitute a more severe test due to blast pressure, but would not disqualify the test if the specimen passed.

d. Arc Initiation

A fine wire not exceeding 0.1 mm diameter may be used to initiate the current discharge of low voltage driven generators without adversely affecting the results. The conducting wire can be metallic (e.g., copper) or carbon fiber. The wire will also enable the arc to be directed to the exact point of interest on the test specimen.

For surface flashover testing, the arc will be directed along the line(s) of the surface flashover(s) determined by the HV tests by supporting the wire throughout its length at a distance between 5 mm and 15 mm from the surface of the test object. The gap between the initiating wire and the surface of the test object shall be unobstructed for not less than 90 percent of the total distance.

An alternative method of initiating the arc may be to use a high voltage discharge generated by a Tesla coil or similar device.

NOTE: *Both the fine wire or the high voltage discharge methods of initiating the arc will introduce very high dE/dt transients (10^{10} v/m/s) into the region above the object under test. Antennas, which are nominally dE/dt detectors, will respond to such transients.*

e. Electrode Polarity

In most cases, electrode polarity is not important when the electrode spacing complies with subparagraph 23.6.3.1.c. However, if in doubt, the electrode polarity should be negative.

f. Conducted Entry Tests

For conducted entry tests (Category 3), the test current shall be conducted through the ground plane on which the test object is mounted in a manner representative of the lightning current distribution in an aircraft during a lightning strike. As a minimum, a surface current density of 50 kA/m should be applied. This represents the surface current density approximately 650 mm from the arc root.

23.6.3.2 Test Set-up - Non Fuel Vapor Region Equipment

a. Current Flow Through the Test Specimen

The test set-up should ensure that the simulated lightning current distribution through the test specimen is representative of an aircraft being struck by lightning.

b. Electrode Location

The test electrode should be positioned so as to direct the arc to the equipment surface selected for the test.

c. Test Apparatus

The test apparatus shall include:

(1) A high current generator(s) capable of producing the waveforms specified in paragraph 23.5.2.

(2) All necessary high current, high voltage, thermal and other measuring devices or recording instruments.

(3) Photographic equipment for recording strike points/damage areas.

d. Installation of Recording Instrumentation

The recording instrumentation shall be adequately shielded or decoupled from electromagnetic fields associated with the simulated lightning test currents or other sources. A calibration check shall be carried out to verify the accuracy of all recorded data.

e. Test Arrangement

A schematic diagram of the high current test setup is illustrated in Figures 23-7 and 23-8. Measurements shall be made of voltages and currents originating within the equipment as a consequence of this test in accordance with applicable equipment performance standards. This may require that a short length of cable be utilized to facilitate measurement of voltages and currents, as illustrated in Figures 23-7 and 23-8. All measurements must be recorded in the test report.

It should be noted that voltages and currents measured in cable shields or conductors are not necessarily representative of those that would occur in specific aircraft installations and may only be significant in establishing whether or not there are any voltages or currents.

23.6.3.3 Test Set-up - Fuel Vapor Region Equipment

The test set-up requirements detailed for non-fuel vapor regions in subparagraph 23.6.3.2 also apply to fuel vapor regions in addition to the points listed below. A typical setup is shown in Figure 23-9.

a. Test Specimen

The external equipment (test object) shall be mounted on an appropriate section of the simulated airframe skin, and a light or gas tight chamber shall be constructed on the inside (vapor side) of the skin. The applied test currents shall be in accordance with paragraph 23.5.2.

b. Detection of Sparking and Arcing

Where photography is employed, the film speed, aperture number and the distance from lens to object shall be such that the apparatus can detect and record voltage sparks of 200 μJ or less. An acceptable technique is one using a 3000 ISO/ASA panchromatic film together with a lens aperture no smaller than f/4.7 with a field of view not exceeding one meter wide. The sensitivity of the ignition detection technique employed to 200 μJ sparks must be demonstrated and that data included in the test report. It shall be verified that the chamber is light-tight and shall, if necessary, be fitted with an array of mirrors to make any sparks visible to the camera. Some means shall be employed to demonstrate that the camera shutter was open during the current discharge.

Alternative methods of achieving the same sensitivity of detection and recording may be used instead of, or in addition to, photographic methods.

c. Detection of Hot Spots

A number of techniques are available for detection of ignition sources due to hot spots. They include infra-red detection systems, optical pyrometry, fast response thermocouples and temperature sensitive paints.

d. Ignition Detection Using Ignitable Mixtures

If there are regions where a hot spot or sparking activity is not accessible to detection by any of the above means, then ignition tests may be carried out by placing an ignitable gas-air mixture inside the chamber. This may be any gas mixture that has a high ignition probability from a 1.5 to 2 mm long, 200 μJ spark, such as ethylene/air in a 1.3 to 1.4 stoichiometric mixture. A propane/air mixture requires oxygen enrichment to obtain adequate sensitivity.

WARNING

When making tests with combustible gas mixtures, suitable precautions shall be taken such as blow out panels to preclude explosions of the structure, the location of fire extinguishing equipment nearby and protection of test personnel from possible flame or blast effects and possible flying parts. The possibility of seepage of the gas mixture into unvented parts of the structure resulting in serious explosion damage, should be considered.

23.6.3.4 General Operating Requirements

a. Arcing

The discharge circuit of the current generator(s) should be designed and maintained to avoid inadvertent arcing and other phenomena that may affect personnel and equipment safety, and test accuracy.

b. Personnel Protection

All personnel should be provided with appropriate eye and ear protection.

23.6.3.5 Test Procedures

This method is used to determine the direct effects that result from the interaction of lightning currents with externally mounted electrical and electronic equipment.

a. Set up the high current generator(s), discharge circuit and sensing and recording equipment.

b. Insert a dummy test object beneath the electrode or place a conductive bar over the actual test object such that waveform checkout discharges cannot damage the test object. Preferably, these should have the same inductance and resistance as the test object.

c. Inspect the test set-up, test and calibration equipment and areas for safe operation.

d. Initiate a discharge to the dummy test object or conductive bar to check the current waveforms, to verify that the specified levels are being met and to check the correct functioning and calibration of the diagnostic equipment.

e. Remove the dummy test object and place the actual test object in the discharge circuit and record its physical and functional condition.

f. Initiate a discharge and inspect the specimen after the test and record the result.

g. Correlate photographs with the arc entry points/damage areas observed on the test object.

h. Any requirements for functional tests before or after the application of the test current waveforms shall be in accordance with the applicable equipment performance standard.

<u>NOTE</u> *When these procedures are used for tests on equipment to be used in fuel vapor regions, or to determine the possibility of combustible vapor ignition as a result of equipment skin puncture, internal hot spot temperatures and/or sparking and arcing, the following additional procedures must be observed.*

i. Determine the presence of an ignition source by photography, ignition of an ignitable mixture or temperature measurement, as appropriate. If photography is employed, any light indication due to internal sparking during the test shall be taken as sparking sufficient to ignite fuel. If an ignitable mixture is used and no ignition occurs during the test, verification of the mixture combustibility shall be obtained by ignition with a spark of the defined energy and length introduced into the test chamber or exhaust (see <u>Figure 23-9</u>) immediately after the lightning test. If the combustible mixture is not ignited by the artificial source, the lightning tests shall be considered invalid and the tests repeated with a new mixture until either the lightning tests or the artificial source ignites the mixture.

j. If photography is employed, verify that the camera shutter is open for the entire duration of the discharge. This is normally done by use of a «tell-tale» light. Inspect and record its physical and functional condition.

<u>NOTE:</u> *Sparking may take place well away from the attachment point.*

23.6.4 Data Required to Assist in Interpretation of Test Results

a. Environmental data such as temperature, pressure and humidity.

b. Description and photographs of the test set-up and specimen, including specimen description (model/part no., materials, thicknesses, surface treatments, corrosion protection, sealants, etc.).

c. Date and names of personnel performing and witnessing the tests, and name of the test facility.

d. Photographs and description of the test specimen both before and after the test. Photographs shall clearly show sample identification marks and change(s) in physical condition and a dimensional scale. The sample may be damaged at points remote from the arc attachment.

e. Test voltage and current waveforms and magnitudes.

f. Currents and voltages, as applicable, on the equipment cables and/or terminations.

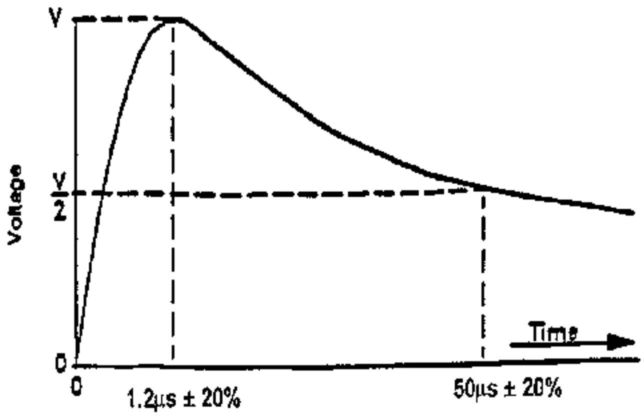
g. Photograph and descriptions of discharges and arc attachment points and all damage on the test object.

NOTE: The following items apply only to fuel vapor region tests.

h. Where applicable, photographs of the interior of the fuel chamber under study during the test, or other evidence of the presence or absence of sparking during the tests.

i. Where photography is used for the detection of sparking, the film speed, aperture number, focal length and lens-to-object distance shall be recorded.

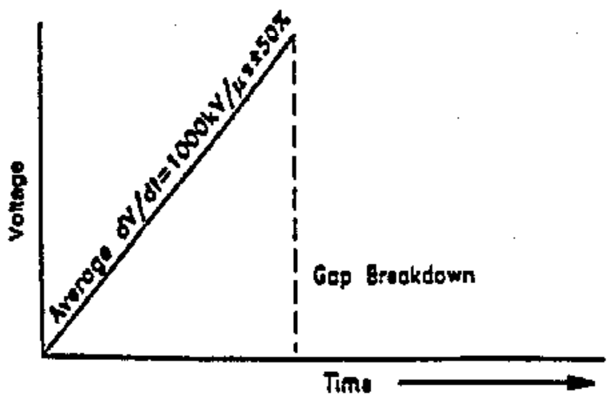
j. If an ignitable gas-air mixture is employed all relevant details shall be recorded, including the method used to verify its ignitability.



Total Gap Length	Electrode Positive	Electrode Negative
0.5m	250kV	600kV
0.8m	400kv	900kV
1.0m	500kV	1100kV
1.5m	800kV	1500kv

Approximate Voltage Requirements

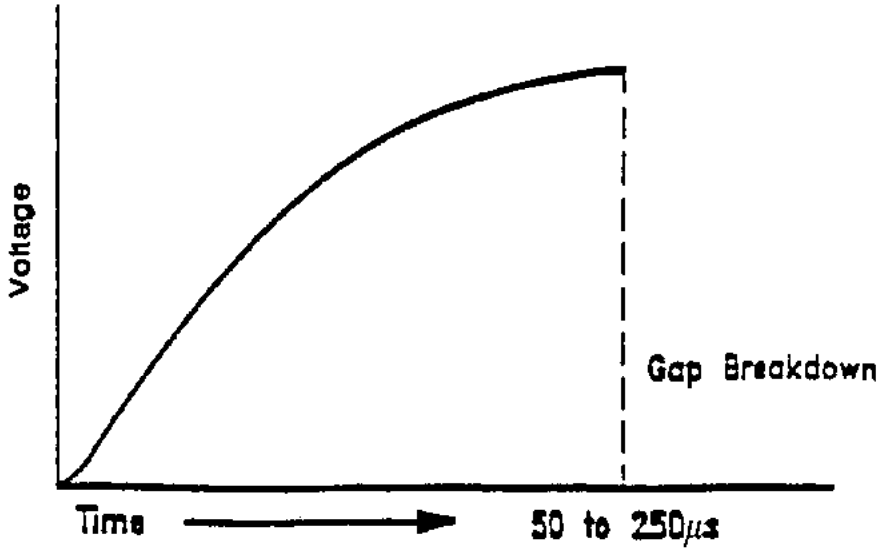
Figure 23-1 High Voltage Waveform for V_{90} Method



Total Gap Length	Electrode Positive	Electrode Negative
0.5m	750kV	790kV
1.0m	1300kv	1400kV
1.5m	2250kV	2400kV

Approximate Voltage Requirements

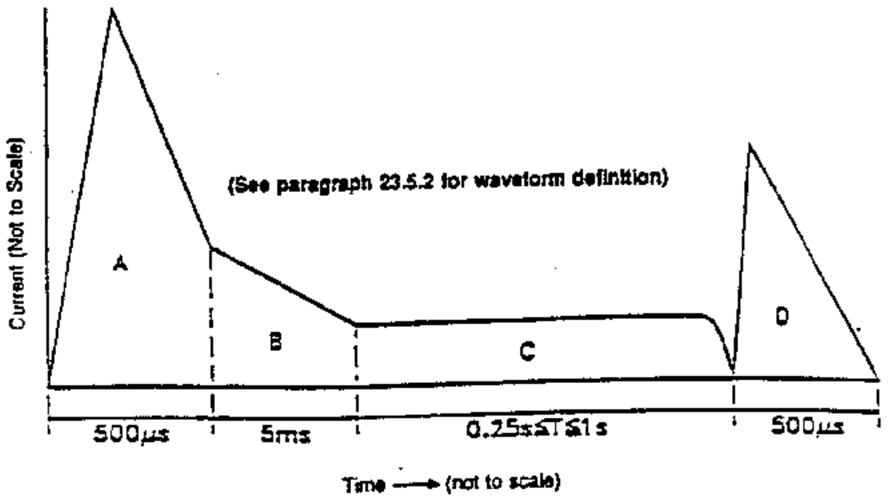
Figure 23-2 High Voltage Waveform for Alternate Method



Total Gap Length	Electrode Positive	Electrode Negative
0.5m	350kV	400kV
1.0m	500kv	600kV
1.5m	600kV	700kV

Approximate Voltage Requirements

Figure 23-3 High Voltage Waveform for Alternate Method
(Voltage Rising to Peak in Between 50 μs and 250 μs)



APPLICATION OF WAVEFORMS FOR LIGHTNING TESTS

Test	Category	Current Components			
		A	B	C	D
Direct Effects on Externally Mounted Equipment	1A	X	X	X[1]	
	1B	X	X	X	X
	2A		X	X[1]	X[3]
	2B		X	X	X[3]
	3	X[2]		X[2]	

NOTE 1: *The full duration of component C is not applied for categories 1A and 2A. Apply the average current of 400 A for 45 ms ±10 percent to deliver 18 coulombs ±20 percent.*

NOTE 2: *These current components are applied by direct connection i.e., not by arc, and in some cases will only be applied to flow in the skin alongside the equipment under test. As a minimum, a surface current density of 50 KA per meter should be applied.*

NOTE 3: *Component D to be applied first.*

Figure 23-4 Current Waveforms

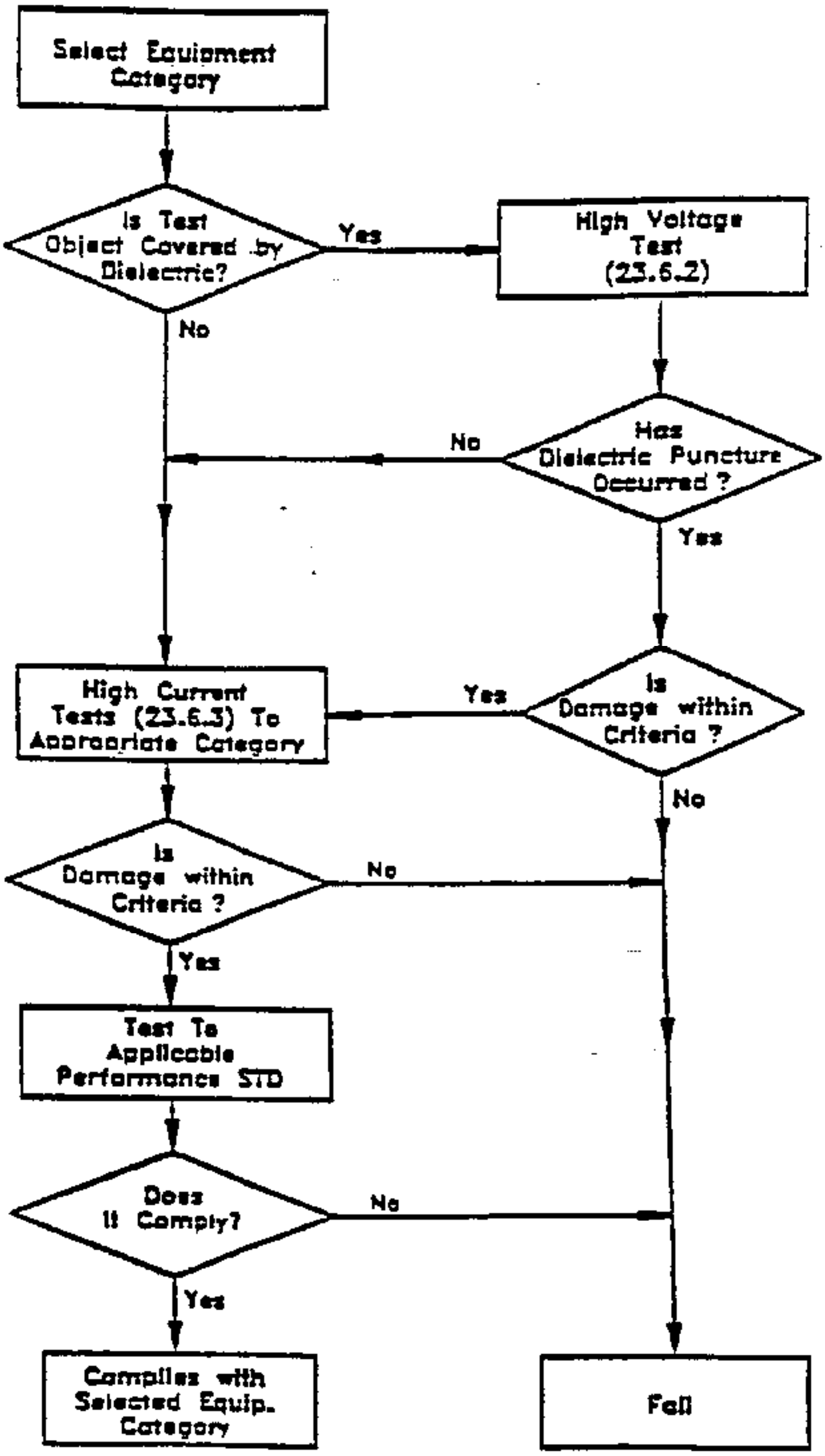
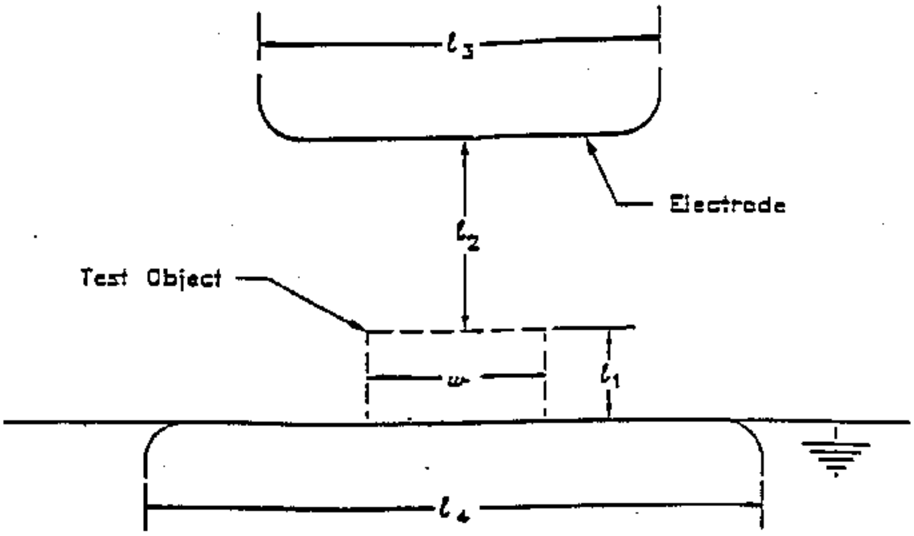


Figure 23-5 Flow Chart for High Voltage and High Current Tests



<u>NOTES</u> 1. *For a symmetrical shape, ω is the smaller of the length or width, or for a non-symmetrical shape, twice the distance from the centroid of the object's surface foot print to its surface edge.*

2. *The ground plane may be either a very broad, flat one, or one with a profiled edge of width ℓ_4.*

Test Set up Dimensions	For ω and ℓ<100mm	For ℓ_1> ω and ℓ_1>100mm	For w>ℓ_1 and ω>100mm
ℓ_2	150mm	≥1.5ℓ_1	≥1.5ω
ℓ_3	>2ℓ_2	>2ℓ_2	>2ℓ_2
ℓ_4	≥ℓ_3	≥ℓ_3	≥ℓ_3

Gap and Electrode Dimensions for High Voltage Tests

<u>NOTES:</u> *The tolerance for ℓ_2 is 20 percent.*

The values for ℓ_2 and ℓ_4 are minimum values.

<u>Figure 23-6</u> Test Arrangement and Dimensions for High Voltage Tests

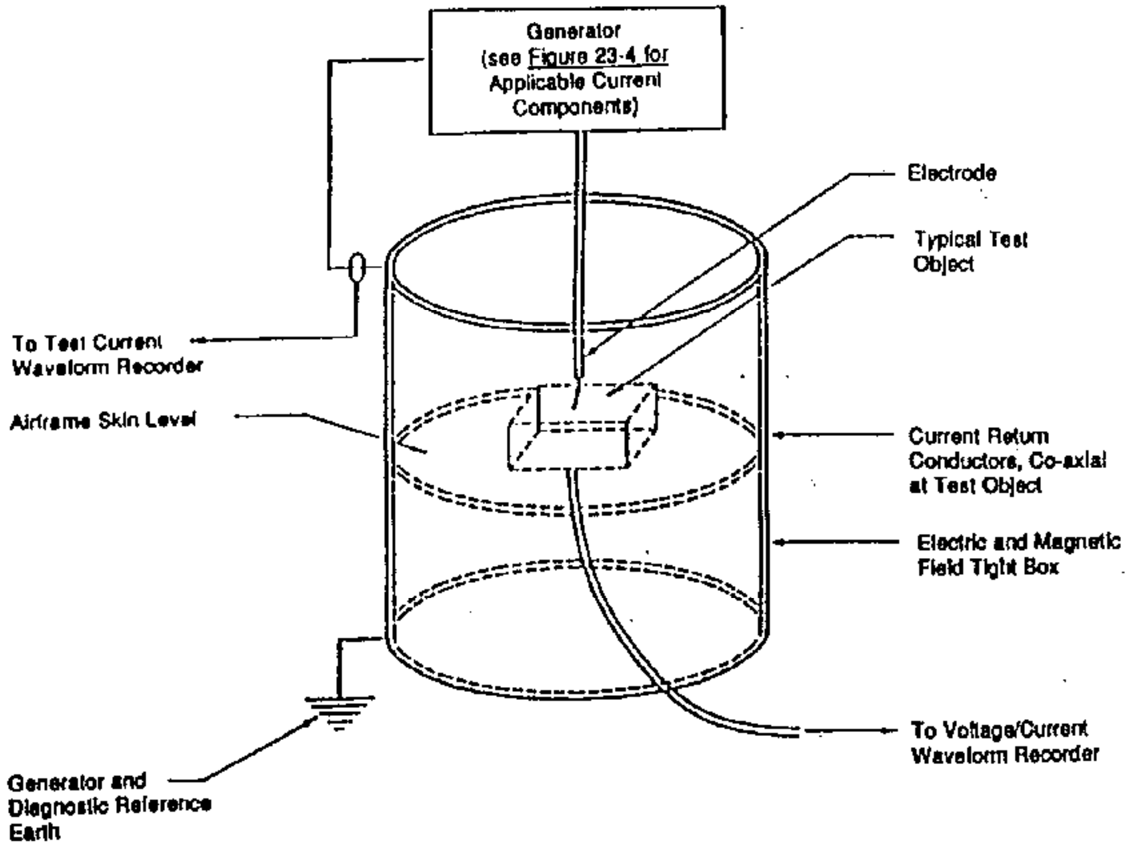


Figure 23-7 Typical High Current Set-Up for Non-Fuel Areas Arc-Entry Tests

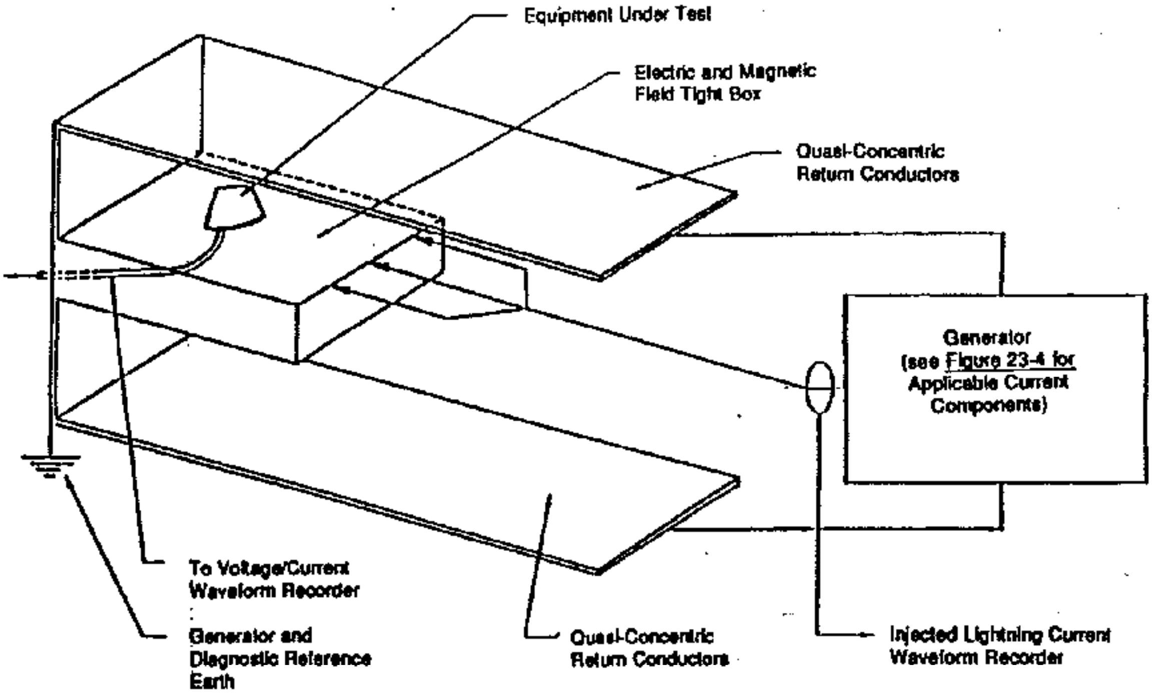


Figure 23-8 Typical High Current Set-Up for Non-Fuel Areas Conducted Entry Tests

Note: May also need injected current and voltage recorder as in Figure 23-8

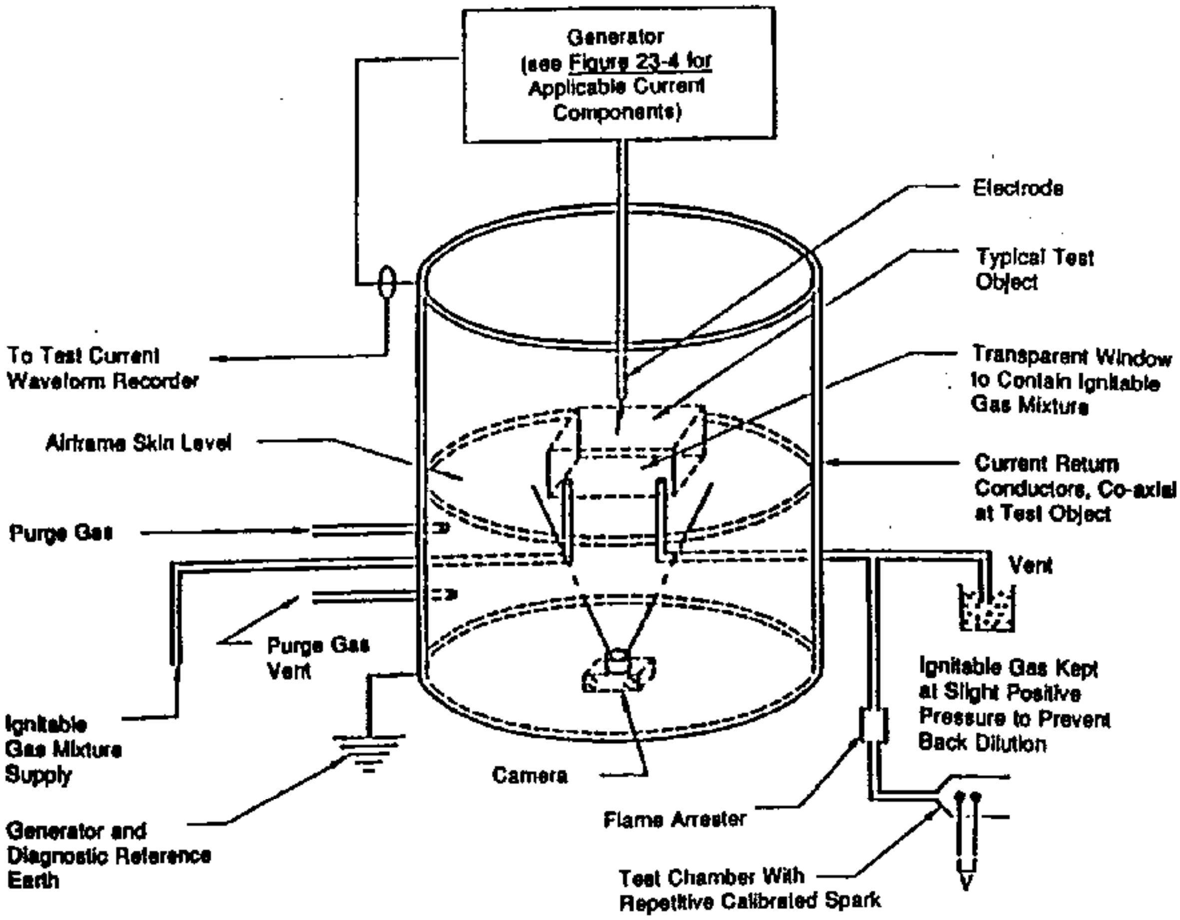


Figure 23-9 Typical High Current Set-Up for Fuel Vapor Region Requirements

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 24

Icing

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

24.0 ICING

24.1 Purpose of the Test

These tests determine performance characteristics for equipment that must operate when exposed to icing conditions that would be encountered under conditions of rapid changes in temperature, altitude and humidity.

24.2 General

Three icing test procedures are specified according to the category for which the equipment is designed to be used and installed in the aircraft (see Subsection 24.3).

NOTE: *The selection of icing category depends on equipment location in (or on) the aircraft and the type of icing conditions expected. These conditions must be considered by the equipment designer in evaluating these requirements, which are determined by the end application and use of the equipment. These tests generally apply to equipment mounted on external surfaces or in non-temperature controlled areas of the aircraft where rapid changes in temperature, altitude and humidity are generally encountered.*

These procedures specify test methods for evaluating the effects of various icing conditions on the performance or aircraft equipment, namely:

a. The effects of external ice or frost adhering to it.

b. The effects of ice caused by freezing of water condensation or by re-freezing of melted ice.

c. The effects of ice build-up caused by direct water exposure.

24.3 Equipment Categories

The following categories cover the anticipated ice formation conditions generally encountered in aircraft.

Category A

This test is applicable to equipment mounted externally or in non-temperature-controlled areas of the aircraft, where ice or frost may form due to condensation when the equipment is cold soaked to extremely low temperatures and subsequently encounters humid air at above freezing temperatures.

Category B

This test is applicable to equipment with moving parts where such movement could be prevented or impeded by ice formation, or where forces resulting from the expansion of ice could damage structural or functional components. The ice formed in or on the equipment results from condensation, freezing, melting and/or re-freezing and may progressively accumulate water or ice inside non-sealed enclosures.

Category C

This test is applicable to items mounted externally or in non-temperature-controlled areas where there is risk of accumulating free water, which could subsequently freeze on the cold surfaces of the equipment. The test is intended to examine the effects of a representative thickness of ice on the performance of the equipment or to determine the maximum thickness that can be permitted before de-icing action is necessary. The required thickness and distribution of ice and any requirement for progressive build-up of ice shall be defined by the APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

24.4 Test Procedure

24.4.1 General

Mount the equipment under test in a manner representative of the normal installation in the aircraft. Remove all non-representative contaminants, such as oil, grease and dirt, which would effect adhesion between ice and the surfaces of the equipment under test, before beginning the appropriate tests. Operation of equipment that generates heat shall be limited to only that period of time necessary to determine compliance. The steps described in the Category A and Category B procedures are illustrated in Figure 24-1 and Figure 24-2.

24.4.2 Category A

a. With the equipment not operating, stabilize the equipment temperature at the low ground survival temperature specified in Table 4-1 at ambient room pressure and humidity.

b. As quickly as practical, expose the equipment to an environment of 30 degrees C with a relative humidity of at least 95 percent. Monitor the surface temperature of the equipment.

c. Maintain the environment at 30 degrees C and a relative humidity of at least 95 percent until the surface temperature of the equipment reaches five degrees C. As quickly as practical, change the environment to the appropriate ground survival low temperature at ambient pressure and humidity.

d. Repeat steps a. through c. for two additional cycles (total of three cycles).

e. At the end of the third cycle, stabilize the equipment at the ground survival low temperature. Increase and maintain the chamber temperature to -10 degrees C and permit the surface temperature of the equipment to rise. When the surface temperature reaches -10 ±5 degrees C, place the equipment into the operating state and DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

NOTE: *This test is designed to expose the equipment alternately to cold dry and warm moist environments. The use of separate chambers representing these two distinct environments is recommended.*

24.4.3 Category B

a. With the equipment not operating, stabilize the equipment temperature at -20 degrees C at ambient room pressure. Maintain this temperature and decrease the chamber pressure to the appropriate maximum operating altitude specified in Table 4-1. Maintain this condition for a period of at least 10 minutes.

b. Raise the chamber temperature at a rate not exceeding three degrees C/minute while simultaneously increasing and maintaining the relative humidity in the test chamber to not less than 95 percent. Maintain this condition for a sufficient period of time to melt all frost and ice or until the surface temperature of the equipment reaches between zero to five degrees C. The chamber temperature should not be allowed to exceed 30 degrees C at any time during this step.

c. Increase the chamber pressure to room ambient at a uniform rate in a period of 15 to 30 minutes. At the completion of the re-pressurization, reduce the relative humidity in the chamber to normal room ambient.

d. Repeat steps a. through c. for a total of 25 cycles or as defined in the applicable equipment specification, whichever is less.

NOTE: If it becomes necessary to interrupt the test sequence, the interruption shall take place while the equipment is held at the low temperature condition.

e. During the last test cycle, after the equipment temperature has stabilized at -20 degrees C, DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

24.4.4 Category C

a. With the equipment not operating, stabilize the equipment at a temperature that will permit clear, hard ice to form on the equipment when sprayed with water.

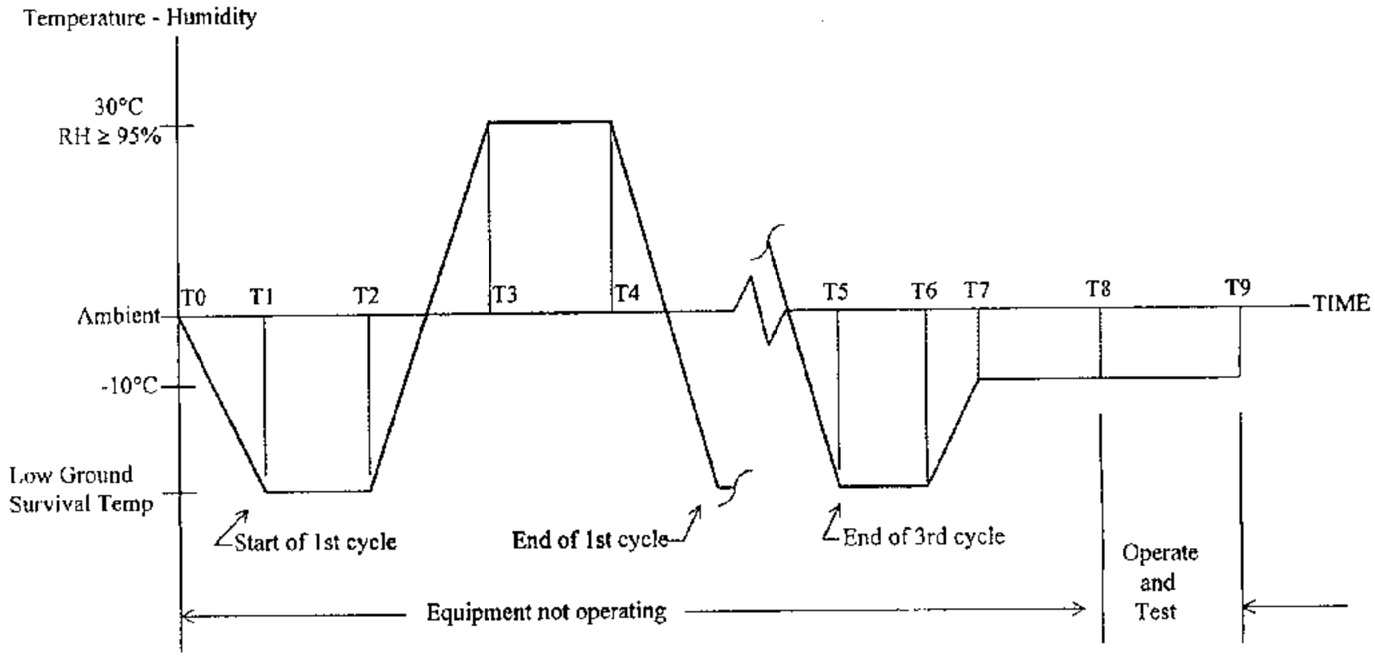
NOTE 1: For this test, the ice formed shall be clear and hard. «White» or air-pocketed ice is not acceptable.

NOTE 2: The optimum temperature is likely to be between -1 and -10 degrees C depending on the thermal mass of the equipment and is best determined by experiment.

b. Build up a homogeneous layer of clear hard ice to a thickness defined by the APPLICABLE EQUIPMENT PERFORMANCE STANDARD by hand spraying a fine mist of water at a temperature that is close to freezing.

c. When the required thickness of ice has been achieved, discontinue the spraying. Place the equipment into the operating state and stabilize the equipment at a temperature of -20 degrees C. DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

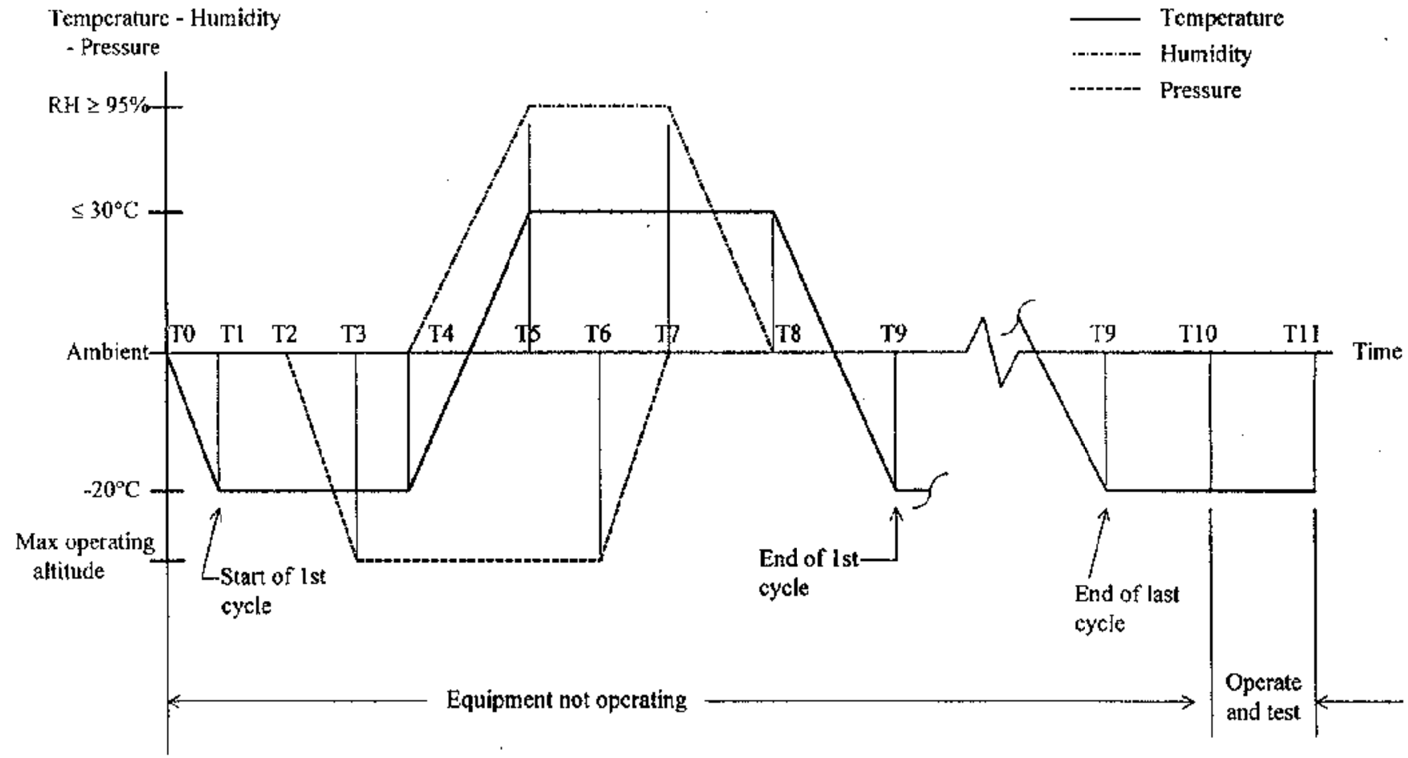
NOTE:: If multiple tests with increasing thickness of ice formation are required, a series of separate tests shall be performed with each thickness level formed in a continuous operation.



NOTES:

1. Unless otherwise specified, temperature and humidity change rates are optional.
2. T1 to T2 and T5 to T6 are times for equipment temperature to stabilize.
3. T2 to T3 and T4 to T5 are to be accomplished as quickly as practical.
4. T3 to T4 is the time for surface temperature of equipment to reach 5 degrees C.
5. T7 to T8 is the time for surface temperature of equipment to reach -10 degrees C.

Figure 24-1 Category A Icing Test



NOTES:

1. Unless otherwise specified, temperature, humidity and pressure change rates are optional.
2. T1 to T2 and T9 to T10 are times for equipment temperature to stabilize.
3. T3 to T4 is 10 minutes, minimum
4. From T4 to T5 the temperature rate of change is 3 degrees C per minute maximum.
5. T5 to T6 is the minimum time to melt all ice and frost.
6. From T5 to T8 the chamber temperature should not exceed 30 degrees C.
7. T6 to T7 is 15 to 30 minutes.

Figure 24-2 Category B Icing Test

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Section 25

Electrostatic Discharge (ESD)

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2, 3 and 20. Further, Appendix A is applicable for identifying the environmental tests performed.

Page

25.0 ELECTROSTATIC DISCHARGE (ESD)

25.1 Scope

The Electrostatic Discharge test relates to airborne equipment which may be involved in static electricity discharges from human contact. Some factors contributing to an ESD event may be: low relative humidity, temperature, use of low conductivity (artificial fiber) carpets, vinyl seats and plastic structures which may exist in all locations within an aircraft. This test is applicable for all equipment and surfaces which are accessible during normal operation and/or maintenance of the aircraft.

25.2 Purpose of the Test

The electrostatic discharge test is designed to determine the immunity or the ability of equipment to perform its intended function without permanent degradation of performance as a result of an air discharged electrostatic pulse.

25.3 Test Description

The immunity to electrostatic discharge shall be determined by the ability of the equipment under test (EUT) to withstand a series of electrostatic pulses at a selected severity level of 15,000 volts, directed at specific human contact locations on the EUT. The quantity of pulses shall be ten (10) in each of the selected locations in both positive and negative voltage polarities. The test configuration is depicted in Figure 25-1.

25.4 Equipment Categories

Category A - Electronic equipment that is installed, repaired or operated in an aerospace environment.

25.5 Test Procedure

With the equipment powered and operated in the required mode the electrostatic discharge test will be performed under the following conditions:

25.5.1 Test Configuration

The EUT shall be set up as shown in Section 20.3a (General Test Requirements). Connect and orient the equipment as specified by the applicable installation and interface control drawings or diagrams. Care must be taken in routing and grounding of the cabling associated with the ESD generator to minimize the potential for secondary effect of the radiated field from the cabling. This test is intended to test the primary effect which is the discharge from the ESD generator to the enclosure of the equipment under test. This includes the normal method of mounting, bonding, and grounding of the equipment.

25.5.2 ESD Generator

The ESD generator shall have a general schematic as shown in Figure 25-2, with a discharge resistor of 330 ohms (±20%) and an energy storage capacitor of 150 pf (±20%), and shall be capable of generating a pulse of 15,000 volts. The ESD generator shall also have an air discharge tip as shown in Figure 25-3. Prior to performing the test, the output of the ESD generator should be calibrated to produce a 15,000 volt minimum peak output pulse. This can be done by verifying the output waveform of the ESD generator or by setting the high voltage power supply to 15,000 volts minimum. The generator setting required to produce this output should be recorded.

25.5.3 EUT Test Modes

EUT test modes should include the software chosen to exercise all normal modes of operation of the EUT.

NOTE: If monitoring equipment is required, it should be decoupled in order to reduce the possibility of erroneous failure indications.

25.5.4 Pulse Application

The ESD discharges shall be applied only to those points and surfaces of the EUT which are accessible to personnel during normal operation (including as installed on aircraft maintenance).

With the ESD generator set at the value recorded during calibration the ESD generator shall be held perpendicular to the surface to which the discharge is applied. The discharge return cable of the generator shall be grounded to the ground plane and kept at a distance of at least 0.2 meters from the EUT and its cabling.

25.5.5 Test Technique

Move the tip of the ESD generator toward the EUT at the same speed a human hand would reach to touch an object (approximately 0.3 meters/second) until the generator discharges or until contact is made with the EUT. After each discharge, the ESD generator (discharge electrode) shall be removed from the EUT. The generator is then retriggered for a single discharge. This procedure shall be repeated until the 10 discharges in each polarity and each location are completed.

25.6 Evaluation of the Test Results

Following application of the pulses, DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS, unless specified otherwise.

25.7 Selection of Test Points

The test points to be considered shall include the following locations as applicable: any point in the control or keyboard area and any other point of human contact, such as switches, knobs, buttons, indicators, LEDs, slots, grilles, connector shells and other operator accessible areas.

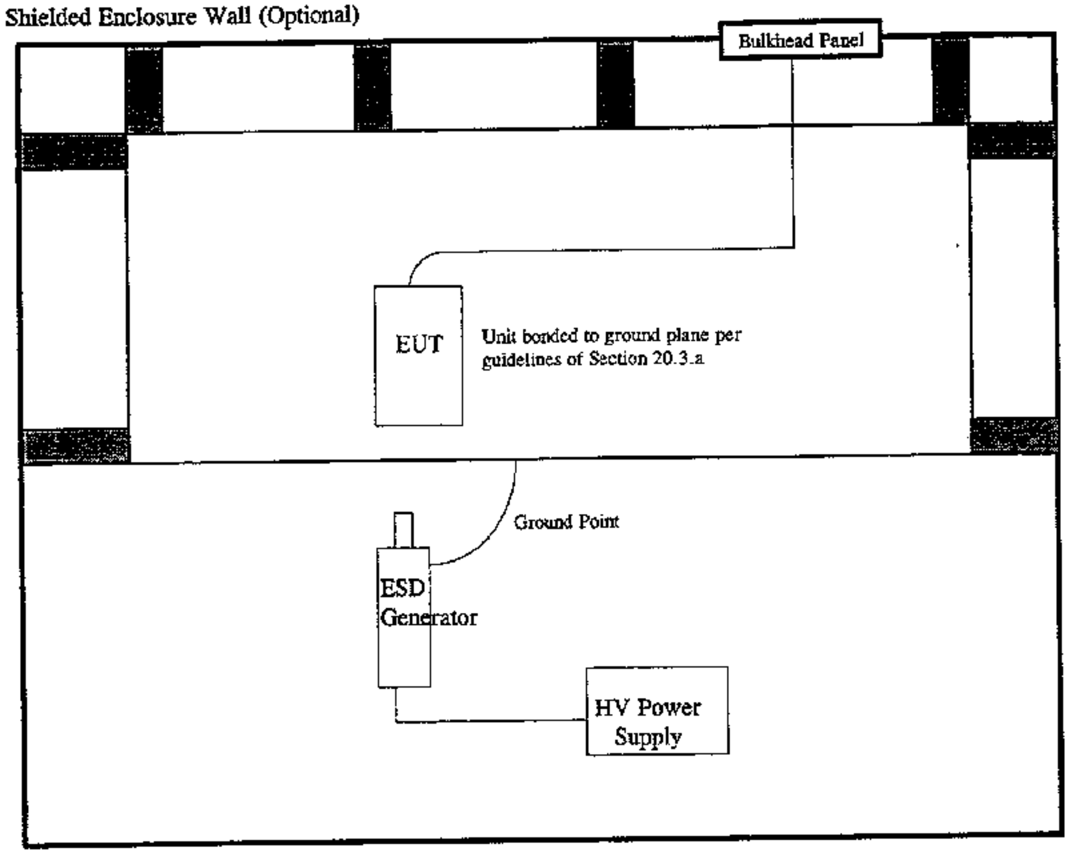
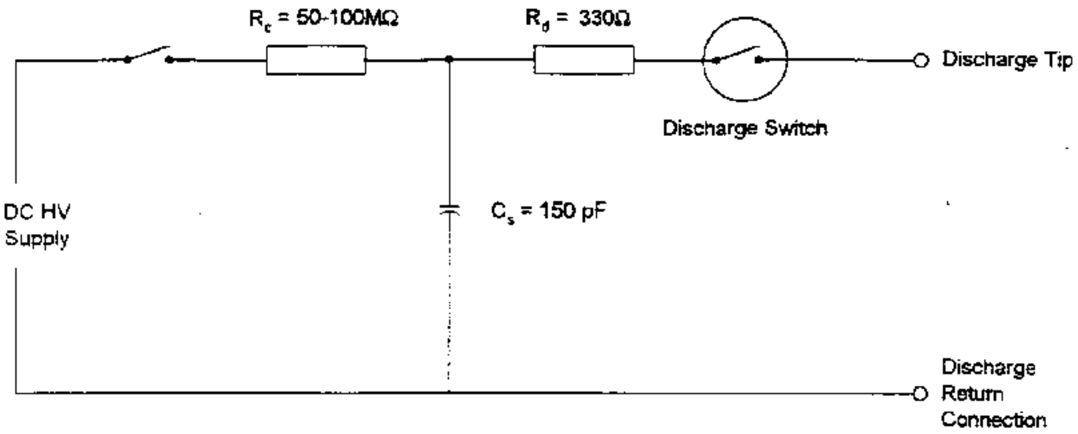
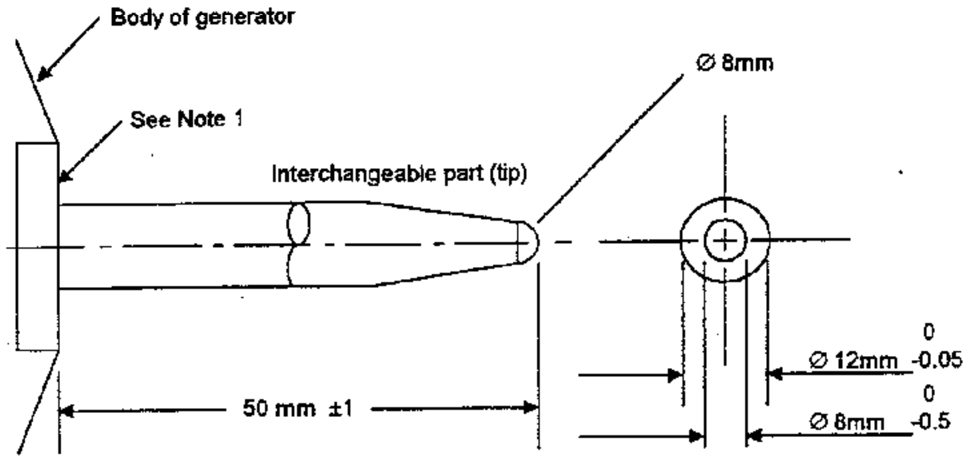


Figure 25-1 Electrostatic Discharge Typical Setup



NOTE - C_d, omitted in the figure, is a distributed capacitance which exists between the generator and the ET, GRP, and coupling planes. Because the capacitance is distributed over the whole of the generator, it is not possible to show this in the circuit.

Figure 25-2 Simplified Diagram of the ESD Generator



NOTE - The discharge switch (e.g., vacuum relay) shall be mounted as close as possible to the tip of the discharge electrode.

Figure 25-3 Discharge Electrode of the ESD Generator

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Appendix A

Environmental Test Identification

Important Notice

Information pertinent to this test procedure is contained in Sections 1, 2 and 3. This appendix is applicable for identifying the environmental tests performed.

APPENDIX A

A.1 INTRODUCTION AND SCOPE

Minimum operational performance standards (MOPS) prepared by EUROCAE and RTCA, Inc. for airborne equipment contain requirements that the equipment must meet to ensure reliable operation in actual aeronautical installations. These equipment requirements must be verified in ambient and stressed environmental conditions. The MOPS contains recommended bench test procedures for ambient conditions and refers to EUROCAE/RTCA Document ED-14/DO-160, «Environmental Conditions and Test Procedures for Airbome Equipment,» for the stressed environmental testing. ED-14 encompasses the full spectrum of environmental conditions that airbome equipment may experience—from benign to very hostile.

A need exists to provide a permanent record of the particular environmental test categories that the equipment has passed. This need includes post-incident or accident investigation, installation certification, repair, etc. This procedure provides for a paper record (hereafter referred to as the Environmental Qualification Form) to be included in the equipment data package submitted for Technical Standard Order (TSO) authorization and in the installation and maintenance instructions. In addition to the Environmental Qualification Form, the traditional nameplate marking system may be used. This nameplate marking system is a supplemental and optional method of identifying the environmental test results. Nameplate marking is useful in those markets where the customers may not request or be in a position to review the TSO data package for a particular equipment.

Since it is not envisioned that the Environmental Qualification Form will be related to a particular equipment by serial number or date of manufacture, association must be achieved through the equipment type, model or part number. Manufactures should identify the method used to establish traceability to the environmental test categories to which the equipment was tested, including the applicable revision number of the test procedure (Section of ED-14) used.

A.2 Environmental Qualification Form (see Figure A-1)

This form provides the necessary information regarding which environmental tests were conducted and, where applicable, the appropriate environmental category of the equipment being tested.

Additional information is included to identify the specific equipment type or model to which the environmental test results apply. A suggested format is depicted in Figure A-1. An example Environmental Qualification Form is shown is Figure A-2 and has been annotated to illustrate a completed form. Equipment manufacturers should expand on the data included on this form to provide added clarity.

In some cases, the manufacturer may wish to qualify the equipment to more than one category for a particular environmental test. If one category is more stringent, only the more stringent category need be identified. In other cases, such as Temperature/Altitude or Vibration, where the test requirements for various categories are different but not necessarily more severe, more than one category should be indicated on the form.

Also, information such as vibration tests conducted with or without shock mounts, fluid tests conducted with Jet A fuel, type of de-icing fluid, and other parameters pertinent to the tests shall be included on the form.

A.3 Supplemental Method of Equipment Nameplate Marking

a. The following is a supplemental method of marking equipment nameplates to indicate the particular environmental test categories to which the equipment has been tested. If this method of marking equipment nameplates is used, an Environmental Qualification Form is still required to completely document the environmental test results. This optional method of marking equipment nameplates provides a supplemental method of communicating the test results to the end customers.

b. There are 23 environmental test procedures in this document for which categories have been established. These should be identified on the equipment nameplate by the words «ED-14D Environmental Categories» or, as abbreviated, «ED-14D Env. Cat.,» followed by the letters and numbers (or sets of letters and numbers) which identify the categories designated in this document. Reading from left to right the category designations should appear on the equipment nameplate in the following order, so that they may be readily identified:

	SECTION	TEST
1.	4.0	Temperature and Altitude Test (2 spaces minimum)
2.	4.5.4	In-Flight Loss of Cooling Test
3.	5.0	Temperature Variation Test
4.	6.0	Humidity Test
5.	7.0	Operational Shock and Crash Safety Test
6.	8.0	Vibration Test (3 spaces minimum)
7.	9.0	Explosion Proofness Test
8.	10.0	Waterproofness Test
9.	11.0	Fluids Susceptibility Test
10.	12.0	Sand and Dust Test
11.	13.0	Fungus Resistance Test
12.	14.0	Salt Spray Test
13.	15.0	Magnetic Effect Test
14.	16.0	Power Input Test
15.	17.0	Voltage Spike Test
16.	18.0	Audio Frequency Conducted Susceptibility Test
17.	19.0	Induced Signal Susceptibility Test
18.	20.0	Radio Frequency Susceptibility Test (3 spaces)
19.	21.0	Emission of Radio Frequency Energy Test
20.	22.0	Lightning Induced Transient Susceptibility Test (4 spaces)
21.	23.0	Lightning Direct Effects Test (1, 2 or 3 spaces)
22.	24.0	Icing Test
23.	25.0	Electrostatic Discharge Test

c. For Vibration, identify the aircraft type and aircraft zone, as well as the applicable test category, by designating the corresponding letters for the test category and for the primary vibration curve(s) (refer to Table 8-1). If the size of the equipment nameplate allows, the following guidelines should be applied for improved readability. Use square brackets [ ] to enclose the category letters for a single section where more than one character is required, such as Vibration. Use parenthesis ( ) within the brackets to enclose category letters where more than one test is performed and more than one letter is required per category, such as Temperature/Altitude (see paragraph d. below). Typical equipment nameplate identifications are as follows:

ED-14D Env. Cat. A2WBABSWLXXXXXXAAAAAVWPLB3D4XXA
or
ED-14D Env. Cat. [AZW]BAB[SWL]XXXXXXAAAAA[VWP]L[B3D4]XXA

d. In some cases, the manufacturer may wish to qualify the equipment to more than one category for a particular environmental test. If one category is definitely more stringent, only the more stringent category need be identified. In other cases such as Temperature/Altitude or Vibration, where the test requirements for various categories are different but not necessarily more severe, more than one category should be marked on the equipment nameplate.

For example, the following nameplate identification is the nameplate marking for the example test results shown in the Environmental Qualification Form in Figure A-2:

ED614D Env. Cat. [(A2)(F2)W]BAB[SWL]XXFXFXA[BE]AAZ[RRR]H[B3D4]XXA

e. In the case of the Vibration Test, the equipment may be qualified for one category without shock mounts and to another with shock mounts. This differentiation should be shown by listing those categories without shock mounts above the line and those with shock mounts below the line. For example, the following nameplate identification is identical to the above example, except that the equipment has been qualified to Vibration category S, aircraft zone 4, for fixed wing turbojet, unducted turbofan, and reciprocating engine aircraft less than 5,700 kg. without shock mounts (primary vibration curves W & L) and for reciprocating engine aircraft over 5,700 kg. with shock mounts (vibration curve U):

SWL
ED-14D Env. Cat. [(A2)(F2)W]BAB[SU]XXFXFXA[BE]AAZ[RRR]H[B3D4]XXA

f. In the case of the fluid test, the detailed category information shall be included in the Environmental Qualification Form. The nameplate shall be marked F if any of the fluid tests have been satisfactorily completed or X if fluid testing was not performed.

NOMENCLATURE: ____________________

TYPE/MODEL/PART NO: ____________ JTSO/TSO NUMBER ____________

MANUFACTURER'S SPECIFICATION AND/OR OTHER APPLICABLE SPECIFICATION: ____________

MANUFACTURER: ____________________

ADDRESS: ____________________

____

REVISION & CHANGE NUMBER OF ED-14: ____________ DATE TESTED: ____________

CONDITIONS 1/	SECTION	DESCRIPTION OF TESTS CONDUCTED
Temperature and Altitude	4.0	
Low Temperature	4.5.1	
High Temperature	4.5.2 & 4.5.3	
In-Flight Loss of Cooling	4.5.4	
Altitude	4.6.1	
Decompression	4.6.2	
Overpressure	4.6.3	
Temperature Variation	5.0	
Humidity	6.0	
Operational Shock and Crash Safety	7.0	
Vibration	8.0	
Explosion	9.0	
Waterproofness	10.0	
Fluids Susceptibility	11.0	
Sand and Dust	12.0	
Fungus	13.0	
Salt Spray	14.0	
Magnetic Effect	15.0	
Power Input	16.0	
Voltage Spike	17.0	
Audio Frequency Susceptibility	18.0	
Induced Signal Susceptibility	19.0	
Radio Frequency Susceptibility	20.0	

1/ The information listed below provides examples only. It is not intended to be a comprehensive listing of all test conditions.

Figure A-1 Environmental Qualification Form

CONDITIONS	SECTION	DESCRIPTION OF TESTS CONDUCTED
Radio Frequency Emission	21.0	
Lightning Induced Transient Susceptibility	22.0	
Lightning Direct Effects	23.0	
Icing	24.0	
Electrostatic Discharge	25.0	
Other Tests		

REMARKS
-
-
-
- Special Conditions: Include power, special cooling, installation instructions, etc.

Figure A-1 Concluded

EXAMPLE

NOMENCLATURE:____________________

TYPE/MODEL/PART NO: ______________ JTSO/TSC NUMBER ______________

MANUFACTURER'S SPECIFICATION AND/OR OTHER APPLICABLE SPECIFICATION: ______________

MANUFACTURER:____________________

ADDRESS:____________________

____

REVISION & CHANGE NUMBER OF ED-14:______________DATE TESTED: ______________

CONDITIONS	SECTION	DESCRIPTION OF TESTS CONDUCTED
Temperature and Altitude Low Temperature High Temperature In-Flight Loss of Cooling Altitude Decompression Overpressure	4.0 4.5.1 4.5.2 & 4.5.3 4.5.4 4.6.1 4.6.2 4.6.3	Equipment tested to Categories A2, F2 With auxiliary air cooling, tested to Category W
Temperature Variation	5.0	Equipment tested to Category B.
Humidity	6.0	Equipment tested to Category A.
Operational Shock and Crash Safety	7.0	Equipment tested to Category B.
Vibration	8.0	Equipment tested to Category S, aircraft zone 4 for fixed wing turbojet engine aircraft, fixed wing unducted turbofan engine aircraft and fixed wing reciprocating/turbojet engine aircraft less than 5,700 kg using vibration test curves W and L.
Explosion	9.0	Equipment identified as Category X, no test performed.
Waterproofness	10.0	Equipment identified as Category X, no test performed.
Fluids Susceptibility	11.0	Equipment identified as Category F Equipment spray tested with phosphate ester-based hydraulic fluid and immersion tested with AEA Type 1 De-icing fluid.
Sand and Dust	12.0	Equipment identified as Category X, no test performed.
Fungus	13.0	Equipment tested to Category F.
Salt Spray	14.0	Equipment identified as Category X, no test performed.
Magnetic Effect	15.0	Equipment is Category A.

FIGURE A-2 Environmental Qualification Form

CONDITIONS	SECTION	DESCRIPTION OF TESTS CONDUCTED
Power Input	16.0	Equipment tested to Categories E and B.
Voltage Spike	17.0	Equipment tested to Category A.
Audio Frequency Susceptibility	18.0	Equipment tested to Category A.
Induced Signal Susceptibility	19.0	Equipment tested to Category Z.
Radio Frequency Susceptibility	20.0	Equipment tested for conducted susceptibility to Category R and for radiated susceptibility to Category R and pulse test to Category R.
Radio Frequency Emission	21.0	Equipment tested to Category H .
Lightning Induced Transient Susceptibility	22.0	Equipment tested to pin test waveform set B, level 3, and cable bundle test waveform set D, Level 4.
Lightning Direct Effects	23.0	Equipment identified as Category X, no test performed.
Icing	24.0	Equipment identified as Category X, no test performed.
Electrostatic Discharge	25.0	Equipment tested to Category A.
Other Tests		Fire resistance tests were conducted in accordance with Federal Aviation Regulations Part 25, Appendix F.

REMARKS

- Tests were conducted at Environmental Laboratories, Inc.
- In the fluids susceptibility tests, material specimens were used
- In the power input test, equipment was tested to subparagraph 16.5.1.4 b requirement for equipment with digital circuits.

FIGURE A-2 Concluded

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE EQUIPMENT

Appendix B

Membership

LIST OF MEMBERS OF EUROCAE WORKING GROUP 14

Successive Chairmen:	R.J. CHRISTIE	CAA/SRG	UK
	Y. GARRIGUES	STNA	France
	P-C ROLLAND	AEROSPATIALE	France
Members :	P. AZOULAY	EUROCOPTER	France
	G. BERTHON	SEXTANT AVIONIQUE	France
	S. BOUSSIN	AEROSPATIALE	France
	E. BOUTELET	SNECMA	France
	M. BREVAN	DASSAULT AVIATION	France
	RTP CARRUTHERS	SMITHS INDUSTRIES	UK
	G. DENARIE	SEXTANT AVIONIQUE	France
	J.P. DEWAULLE	DASSAULT ELECTRONIQUE	France
	M. DUPRE	AEROSPATIALE	France
	M. GASPARD	AEROSPATIALE	France
	M. GOIRAND	AEROSPATIALE	France
	D.P. GOODLAND	BRITISH AEROSPACE	UK
	D. GOUX	SNECMA	France
	W. HONE	LUCAS AEROSPACE	UK
	R. LE LOUARN	DASSAULT ELECTRONIQUE	France
	A. MARQUIS	DASSAULT ELECTRONIQUE	France
	P. MATOSSIAN	SOPEMEA	France
	C. PERKINS	LUCAS AEROSPACE	UK
	M. RANGER	SNECMA	France
	C. RIMOLDI	ALENIA	Italy
	J.C. ROUQUET	AEROSPATIALE	France
	B. TARDY	EUROCOPTER	France
	R. ZANNIER	SNECMA	France

LIST OF MEMBERS OF EUROCAE WORKING GROUP 31

Successive Chairmen:	E. FANIO	AEROSPATIALE	France
	J-P MOREAU	DASSAULT AVIATION	France
Secretary :	J. HARDWICK	AEA	UK
Members :	L. ANDERSSON	SAAB AIRCRAFT	Sweden
	G. BAÜML	FED. ARMED FORCES	Germany
	P. BEECKMAN	FOKKER AIRCRAFT	Netherlands
	H. BEENS	LBA	Germany
	E. BOUTELET	SNECMA	France
	J. CAMMAS	AEROSPATIALE	France
	D. CLARKSON	DERA	UK
	J-P CLERC	CEAT	France
	I. DARNEY	BRITISH AEROSPACE	UK
	A. DOUAY	AEROSPATIALE	France
	F. DRUMM	FED. ARMED FORCES	Germany
	P. GONDOT	AEROSPATIALE	France
	J. HOWELLS	CAA	UK
	D. JAEGER	DASA	Germany
	F. JAGIELKA	DASSAULT AVIATION	France
	C. JONES	BRITISH AEROSPACE	UK
	P. LEROUX	SFIM	France
	P. MATTEI	STPA	France
	S. RILEY	ROLLS-ROYCE	UK
	R. RINGROW	SHORT BROTHERS	UK
	J-A ROUQUETTE	AEROSPATIALE	France
	B. TAGLIANA	EUROCOPTER	France
	J.M. TODD	BRITISH AEROSPACE	UK
	A. ULMANN	CEAT	France
	D. WELLS	BRITISH AIRWAYS	UK
	D.P. WOODLAND	BRITISH AEROSPACE	UK

LIST OF MEMBERS OF EUROCAE WORKING GROUP 33

Chairman:	W. KLEINE-BEEK	LBA	Germany
Successive Secretaries:	R. HATHAWAY	CAA/SRG	UK
	P. YOUNG	LUCAS AEROSPACE	UK
Members :	J. BARON	SPAé	France
	A. BUCHNER	EUROCOPTER	Germany
	D.A. BULL	ERA Technology	UK
	R. BUTLER	Consultant	UK
	N.J. CARTER	DERA	UK
	M. KARSSEN	FOKKER AIRCRAFT	Netherlands
	H-W KRUGER	DASA AIRBUS	Germany
	M. PONCON	EUROCOPTER	France
	S. RILEY	ROLLS-ROYCE	UK
	P-C ROLLAND	AEROSPATIALE	France
	R. SQUIRE	UK MOD	UK
	J. VERPOORTE	NLR	Netherlands
	B. WAHLGREN	ERICSSON-SAAB	Sweden
	D. WELLS	BRITISH AIRWAYS	UK

LIST OF MEMBERS OF RTCA SC-135

Chairman:	CHARLES DEBLIECK	ROCKWELL COLLINS, INC.
Secretary:	RICHARD GAYNOR	DAYTON T. BROWN, INC.
Members :	CHUCK BEUNING	CESSNA AIRCRAFT COMPANY
	JOHN BIRKLAND	ROCKWELL COLLINS, INC.
	COSIMO BOSCO	FEDERAL AVIATION ADMINISTRATION
	DOUGLAS BROADDUS	DNB ENGINEERING, INC.
	CHRIS CARLSON	RADIOMETRICS MIDWEST CORP.
	JOHN COVELL	ROCKWELL COLLINS, INC.
	JAMES DAN	HUGHES AVICOM INTERNATIONAL
	WILLIAM DONOGHUE	PRATT WHITNEY
	TERENCE DONOHOE	EMC ENGINEER
	ERVIN E. DVORAK	FEDERAL AVIATION ADMINISTRATION
	HERB EGBERT	US ARMY TEST & EVALUATION COMMND
	JACK GLECIER	LEARJET, INC.
	JIM GRANDFIELD	CESSNA AIRCRAFT COMPANY
	BRADLEY GREEN	ALLIEDSIGNAL GENERAL AVIATION
	G.N. GROMOV	AUSRIRE
	KEITH HANNEMAN	ALLIEDSIGNAL GENERAL AVIATION AVIONICS
	TOM HERRON	HUGHES-AVICOM INTERNATIONAL
	RICHARD HESS	HONEYWELL/ATS
	GLENN HINOTE	MCDONNELL DOUGLAS AEROSPACE
	WALTON HUNTER	ALLIED SIGNAL AVIONICS SYSTEMS
	RICHARD JANIEC	INSTRUMENTS FOR INDUSTRY
	V.P. JIKHAREV	AUSRIRE
	LEE JOHNSON	ROCKWELL COLLINS, INC.
	JEFF JONES	FEDERAL AVIATION ADMINISTRATION
	KEAKINI KAULIA	AIR LINE PILOTS ASSOCIATION
	MICHAEL KROEGER	HONEYWELL—BCAS
	FRANCOIS LAMARCHE	CANADIAN MARCONI, AVIONICS DIVISION
	MICHAEL LAPSHINE	INSTITUTE OF AIRCRAFT EQUIPMENT
	BILL LARSEN	FEDERAL AVIATION ADMINISTRATION
	DOULAS LEE	TRANSPORT CANADA
	MARTIN LOCKNER	NARCO AVIONICS INC.
	JAMES LYALL	EMBRY RIDDLE AERONAUTICAL UINVERSITY
	MANUEL MACEDO	FEDERAL AVIATION ADMINISTRATION
	MARTIN METSON	IPECO EUROPE
	KEVIN MOONEY	GTE AIRFONE INC.
	HAROLD MOSES	RTCA, INC.
	HEINZ MUELLER	FEDERAL AVIATION ADMINISTRATION
	ALFRED NORWOOD	CONSULTANT
	HARRY OGASIAN	HAMILTON STANDARD
	FRANCIS ROCK	FEDERAL AVIATION ADMINISTRATION
	JOHN RUSSELL	CANADIAN MARCONI COMPANY
	SCOTT SWIFT	DB SYSTEMS, INC.
	BRIAN TUCKER	ARINC
	WAYNE TUSTIN	
	ANTONY VAUDREY	CIVIL AIR ATTACHE—BRITISH EMBASSY
	WALT VIATOR	GABLES ENGINEERING, INC.
	JEROME VONDERHEIDE	ROCKWELL COLLINS, INC.
	DAVID WALEN	FAA

STEVE WALKER	HONEYWELL COMMERCIAL FLIGHT
WILBURN WILSON	LITTON AERO PRODUCTS DIVISION
JOHN WONG	LITTON AERO PRODUCTS DIVISION
ROBERT ZELLS	WILLIAMS INTERNATIONAL
STEVE UHRICH	BOEING COMMERCIAL AIRPLANE GROUP

EUROCAE
17, rue Hamelin
75783 PARIS CEDEX 16

RTCA
1140 Connecticut Ave., N.W. Suite 1020
WASHINGTON DC 20036

EUROCAE ED-14D / RTCA DO-160D

"A Joint EUROCAE RTCA achievement"

ENVIRONMENTAL CONDITIONS AND TEST
PROCEDURES FOR AIRBORNE EQUIPMENT

Appendix C

Change Coordinators

SC-135 Change Coordinators and Assignments

Sections	Section Title/Assignment	Change Coordinator Address, Phone/Fax
1.0	Purpose and Applicability	Jim Lyall Embry-Riddle Aeronautical University 3200 North Willow Creek Road Prescott, AZ 86301 (P) 520-708-3833 (F) 520-708-6945 (E) lyallj@pr.erau.edu
2.0	Definitions of Terms	Jim Lyall
3.0	Conditions of Test	Jim Lyall
4.0	Temperature and Altitude	Steve G. Walker Honeywell, Inc. Commercial Flight Systems Group 8840 Evergreen Blvd., M/S 51-1305 Minneapolis, MN 55433-6040 (P) 612-957-4510 (F) 612-957-4195 swalker@cfsmo.honeywell.com
5.0	Temperature Variation	Steve G. Walker
6.0	Humidity	Herb Egbert US Army Test & Eval Command Attention: AMSTE-TM-T Aberdeen Proving Ground Maryland 21005-5055 (P) 410-278-1476 (F) 410-278-1475 (E) hegbert@tec1.apg.army.mil
7.0	Shock	Glenn Hinote McDonnell Douglas Aerospace 2401 E. Wardlow Road Long Beach, CA 90807-5309 (P) 562-593-2115 (F) 562-982-7787
8.0	Vibration	Glenn Hinote
9.0	Explosion Proofness	Walton Hunter Allied Signal 2100 NW 62nd Street Ft. Lauderdale, FL 33310 (P)305-928-2720 (F)305-928-3000
10.0	Waterproofness	Walton Hunter
11.0	Fluids Susceptibility	Walton Hunter
12.0	Sand and Dust	Herb Egbert

13.0	Fungus Resistance	Chuck Beuning Cessna Aircraft Company P.O. Box 7704 Wichita, KS 67277-7704 (P) 316-941-7179 (F) 316-941-8394 cbeuning@cessna.textron.com
14.0	Salt Spray	Herb Egbert
15.0	Magnetic Effect	Mike Kroeger Honeywell, Inc. Commercial Flight Systems Group 5353 West Bell Road, M/S AV I19B1 Glendale, AZ 85038 (P) 602-436-4554 (F) 602-436-7020 (E) mike kroeger@cas.honeywell.com
16.0	Power Input	John Covell Rockwell Avionics & Communications Collins 400 Collins Road, NE, M/S 106-124 Cedar Rapids, IA 52498 (P) 319-295-5905 (F) 319-295-3661
17.0	Voltage Spike Conducted	John Covell
18.0	Audio Frequency Conducted Susceptibility	Steve Uhrich Boeing Commercial Airplane Group P.O. Box 3707, M/S 9W-FX Seattle, WA 98124-2207 (P) 206-234-1516 (F) 206-237-5118 (E) steve.uhrich@boeing.com
19.0	Induced Signal Susceptibility	Steve Uhrich
20.0	RF Susceptibility (Radiated and Conducted)	Steve Uhrich
21.0	Emission of Radio Frequency Energy	John Covell
22.0	Lightning Induced Transient Susceptibility	Richard Hess Honeywell, Inc. Air Transport Division P.O. Box 21111, M/S L29D1 Phoenix, AZ 85036 (P) 602-436-1285 (F) 602-436-6479
23.0	Lightning Direct Effects	Richard Hess
24.0	Icing	Mike Kroeger

25.0	Electro-Static Discharge	Rick Gaynor Dayton T. Brown, Inc. Church Street Bohemia, N.Y. 11716 (P) 516-589-6300 (F) 516-589-3648 (E) test@dtbrown.com
Appendix		Mike Kroeger
SC-135	Chairman	Chuck DeBlieck Rockwell Avionics and Communications 400 Collins Road, NE, M/S 106-183 Cedar Rapids, IA 52498 (P) 319-295-2306 (F) 319-295-5429 (E) crdeblie@cacd.rockwell.com
SC-135	Secretary	Rick Gaynor
RTCA	Program Director	Harold Moses 1140 Connecticut Ave., NW, Suite 1020 Washington, DC 20036 (P) 202-833-9339 (F) 202-833-9434 E-Mail/Internet: hmoses@rtca.org