RAKSHA MANTRALAYA
MINISTRY OF DEFENCE

JOINT SERVICES SPECIFICATION

ON

ENVIRONMENTAL TEST METHODS
FOR
ELECTRONIC AND ELECTRICAL EQUIPMENT

~~JSS 55555 : 2000~~
Revision No.2

MANAKIKARAN NIDESHALAYA
RAKSHA UTPADAN TATHA POORTI VIBHAG
RAKSHA MANTRALAYA, 'H' BLOCK, DHQ PO
NEW DELHI - 110 011

DIRECTORATE OF STANDARDISATION
DEPARTMENT OF PRODUCTION & SUPPLIES
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MEMBERS ASSOCIATED WITH THE PREPARATION OF THIS DOCUMENT

This revised Joint Services Specification has been approved by Maj Gen AR Nambiar, Chairman, Electronic Standardisation Sub Committee in the meeting held on 24 Aug 2000 / by circulation.

2. The following members have been associated in approving the draft.

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RECORD OF AMENDMENTS

Amendment		Amendment pertains to: Sl.No./Para No. / Column No.	Authority	Amended by	Signature & Date
No.	Date			Name & Appointment (IN BLOCK LETTERS)	

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SECTION 5 : GUIDANCE

PREFACE

In our efforts to achieve self reliance in vital areas of defence preparedness , the equipment developed and produced has to meet the most stringent quality standards and should fully meet the operational requirements laid down by the users . This calls for the relevant equipment specification, which is a governing document for production and supply of the equipment for the users and shall always invoke the tests and conditions laid down in this specification, to provide a common basis for comparison for performance of various electronic and electrical equipment under Service environments.

Keeping in view the stringent quality and operational requirements of the users, the Joint Services Specification No. 55555 on "Environmental Test Methods for Electronic and Electrical Equipment" (JSS 55555) was prepared in 1979 which was later revised in 1988. Considerable experience has been gained over the years since 1988 and this has necessitated revision of the existing JSS 55555 .

This document JSS 55555 on "Environmental Test Methods for Electronic and Electrical Equipment" has been reprinted with the various amendments incorporated . In this revised JSS 55555, major changes like introduction of modified L-2 Table and recasting of five Tables pertaining to Naval and Naval Air Services, have been incorporated. In addition Test No. 8 on " Corrosion (Alkaline)", Test No. 30 on " Temperature, Humidity, Vibration and Altitude" and Test No. 31 on " Vibro Acoustic, Temperature" have been added in this revised document.

(AS Jolly)
CMDE
Director
Directorate of Standardisation

0. FOREWORD

0.1 This specification has been prepared by the Electronics Standardisation SubCommittee on the authority of the Standardisation Committee, Ministry of Defence.

0.2 This specification is a revision of JSS 55555:1988 and supersedes the same.

0.3 This specification has been approved by the Ministry of Defence and is mandatory for the purposes of preparation of environmental test schedules for any Electronic and Electrical Equipments (except those used in explosives and guided weapons systems)

0.4 Enquiries regarding this specification, in relation to any contractual conditions, should be addressed to the Quality Assurance Authority named in the tender or contract. Other enquiries/suggestions regarding corrections, additions, or amendments should be addressed to :

The Director,
Directorate of Standardisation,
Ministry of Defence,
`H'Block, DHQ PO,
New Delhi - 110 011

0.5 Copies of this specification can be obtained on payment from :

The Director,
Directorate of Standardisation,
Ministry of Defence,
'H' Block, DHQ PO,
New Delhi - 110 011

SECTION 1

GENERAL INFORMATION

1. SCOPE

1.1 This specification describes standard procedures and conditions for Environmental tests for Service Electronic and Electrical Equipment (except those associated with explosives and guided missiles).

1.2 This specification includes environmental conditions obtainable in the laboratory, such that if an item is exposed to these conditions and continues to operate in a satisfactory manner, a high degree of confidence will have been established that the item could survive the field environment during its expected operational and storage life. The tests described herein are not to be interpreted as an exact and conclusive representation of actual operational and storage conditions. It is also the purpose of this document to standardize environmental tests in order to obtain, as much as possible, reproducible test results.

1.3 The tests specified herein are intended to serve the need for predetermining the potential causes of failure of equipment under operational and storage environments. In some of the tests, the test conditions are varied in order to enable the designers to select the conditions which will be adequate to meet the users (qualitative) requirements, commensurate with the design efforts.

1.4 The acceptable performance limits of the equipment when subjected to environmental tests are not included in this specification. The relevant equipment specification shall define the acceptable performance limits during and after the specified environmental tests.

1.5 The relevant equipment specification, which is the governing document for production and supply of the equipment for the users, shall always invoke the tests and conditions laid down in this specification, to provide a common basis for comparison for performance of various Electronic and Electrical Equipment under Service environments.

1.6 This specification, in itself, does not constitute an instruction to apply the tests. Such instructions; together with the incidence and grouping of Equipment for tests for the purposes of design approval and the acceptance (inspection) shall be specified in the relevant equipment specification. While conducting any test described in Section 4 of this specification, standard procedures and conditions of tests shall be followed (see clause 1.9).

1.7 In section 4 and elsewhere terms "specified", "as specified", "unless otherwise specified", "as required", "if required", and "when required" have been used. In such cases the details shall be as given in the relevant equipment specification.

1.8 The tests included in this specification do not cover all operational and storage environments and additional tests, where necessary, may need to be specified in the relevant equipment specification.

1.9 The relevant equipment specification shall specify the deviations in test procedure which may be necessary when applying the tests and also any special procedures which may be required.

2. RELATED SPECIFICATIONS

2.1 Joint Services Specifications

JSS 50101 : 1996 Revision No.1	-	Environmental test methods for Service electronic components.

2.2 Other Specifications

IS 10005 : 1994	-	SI units and recommendations for the use of their multiples and of certain other units. (second revision)
IS 554 : 1985	-	Dimensions for pipe threads where pressure tight joints are required on the threads (third revision) Reaffirmed 1996
IS 460 (Part 1) : 1985	-	Test sieves : Part (1) Wire cloth test sieves (third revision) Reaffirmed 1980
BS 2475 : 1964 (1988)	-	Specification for Octave and MC-third Octave band-pass filter

2.3 Source of Supplies

2.3.1 Copies of Joint Services Specification are obtainable on payment from :

The Controller,

Controllerate of Quality Assurance (Electronics),
JC Nagar PO,
Bangalore – 560 006.

2.3.2 Copies of the Indian Standards and British Standards are obtainable on payment from:

Bureau of Indian Standards
Manak Bhavan,
9, Bahadur Shah ZafarMarg,
New Delhi – 110 002

or

their regional/branch offices.

3. DEFINITIONS

3.1 Ambient Temperature

3.1.1 **For Non-Heat Dissipating Equipment** - The temperature of the medium surrounding the equipment.

3.1.2 **For Heat Dissipating Equipment** - Where the conditions are those of ideal cooling by convection, the temperature of the medium at such a distance from the equipment that the effect of dissipation is negligible.

Note : 1 In practice it is taken as the average of temperatures measured at a number of points in a horizontal plane through a point 0 mm to 50 mm below the equipment at half the distance between the equipment and the wall of the test chamber or at 1 m distance, whichever is less.

2 If forced circulation is used in the testing of heat dissipating equipment, the concept of ambient temperature is no longer valid.

Under these conditions, the testing should be based on the specification of the surface temperature or on the requirements of the relevant equipment specification.

3.2 **Conditioning -** The exposure of an equipment to an environmental condition in order to determine the effect of such a condition on it.

3.3 **Final Measurement -** The final measurement made at the conclusion of a test to make comparison with the initial measurement will show the effect of the on the equipment

Note : Final measurement made at the end of one test may be taken as the initial measurement for the subsequent tests.

3.4 **Heat Dissipating Equipment -** For the purpose of environmental testing, an equipment is considered as heat dissipating when the hottest point on its surface, measured in free air conditions, is more than 5 degC above the ambient temperature of the surrounding atmosphere after temperature stability has been reached.

Note : Measurement required to prove that an equipment can be regarded as non-heat dissipating, can be made in normal laboratory conditions, if care has been taken that no outside influence (for example, draughts or sunlight) affects the measurements. In the case of large or complicated Equipment, it may be necessary to make measurements at several points.

3.5 **Initial Measurements** - The measurements made prior to a test to determine the characteristics of the equipment.

3.6 **Performance checks** - Tests specified in the relevant equipment specification, generally in the form of electrical test, in order to check the performance of an equipment during the conditioning or immediately after it.

3.7 **Preconditioning** - The treatment of an equipment with the object of removing or partly counteracting the effects of its previous history. Where called for, it is the first process in the test procedure.

3.8 **Recovery** - The treatment of an equipment, after conditioning, in order that the properties of the equipment may be stabilized before final measurement.

3.9 **Relevant Equipment Specification** - A document specially drawn up or provided which lays down the characteristics and performance capabilities of an equipment under specified conditions of operation and storage as required by the Services.

3.10 **Temperature Stability** - Temperature stability has been reached when the temperature of all the parts of the equipment are within 3 degC, or as otherwise specified, of their final temperature.

3.10.1 For non-heat dissipating equipment, the final temperature will be the mean (in time) temperature of the chamber in which the equipment is placed.

3.10.2 For heat dissipating equipment it is necessary to make repeated measurements to ascertain the interval of time required for the temperature to change 3 degC or as otherwise specified. Temperature stability has been reached when the ratio between consecutive intervals exceeds 1.7.

Note : 1 Where the thermal time constant of the equipment is short compared with the duration of the exposure to a given temperature, no measurement is needed.

2 Where the thermal time constant of the equipment is of the same order as the duration of the exposure, checks should be made to ascertain :-

a) That non-heat dissipating Equipment are within the required limit from the mean (in time) temperature of the atmosphere in which the equipment is placed.

b) That for heat dissipating Equipment the ratio between two consecutive time intervals exceeds 1.7 when repeated measurements are made to ascertain the interval of time required for the temperature to change by 3 degC or as specified.

3 In practice, it may not be possible to make direct measurements of the internal temperature of the equipment. A check may then be made by measuring some other parameter which is temperature dependent and for which the law of temperature dependence is known.

3.11 **Test** - A complete series of operations covered under a test heading.

3.12 **Test Chamber** - An enclosure in which the equipment can be exposed to the specified environmental test conditions.

3.13 **Test Procedure** - A complete series of operations covered by any one heading and shall normally consist of the following ;

a) Preconditioning (where required).

b) Initial measurements (where required).

c) Conditioning, including performance check (when specified).

d) Recovery.

e) Final measurements.

3.14 **Visual Examination** - Visual examination is generally made before and after the conditioning in each test and form a part of Initial and Final Measurements. During the visual examination of the equipment, defects in construction, the presence of foreign bodies, moisture, dust, etc., corrosion of metal parts and any form of deterioration of materials and finishes, distortion or mechanical imperfections shall be noted.

3.15 **Working Space** - That part of the test chamber in which the specified environmental test conditions can be maintained within the specified tolerances.

4. STANDARD ATMOSPHERIC CONDITIONS

4.1 **Standard Reference Conditions** - If the parameters to be measured depend on temperature and/or air pressure and if the law of dependence is known, the values are measured at conditions specified under clause 4.3 and, if necessary, corrected by calculation to the following reference values ;

Temperature	$20^{\circ}C$
Air pressure	101.3 kPa

Note : No requirement for relative humidity is given because its correction by calculation is generally not possible.

4.2 **Standard Reference Conditions** - If the parameters to be measured depend on temperature and/or air pressure and if the law of dependence is not known, the measurements shall be made under the following reference conditions ;

Temperature	:	$20^{o}C \pm 2$ degC
Relative humidity	:	65 to 75 percent
Air pressure	:	85 to 106 kPa

Note : In the case of large Equipment or test chambers where temperature and relative humidity and/or air pressure limits specified above are difficult to maintain, where tolerance may be permissible. In such cases, the actual values used shall be given in the specification.

4.3 **Standard Testing Conditions** - Measurements and mechanical check may be carried out at any combination of temperature, relative humidity and air pressure, within the following limits :

Temperature	:	15o to 35oC
Relative humidity	:	45 to 75 percent
Air pressure	:	85 to 106 kPa

Note : 1 The temperature range may be extended beyond these limits, upto 10 to 40^{o}C for large Equipment.

2 The limits of variation of temperature and relative humidity during a series of measurements carried out as part of one test on any equipment shall, if necessary, be specified in the relevant equipment specification.

4.3.1 Where it is impracticable to carry out measurements within the limits of the standard atmospheric conditions for testing, a note to this effect, stating the actual conditions of tests shall be added to the test report.

4.4 **Standard Recovery Conditions** - The standard conditions for recovery shall be actual laboratory conditions subject to the overriding requirements of clause 4.3. above.

SECTION 2

GENERAL PRECAUTIONS IN TESTING

1. GENERAL

1.1 This section covers certain general precautions which the test engineers and test personnel are required to observe.

2. MODIFICATION TO TESTS

2.1 In certain cases, there may be very good reasons for departing from the standard test methods, given in Section 4. It is therefore, essential to refer, before carrying out a test, to the relevant equipment specification to ascertain, if any modifications, have been made in the test conditions.

3. EQUIPMENT UNDER TESTS

3.1 **Carriers, Covers etc.** - Complete equipment should be tested with the appropriate carriers, covers, shock and vibration mounts etc, which would be fitted to the equipment under normal services conditions, unless otherwise specified by the relevant equipment specification.

3.2 **Equipment with Air Conditioning** - Where plant for air conditioning or refrigeration forms an integral part of an equipment, such plant is to be operated normally throughout the tests, described in this specification unless the tests represent storage conditions.

3.3 **Equipment of Large Size** - When the physical size of an equipment would prohibit its being tested as a complete unit, it may be broken down into sections of the largest possible size which can be accommodated satisfactorily (see clause 5.1) in the test chamber available. While doing so, attention should be paid to the thermal geometry considerations of the equipment, if any, and if so specified in the relevant equipment specification.

4. CONDITIONS AT START AND END OF THE TEST

4.1 The equipment shall be introduced into or removed from the test chamber at the laboratory atmospheric conditions unless otherwise specified by the relevant equipment specification. While conducting the temperature low air pressure test, the temperature of the chamber shall be stabilized at the specified temperature before reducing/increasing the air pressure.

5. TEST CHAMBERS

5.1 **Volume of Test Chamber** - The volume of the test chamber shall be such that the bulk of the equipment under test shall not interfere with the control and maintenance of test conditions in the working space of the chamber and any heat dissipated from the equipment under test shall not appreciably influence the conditions in the chamber. For this purpose, the volume of the test chamber should preferably be not less than eight times the volume of the equipment under test.

5.2 **Control of Temperature and Relative Humidity** - Wet and dry bulb thermometers of mercury in glass type or thermocouples or equivalent sensors shall be used to control or determine the specified chamber temperature and relative humidity. These sensors shall be centrally located within the test chamber, where possible, or in the return air-stream and shall be baffled or otherwise protected against direct impingement of supply air and against radiation effects.

5.3 **Rate of Change of Temperature** - Unless otherwise specified, the rate of change of temperature within the test chamber shall not exceed 1 degC per minute, averaged over a period of not more than 5 minutes.

5.4 **Uniformity of Conditions in Test Chamber** - Necessary measures shall be taken to ensure that conditions throughout the chamber are homogeneous and are as near as possible to those prevailing in the immediate vicinity of the temperature and relative humidity sensors. The high/low temperature conditions inside the chamber should, therefore, be achieved only by circulating hot/cold air. The air in the chamber shall be continuously agitated but not so vigorously as to cause undue cooling of the equipment under test.

5.5 **Heat Source for Test Chamber** - The heat source for the test chamber shall be so located that the radiant heat does not fall directly on the equipment under test except where radiant heat is one of the test conditions.

SECTION 3

CLASSIFICATION OF EQUIPMENT AND RECOMMENDED SEQUENCE OF TESTS

1. GENERAL

1.1 Ideally, equipment should be suitable for use in all conditions but this is seldom possible in practice because of high cost of design and production and in some cases, because of increased size. Most of the Equipment have a restricted sphere of use which, by limiting the severity of conditions of use, may allow simplification of the design, with resultant reduction in cost.

1.2 Restriction of the conditions of use permits reduction in the number of tests required to indicate the behaviour of the equipment. Accordingly, a relatively small number of sets of conditions of use have been selected and classified as described in Clause 2 below.

2. CLASSIFICATION

2.1 All electronic and electrical Equipment are broadly classified as follows :

a) Air Service	Class A
b) Land Service	Class L
c) Naval Service	Class N
d) Naval Air Service	Class NA

2.2 **Air Service**

2.2.1 For the airborne equipment, the further classification similar to that which has been done for Land Service, Naval Service and Naval Air Service is not feasible.

2.2.2 The main reason for this is that the accepted method of classification for airborne equipment differs for various tests. For instance, the classification applicable for the high temperature, low temperature and altitude tests is not applicable to the acceleration (steady state) test and vibration test. What is applicable for vibration test is not applicable for acceleration (steady state) test and vice versa.

2.2.3 To overcome this difficulty, the classification, wherever found necessary has been done individually for each test or a group of tests. For instance, the classification applicable for high temperature test, low temperature test and altitude test is given in subsection 5.20. The classification applicable for the acceleration (steady state) and vibration test are shown respectively in the text of these two tests (Section 4).

2.2.4 Although this specification is primarily intended for use by the defence services, the civil class of aircraft and grades of equipment have also been given in subsection 5.20. for the following reasons :

a) Defence services may make use of aircrafts or originally designed for use in civil aviation.

b) This specification may also be used by other professional users like Civil Aviation, if they so desire.

2.2.5 Considering the above, for the purpose of listing out the applicable tests and the test sequences for airborne equipment only one table (see Table 3-1) has been included.

2.3 Equipment other than those in Air Service, have been further sub-classified as follows :

2.3.1 **Land Services**

a)	L1 : Ground equipment	:	To be used in permanent protected (unpacked) buildings. May be required to function at high ground altitudes.
b)	L2A : Ground equipment partially protected	:	To be used in light buildings, structures and vehicles where it is protected from direct rain, sun, etc. MIL grade all weather conditions.
c)	L2B : Ground equipment partially protected	:	Commercial Grade
d)	L2C : Ground equipment partially protected	:	Extreme cold climate
e)	L2D : Ground equipment partially protected	:	High Ground altitude
f)	L2E : Ground equipment partially protected	:	Desert condition
g)	L2F : Ground equipment partially protected	:	High humid conditions
h)	L2G : Ground equipment	:	Stationery use

	partially protected		
j)	L2H : Ground equipment partially protected	:	Installed in wheeled vehicles
k)	L2J : Ground equipment partially protected	:	Installed in tracked vehicles
l)	L3 : Ground equipment exposed and immersible (unpacked)	:	To be used in the field or in a vehicle where it is fully exposed to the weather during storage and use and liable to immersion in water. May be required to function at high ground altitudes.

2.3.2 **Naval Services**

a)	N1 : Shipborne equipment protected (unpacked)	:	To be used in positions well shielded from the weather.
b)	N2 : Shipborne equipment exposed (unpacked)		To be used in positions completely exposed to the weather.
c)	N3 : Shipborne equipment submersible (unpacked)		Submarine equipment liable to submersion

2.3.3 **Naval Air Service**

a)	NA1 : Fleet air arm flight deck test equipment (unpacked)	To be used in exposed positions ashore and afloat, but normally stowed in a protected position.
b)	NA2 : Fleet air arm workshop and hanger test equipment (unpacked)	To be used in position shielded from the weather ashore and afloat. Not required to operate under conditions of flooding

2.4 Although the above classification refers to airborne, land service, naval service and naval aircraft service it should be appreciated that, for instance, tests to be applied to the shipborne equipment may be used for other Equipment also. Quite often, equipment may have a dual use in such cases, tests for more than one class may be required.

3. TESTS REQUIRED FOR EACH CLASS AND RECOMMENDED SEQUENCE OF TESTS

3.1 The tables 3-1 to 3-9, with Table 3-3 further divided into nine categories separately, detail the tests applicable for each class of equipment and the recommended sequence in which these tests should be applied. Some of the tests in these tables may be applicable only if the equipment is likely to encounter the corresponding conditions of operation and/or storage. Therefore, the relevant equipment specification should choose only those tests out of each table which are considered essential with clearly specifying the severity limits for the equipment under test. If required, the recommended sequence may be changed for a particular equipment depending upon the conditions of use and/or storage.

TABLE 3-1 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR AIRBORNE EQUIPMENT (CLASS A)
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1	Vibration	28
2.	Acceleration	1
3.	Low temperature	20
4.	Altitude (Procedure 1 and 2)	3
5.	High temperature	17
6.	Solar radiation	25
7.	Altitude (Procedure 3 and 4)	3
8.	Sealing	23
9.	Fine mist (see Note 1)	16
10.	Driving rain	12
11.	Icing (see Note 1)	18
12.	Dust	14
13.	Tropical exposure (see Note 2)	27
14.	Mould growth (see Note 2 and 3)	21
15.	Corrosion (salt) (see Note 1, 2, 3 and 4)	
16.	Corrosion (acid) (see Note 1, 2 and 3)	7
17.	Corrosion (alkaline) (see Note 1,2 and 3)	8
18.	Contamination (see Note 2 and 3)	6
19.	Drop	13
20.	Toppling	26
21.	Bump (see Note 1)	5
22.	Shock (see Note 1)	24
23.	Acoustic noise (see Note 1)	2
24.	Explosion (see Note 1)	15

Notes : 1 Depending upon the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.

2 Separate equipment can be used for this test.

3 For sealed equipment, a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.

4 This Test may be omitted in accordance with the relevant equipment specifications.

TABLE 3-2 APPLICABLE TESTS AND RECOMMENDED SEQUENCE GROUND EQUIPMENT PROTECTED (CLASS L1)
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration	28
2.	High temperature	17
3.	Damp heat	10
4.	Low temperature	20
5.	Sealing	23
6.	Tropical exposure (see Note 1)	27
7.	Mould growth (see Note 1 and 2)	21
8.	Toppling (see Note 3)	26
9.	Bump	5

Notes : 1 Separate equipment can be used for this test.

2 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.

3 This test may be omitted by the relevant equipment specification.

TABLE 3-3-1 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (MIL GRADE-ALL WEATHER) CLASS L2A
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 Sl.3) (see Note 8)	28
2.	High temperature (Procedure 6, Test Condition `K')	17
3.	Damp heat	10
4.	Low temperature (Test Condition `K')	20
5.	Altitude (Test condition A 1 L2)(Procedure 5)	3
6.	Rapid temperature cycling (see Note 1)	22
7.	Sealing (see Note 2)	23
8.	Dust	14
9.	Tropical exposure (14 cycles)	27
10.	Mould growth (see Note 3 & 4)	21
11.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
12.	Contamination (see Note 1 & 5)	6
13.	Drop (see Note 6)	13
14.	Toppling (see Note 7)	26
15.	Bump	5
16.	Bounce/Roadability (see Note 8)	4/29

Note :

1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.

2 This test is meant only for hermetically sealed equipment.

3 Separate equipment can be used for this test.

4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.

5 This test may be omitted in accordance with the relevant equipment specification.

6 This test may be omitted if the equipment is not likely to be dropped.

7 This test is applicable only for portable equipment and spares which are not fitted permanently.

8 Bounce test may be carried out instead of Vibration Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-2 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (COMMERCIAL GRADE-RUGGEDISED) CLASS L2B
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 Sl.3) (see Note 8)	28
2.	High temperature (Procedure 6, Test Condition `K')	17
3.	Damp heat	10
4	Low temperature (Test Condition `H')	20
5.	Rapid temperature cycling (see Note 1)	22
6.	Sealing (see Note 2)	23
7.	Tropical exposure (14 cycles)	27
8.	Mould growth (see Note 3 & 4)	21
9.	Corrosion (salt) (Procedure 2)(see Note 3,4&5)	9
10.	Contamination (see Note 1 & 5)	6
11.	Drop (see Note 6)	13
12.	Toppling (see Note 7)	26
13.	Bump	5
14.	Bounce/Roadability (see Note 8)	4/29

Note :

1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.

2 This test is meant only for hermetically sealed equipment.

3 Separate equipment can be used for this test.

4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.

5 This test may be omitted in accordance with the relevant equipment specification.

6 This test may be omitted if the equipment is not likely to be dropped.

7 This test is applicable only for portable equipment and spares which are not fitted permanently.

8 Bounce test may be carried out instead of Vibraion Test on items which are not rigidly mounted and Roadabilty test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-3 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (EXTREME COLD CLIMATE) CLASS L2C
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 Sl.3) (see Note 8)	28
2.	High temperature (Procedure 5, Test Condition `G')	17
3.	Damp heat	10
4.	Low temperature (Test Condition `K')	20
5.	Rapid temperature cycling (see Note 1)	22
6.	Sealing (see Note 2)	23
7.	Dust	14
8.	Tropical exposure (14 cycles)	27
9.	Mould growth (see Note 3 & 4)	21
10.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
11.	Contamination (see Note 1 & 5)	6
12.	Drop (see Note 6)	13
13.	Toppling (see Note 7)	26
14.	Bump	5
15.	Bounce/Roadability (see Note 8)	4/29

Notes :
1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specification.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibraion Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-4 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (HIGH GROUND ALTITUDE) CLASS L2D
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 Sl.3) (see Note 8)	28
2.	High temperature (Procedure 5, Test Condition `G')	17
3.	Damp heat	10
4.	Low temperature (Test Condition `K')	20
5.	Altitude (Test condition `A'1, L2 procedure 5)	3
6.	Rapid temperature cycling (see Note 1)	22
7.	Sealing (see Note 2)	23
8.	Dust	14
9.	Tropical exposure (14 cycles)	27
10.	Mould growth (see Note 3 & 4)	21
11.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
12.	Contamination (see Note 1 & 5)	6
13.	Drop (see Note 6)	13
14.	Toppling (see Note 7)	26
15.	Bump	5
16.	Bounce/Roadability (see Note 8)	4/29

Note :
1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specification.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibraion Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-5 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (DESERT CONDITION) CLASS L2E
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1	Vibration (Refer Table 4.28.2 Sl.3) (see Note 8)	28
2.	High temperature (Procedure 6, Test Condition `M')	17
3.	Damp heat	10
4.	Low temperature (Test Condition `H')	20
5.	Rapid temperature cycling (see Note 1)	22
6.	Sealing (see Note 2)	23
7.	Dust	14
8.	Tropical exposure (14 Cycles)	27
9.	Mould growth (see Note 3 & 4)	21
10.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
11.	Contamination (see Note 1 & 5)	6
12.	Drop (see Note 6)	13
13.	Toppling (see Note 7)	26
14.	Bump	5
15.	Bounce/Roadability (see Note 8)	4/29

Note :
1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specification.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibraion Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-6 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (HIGH HUMID CONDITIONS) CLASS L2F
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 Sl.3) (see Note 8)	28
2.	High temperature (Procedure 6, Test Condition `K')	17
3.	Damp heat	10
4.	Low temperature (Test Condition `H')	20
5.	Rapid temperature cycling (see Note 1)	22
6.	Sealing (see Note 2)	23
7.	Dust	14
8.	Tropical exposure (14 Cycles)	27
9.	Mould growth (see Note 3 & 4)	21
10.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
11	Contamination (see Note 1 & 5)	6
2.	Drop (see Note 6)	13
13.	Toppling (see Note 7)	26
14.	Bump	5
15.	Bounce/Roadability (see Note 8)	4/29

Notes :
1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specification.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibraion Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-7 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (STATIONERY USE) CLASS L2G
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 Sl.3)(see Note 8)	28
2.	High temperature (Procedure 6, Test Condition `K')	17
3.	Damp heat	10
4.	Low temperature (Test Condition `H')	20
5.	Rapid temperature cycling (see Note 1)	22
6.	Sealing (see Note 2)	23
7.	Dust	14
8.	Tropical exposure (14 Cycles)	27
9.	Mould growth (see Note 3 & 4)	21
10.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
11	Contamination (see Note 1 & 5)	6
12.	Drop (see Note 6)	13
13.	Toppling (see Note 7)	26
14.	Bump	5
15.	Bounce/Roadability (see Note 8)	4/29

Notes :
1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specification.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibraion Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-8 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (INSTALLED IN WHEELED VEHICLES) CLASS L2H
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 Sl.1 & 4) & 4.28.3) (see Note 8)	28
2.	High temperature (Procedure 6, Test Condition `M')	17
3.	Damp heat	10
4	Low temperature (Test Condition `J')	20
5.	Altitude	3
6	Rapid temperature cycling (see Note 1)	22
7	Sealing (see Note 2)	23
8	Dust	14
9	Tropical exposure (14 Cycles)	27
10.	Mould growth (see Note 3 & 4)	21
11.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
12	Contamination (see Note 1 & 5)	6
13	Drop (see Note 6)	13
14	Toppling (see Note 7)	26
15	Bump	5
16.	Bounce/Roadability (see Note 8)	4/29

Note :
1 Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specification.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibraion Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-3-9 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT PARTIALLY PROTECTED (INSTALLED IN TRACKED VEHICLES) CLASS L2J
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (Refer Table 4.28.2 and Sl.1.4.28.3) (see Note 8)	28
2.	High temperature (Procedure 6, Test Condition `M')	17
3.	Damp heat	10
4.	Low temperature (Test Condition `J')	20
5.	Altitud	3
6.	Rapid temperature cycling (see Note 1)	22
7.	Sealing (see Note 2)	23
8	Dust	4
9	Tropical exposure (28 Cycles)	27
10.	Mould growth (see Note 3 & 4)	21
11.	Corrosion (salt) (Procedure 2) (see Note 3,4 & 5)	9
12	Contamination (see Note 1 & 5)	6
13.	Drop (see Note 6)	13
14.	Toppling (see Note 7)	26
15.	Bump	5
16.	Bounce/Roadability (see Note 8)	4/29

Note :
1. Depending on the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2. This test is meant only for hermetically sealed equipment.
3. Separate equipment can be used for this test.
4. For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5. This test may be omitted in accordance with the relevant equipment specification.
6. This test may be omitted if the equipment is not likely to be dropped.
7. This test is applicable only for portable equipment and spares which are not fitted permanently.
8. Bounce test may be carried out instead of Vibration Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the Vibration Testing may not be feasible.

TABLE 3-4 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR GROUND EQUIPMENT EXPOSED AND IMMERSIBLE (CLASS L3)

(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration	28
2.	High temperature	17
3.	Solar radiation (see Note 1)	25
4.	Damp heat	10
5.	Low temperature	20
6.	Altitude	3
7.	Rapid temperature cycling (see Note 1)	22
8.	Sealing	23
9.	Driving rain (see Note 1)	12
10.	Immersion (see Note 1)	19
11.	Dust	14
12.	Tropical exposure (see Note 2)	27
13.	Mould growth (see Note 2 and 3)	21
14.	Corrosion (salt) (see Note 2, 3 and 4)	9
15.	Corrosion (acid) (see Note 1, 2 and 3)	7
16.	Corrosion (alkaline) (see Note 1,2 and 3)	8
17.	Contamination (see Note 1 and 3)	6
18.	Drop	13
19.	Toppling	26
20.	Bump	5
21.	Shock	24

Note :

1 Depending upon the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.

2 Separate equipment can be used for this test.

3 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.

4 This test may be omitted in accordance with the relevant equipment specifications.

TABLE 3-5 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR SHIPBORNE EQUIPMENT PROTECTED (CLASS N1)

(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (see Note 8 & 9)	28
2.	High temperature (Procedure 6, Test Condition K)	17
3.	Damp heat	10
4.	Low temperature (Test Condition H, -10^{o} C 16 hrs)	20
5.	Drip proof	11
6.	Sealing (for hermitically sealed eqpt only)	23
7.	Immersion (see Note 1)	19
8.	Tropical exposure (see Note 2) (Condition A, 7 Cycles)	27
9.	Mould growth (see Note 3 & 4) (On samples)	21
10.	Corrosion (salt) (see Note 3, 4 & 5) (Procedure 2)	9
11.	Corrosion (acid) (see Note 1, 3 and 4)	7
12.	Corrosion (alkaline) (see Note 1,3 and 4)	8
13.	Contamination (see Note 1 and 4)	6
14.	Toppling (see Note 1 & 7)	26
15.	Bump (See Note 1)	5
16.	Shock or impact (NSS Gr.I or Gr.II, shocks as per face)	24

Note :

1 Depending upon the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specifications.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable eqpt and spares which are not Fitted permanently.
8 Bounce test may be carried out instead of Vibration Test on items which are not rigidly mounted and Roadability Test may be carried out on items which are large in size for which the Vibration testing may not be feasible.

9 a) Frequency & amplitude as per table 4.28.2

b) Test sequence

i) Initial resonance search,
ii) Endurance at resonance or fixed frequencies,
iii) Final resonance search

c) Fixed frequencies & duration recommended.

i) Major warships & submarines 14, 22 & 33 Hz, 40 minutes each
ii) Minor warships 35, 140 & 350 Hz, 40 minutes each

d) Repeat above in all 3 axes.

TABLE 3-6 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR SHIPBORNE EQUIPMENT EXPOSED (CLASS N2)

(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (see Note 8 & 9)	28
2.	High temperature (Procedure 6, Test Condition M)	17
3.	Solar radiation (see Note 1)	25
4	Damp heat	10
5.	Low temperature (Test Condition H, -10^{o} C 16 hrs)	20
6.	Rapid temperature cycling (see Note 1)	22
7	Sealing (for hermetically sealed equipment only)	23
8.	Driving rain (Test Condition C)	12
9	Immersion (see Note 1)	19
10	Tropical exposure (see Note 3) (Test Condition A, 7 Cycles)	27
11.	Mould growth (see Note 3 & 4) (on equipment)	21
12.	Corrosion (salt) (see Note 3, 4 & 5) (Procedure 1)	9
13.	Corrosion (acid) (see Note 1, 3 and 4) (Procedure 2)	7
14.	Corrosion (alkaline)(see Note 1,3 and 4)	8
15	Contamination (see Note 1 and 4)	6
16	Toppling (see Note 1 & 7)	26
17.	Bump (see Note 1)	5
18.	Shock or impact (NSS Gr.I or Gr.II, 3 shocks per face)	24

Note :
1 Depending upon the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specifications.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibration Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the vibration testing may not be feasible.

9 a) Frequency & amplitude as per table 4.28.2

b) Test sequence

i) Initial resonance search,
ii) Endurance at resonance or fixed frequencies,
iii) Final resonance search

c) Fixed frequencies & duration recommended.

i) Major warships & submarines 14, 22 & 33 Hz, 40 minutes each
ii) Minor warships 35, 140 & 350 Hz 40 minutes each

d) Repeat above in all 3 axes.

TABLE 3-7 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR SHIPBORNE EQUIPMENT SUBMERSIBLE (CLASS N3)
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (see Note 8 & 9)	28
2.	High temperature (Procedure 6, Test Condition K)	17
3.	Solar radiation (see Note 1)	25
4.	Damp heat	10
5.	Low temperature (Test Condition H, -10° C, 16 hrs)	20
6.	Rapid temperature cycling (see Note 1)	22
7.	Sealing (for hermetically sealed equipment only)	23
8.	Immersion	19
9.	Tropical exposure (see Note 3) (Test Condition C, 28 Cycles)	27
10.	Mould growth (see Note 3 & 4) (On equipment)	21
11.	Corrosion (salt) (see Note 3, 4 & 5) (Procedure 1)	9
12.	Corrosion (acid) (see Note 1, 3 and 4)	7
13.	Corrosion (alkaline)(see Note 1,3 and 4)	8
14.	Contamination (see Note 1 and 4)	6
15.	Toppling (see Note 1 & 7)	26
16.	Bump	5
17.	Shock or impact (NSS Gr.I or Gr.II, 3 shocks as per face)	24

Note :
1 Depending upon the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specifications.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibration Test on items which are not rigidly mounted and Roadability test may be carried out on items which are arge in size for which the vibration testing may not be feasible.

9 a) Frequency & amplitude as per table 4.28.2

b) Test sequence

   i) Initial resonance
   ii) Endurance at resonance or fixed frequencies,
   iii) Final resonance search

c) Fixed frequencies & duration recommended.

   i) Major warships & submarines 14, 22 & 33 Hz, 40 minutes each
   ii) Minor warships 35, 140 & 350 Hz, 40 minutes each

d) Repeat above in all 3 axes.

TABLE 3-8 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR FLEET AIR ARM FLIGHT DECK TEST EQUIPMENT (CLASS NA1)
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (see Note 8 & 9)	28
2.	High temperature (Procedure 6, Test Condition K, 16 hrs)	17
3.	Solar radiation (see Note 1)	25
4.	Damp heat	10
5.	Low temperature (Test Condition H, -10^{o} C, 16 hrs)	20
6.	Rapid temperature cycling (see Note 1)	22
7.	Sealing (for hermetically sealed equipment only)	23
8.	Driving rain (Test Condition C)	12
9.	Dust (see Note 1)	14
10.	Tropical exposure (see Note 3) (Test Condition A, 7 Cycles)	27
11.	Mould growth (see Note 3 & 4) (On samples)	21
12.	Corrosion (salt) (see Note 3, 4 & 5) (Procedure 2)	9
13.	Corrosion (acid) (see Note 1, 3 and 4) (Procedure 2)	7
14.	Corrosion (alkaline)(see Note 1,3 and 4)	8
15.	Contamination (see Note 1 and 4)	6
16.	Drop (See Note 6) (Test Condition D	13
17.	Toppling (see Note 1 & 7)	26
18.	Bump (see Note 1)	5
19.	Shock or impact (NSS Gr.I or Gr.II, 3 shocks as per face)	24

Note :
1 Depending upon the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specifications.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibration Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the vibration testing may not be feasible.
9 a) Frequency & amplitude as per table 4.28.2

b) Test sequence

i) Initial resonance
ii) Endurance at resonance or fixed frequencies,
iii) Final resonance search

c) Fixed frequencies & duration recommended.

i) Major warships & submarines 14, 22 & 33 Hz, 40 minutes each
ii) Minor warships 35, 140 & 350 Hz, 40 minutes each

d) Repeat above in all 3 axes.

TABLE 3-9 APPLICABLE TESTS AND RECOMMENDED SEQUENCE FOR FLEET AIR ARM WORKSHOP AND HANGER TEST EQUIPMENT (CLASS NA2)
(Clause 3.1)

SEQUENCE	TESTS	TEST NUMBER
1.	Vibration (see Note 8 & 9)	28
2.	High temperature (Procedure 6, Test Condition K)	17
3.	Solar radiation (see Note 1)	25
4.	Damp heat	10
5.	Drip Proof	11
6.	Rapid temperature cycling (see Note 1)	22
7.	Sealing (for hermetically sealed equipment only)	23
8.	Dust	14
9.	Tropical exposure (see Note 3) (Test Condition A, (7 Cycles)	27
10.	Mould growth (see Note 3 & 4)(on samples)	21
11.	Corrosion (salt) (see Note 3, 4 and 5) (Procedure 2)	9
12.	Corrosion (acid) (see Note 1, 3 and 4) (Procedure 2)	7
13.	Corrosion (alkaline)(see Note 1,3 and 4)	8
14.	Contamination (see Note 1 and Note 4)	6
15.	Toppling (see Note 1 & 7)	26
16.	Bump	5
17.	Shock or impact (NSS Gr.I or Gr.II, 3 shocks as per face)	24

Note :
1 Depending upon the operational/storage conditions encountered, this test may be omitted by the relevant equipment specification.
2 This test is meant only for hermetically sealed equipment.
3 Separate equipment can be used for this test.
4 For sealed equipment a dummy unit may be used and this test may be applied only to the components and finishes located outside the seal.
5 This test may be omitted in accordance with the relevant equipment specifications.
6 This test may be omitted if the equipment is not likely to be dropped.
7 This test is applicable only for portable equipment and spares which are not fitted permanently.
8 Bounce test may be carried out instead of Vibration Test on items which are not rigidly mounted and Roadability test may be carried out on items which are large in size for which the vibration testing may not be feasible.
9 a) Frequency & amplitude as per table 4.28.2

b) Test sequence

   i) Initial resonance search
   ii) Endurance at resonance or fixed frequencies,
   iii) Final resonance search

c) Fixed frequencies & duration recommended.

   i) Major warships & submarines 14, 22 & 33 Hz, 40 minutes each
   ii) Minor warships 35, 140 & 350 Hz, 40 minutes each

d) Repeat above in all 3 axes.

SECTION 4 : DESCRIPTION OF TEST METHODS

TEST NUMBER 1
ACCELERATION (STEADY STATE)

1. OBJECT

1.1 To determine the structural integrity and satisfactory performance of electronic and electrical equipment during and after subjection to a steady acceleration other than gravity.

2. TEST EQUIPMENT

2.1 **Characteristics of the Test Machine** - A centrifuge having the characteristics specified in Clause 2.2 to 2.7 shall be used for this test.

2.2 The centrifuge shall be capable of being brought up to a speed of rotation sufficient to develop a steady acceleration, corresponding to any of the values specified in Tables 4.1-1 and 4.1-2 and shall also be capable of maintaining this value for the period specified in 3.3.1.6 and 3.3.2.6.

2.3 The centrifuge shall be such that the acceleration is directed towards the centre of the rotating system. In certain cases, however, the equipment may be sensitive to gyroscopic couples and it may not be possible to perform this test using the centrifuge. In such cases, the relevant equipment specification shall specify a suitable test equipment for performing this test.

2.4 The centrifuge shall have provisions to enable electrical connections to power supplies, operation of the equipment, measurements during the test, etc, if so required.

2.5 **Tangential Acceleration** - While increasing the rotational speed of the centrifuge, from zero to a value necessary to achieve the specified acceleration or when decreasing back to zero, the centrifuge shall be so controlled that the equipment is not subjected to a value of tangential acceleration greater than 10 per cent of the specified steady acceleration.

2.6 **Acceleration Gradient** - The dimensions of the centrifuge relative to the equipment under test, shall be such that no part of the equipment, other than flying leads, shall be subjected to a value of acceleration outside the tolerance specified in clause 2.7.

2.7 **Acceleration Tolerance** - If the linear dimensions of the equipment are less than 100 mm, the acceleration on all parts of the equipment (excluding flying leads) shall be within ±10 percent of the specified steady acceleration. In other cases, the acceleration on all parts of the equipment (excluding flying leads) shall be within -10 percent and +30 percent of the specified steady acceleration.

> Note : In certain cases, while testing large Equipment, exceptions may have to be made to allow for a wider tolerances than those specified above, based on the availability of centrifuges in testing laboratories.

3. TEST PROCEDURE

3.1 Method of Mounting

3.1.1 The equipment shall be mounted on the centrifuge either directly or by means of suitable fixtures. These fixtures shall be such as to enable the equipment to be subjected to an acceleration in the direction or directions as specified. Any external connections necessary for measuring purposes shall add a minimum restraint and mass.

> Note : For reasons of safety, care should be taken to prevent the equipment under test, from being thrown off, if the mounting attachments are broken, but any safety devices used should not introduce additional constraint during the test.

3.1.2 The equipment shall be fastened to the centrifuge through its normal means of attachments, in its operational attitude. If isolators are used in the normal mounting of the equipment, these isolators shall also be used for mounting the equipment for testing, if so required. Any additional stays or straps shall be avoided, wherever possible.

3.1.3 If cables and pipes are required to be connected to the equipment during the test, as specified in the relevant equipment specification, these should be so arranged as to add similar restraint and mass as in the normal installation.

3.2 **Initial Measurements** - The equipment shall be visually examined and shall be Electrically and mechanically checked as specified

3.3 **Conditioning** - Two procedures are specified. Procedure 1 is applicable for Equipment subjected to normal acceleration. Procedure 2 is applicable for Equipment subjected to crash condition acceleration.

3.3.1 Procedure 1

3.3.1.1 The equipment shall be subjected to the test in its `unpacked' and `switched-off' condition.

3.3.1.2 The equipment shall be mounted on the centrifuge as in clause 3.1 and shall be subjected to the acceleration corresponding to one or more acceleration classes given in Table 4.1-1, as required.

3.3.1.3. Equipment which may be mounted in any attitude in the aircraft shall be subjected to the appropriate resultant acceleration as shown in column 5 of Table 4.1-1 applied in the direction of :

a) Three mutually perpendicular axes and

b) The axis of any suspected weakness.

Note : Unless otherwise specified the equipment shall be subjected to conditions stated in clause 3.3.1.3(a) above only.

3.3.1.4 Equipment which will always be mounted in one fixed attitude in the aircraft, shall be subjected to the appropriate acceleration applied in each of the axes and senses as shown in columns 6, 7 and 8 of Table 4.1-1.

3.3.1.5 The relevant equipment specification shall indicate in clear terms whether :

a) The equipment is required to continue to function satisfactorily during and after being subjected to the appropriate acceleration, or

b) The equipment is required to regain its ability to function satisfactorily immediately after removal of the acceleration, and is also required to function satisfactorily during and after being subjected to a smaller load due to acceleration, the value of which shall, if applicable, be specified.

3.3.1.6 Unless otherwise specified the acceleration shall be applied continuously for a period of 10 seconds.

3.3.2 **Procedure 2**

3.3.2.1 The equipment shall be subjected to this test in its `unpacked' and switched- off' condition.

3.3.2.2 The equipment shall be mounted on the centrifuge as in clause 3.1 and shall be subjected to the acceleration corresponding to the one or more acceleration classes given in Table 4.1-2 as required.

3.3.2.3 Equipment which can be mounted in any attitude in the aircraft, shall be subjected to the appropriate resultant acceleration as shown in column 4 of Table 4.1-2, applied in the direction of :

a) three mutually perpendicular axes, and
b) the axis of any suspected weakness.

Note : Unless otherwise specified, the equipment shall be subjected to conditions stated in clause 3.3.2.3(a) above only.

3.3.2.4 Equipment that will always be mounted in one fixed attitude in the aircraft shall be subjected to the appropriate acceleration applied in each of the axes and senses as shown in columns 5, 6 and 7 of Table 4.1-2.

3.3.2.5 The relevant equipment specifications shall indicate in clear terms whether ;

a) the equipment is required to continue to function satisfactorily during and after being subjected to the appropriate acceleration, or

b) the equipment is required to regain its ability to function satisfactorily, immediately after removal of the acceleration, or

c) the equipment may cease to operate during and after being subjected to appropriate acceleration.

3.3.2.6 Unless otherwise specified, the acceleration shall be applied continuously for a period of 10 seconds.

3.4 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Use of isolators (see clause 3.1.2).

4.2 Initial measurements (see clause 3.2)

4.3 The applicable test procedure or test procedures (see clause 3.3)

4.4 For procedure 1 :

a) The applicable acceleration class (see clause 3.3.1.2),

b) The appropriate axis along which the test is to be conducted (see clause 3.3.1.3(b),

c) Details of operation of the equipment (see clause 3.3.1.5), and

d) Duration of test, if other than 10 Seconds. (see clause 3.3.1.6).

4.5 **For procedure 2 :**

a) The applicable acceleration class (see clause 3.3.2.2),

b) The appropriate axis along which the test is to be conducted (see clause 3.3.2.3(b),

c) Details of operation of the equipment (see clause 3.3.2.5), and

d) Duration of test, if other than 10 seconds (see clause 3.3.2.6)

4.6 Final measurements (see clause 3.4).

4.7 Any deviation from the normal test procedure.

TABLE 4.1-1 ACCELERATION CLASSES (NORMAL) AT CG OF AIRCRAFT (Clauses 3.3.1.2, 3.3.1.3 and 3.3.1.4)

TYPICAL AIRCRAFT	INSTALLATION		TYPICAL MANOEUVRES COVERED	RESULTANT PROOF ACCELE-RATION	COMPONENTS OF PROOF ACCELERATION (m/s^2)			ACCELE-RATION CLASS
	Position	Altitude			X	Y	Z	
1	2	3	4	5	6	7	8	9
Highly manoeuv-rable (military) aircraft	Any	Any		170 in any direction	-	-	-	A
Highly manoeuv-rable (military) aircraft	Any	Fixed	Pull out landing and assisted take off	170	±90	±25	-140	B
Highly manoeuv-rable (military) aircraft	Any	Fixed	Roll, down gust	170	0	±140	+90	C
Highly manoeuv-rable (military) aircraft	Any	Any		130 in any direction	-	-	-	D
Highly manoeuv-rable (military) aircraft	Fuselage @	Fixed	Pullout, spin, roll	100	±25	±20	-90	E
Highly manoeuv-rable (military) aircraft	Fuselage @	Fixed	Landing and assisted take off	130	±90	±25	-85	F
Highly manoeuv-rable (military) aircraft	Fuselage @	Fixed	Down gust	-50	+10	0	45	G
Other Military Aircraft and fully aero Aerobatic Civil Aircraft	Any	Any		70 in any direction	-	-	-	H
Other Military Aircraft and fully aero Aerobatic Civil Aircraft	Any	Fixed	Pullout	70	±25	±10	-60	J
Other Military Aircraft and fully aero Aerobatic Civil Aircraft	Any	Fixed	Down gust	40	+10	0	+35	K
Other Military Aircraft and fully aero Aerobatic Civil Aircraft	Any	Fixed	Roll	50	0	+40	-25	L
Other Military Aircraft and fully aero Aerobatic Civil Aircraft	Fuselage @	Any		65 in any direction	-	-	-	M
Other Military Aircraft and fully aero Aerobatic Civil Aircraft	Fuselage @	Fixed	Pullout, roll	65	±20	±10	-60	N
Other Military Aircraft and fully aero Aerobatic Civil Aircraft	Fuselage @	Fixed	Down gust	-40	+10	0	+35	P
Military and civil rotor craft and semi aerobatic civil aircraft	Any	Any		55 in any direction	-	-	-	Q
Military and civil rotor craft and semi aerobatic civil aircraft	Any	Fixed	Pullout, roll	55	±20	±20	-45	R
Military and civil rotor craft and semi aerobatic civil aircraft	Any	Fixed	Down gust	-25	±10	0	+20	S

X* : represents the longitudinal axis (forward positive, backward negative).
Y* : represents the transverse axis, that is, lateral (starboard positive, port negative).

Z^* : represents the normal axis, that is, vertical (downwards positive, upwards negative).

@ : The `fuselage' position shall be taken as applying only to equipment within a radius of 1/4 fuselage length from the centre of gravity (CG).

TABLE 4.1-2 ACCELERATION CLASSES (CRASH) AT CG OF AIRCRAFT

(Clauses 3.3.2.2, 3.3.2.3 and 3.3.2.4)

TYPICAL AIRCRAFT	INSTA-LLAT-ION ATTI-TUDE	EQUIPMENT LOCATION	MAXIMUM RESULTANT PROOF ACCELERA-TION (m/s^2)	MAXIMUM COMPONENTS OF PROOF ACCELERATION (m/s^2)			TEST CONDI-TION
				X*	Y*	Z*	
1	2	3	4	5	6	7	8
Military Aircraft	Fixed	Where, if a broke loose it could either injure occupants at their crash stations or prevent the use of emergency equipment or exists	255	-250	±40	0	T
		Where, if a broke loose it could injure occupants at their crash stations	110	-100	±40	0	U
Civil aircraft	Fixed	Where, if a broke loose it could either injure occupants at their crash stations or prevent the use of emergency equipment or exists	100	-90	±22.5	-45 +40	V
Rotorcraft (military and civil)	Any direction	Where, if a broke loose it could either injure occupants at their crash stations or prevent the use of emergency equipment or exists	60 in any direction	--	--	--	W

X* : represents the longitudinal axis (forward positive, backward negative)

Y* : represents the transverse axis, that is, lateral (starboard positive, lateral negative).

Z* : represents the normal axis, that is, vertical (downwards positive, upwards negative).

TEST NUMBER 2
ACOUSTIC NOISE

1. OBJECT

1.1. To determine the effects of an acoustic field as produced by aerospace vehicles, vehicle power plants etc on electronic and electrical Equipment.

2.1 TEST EQUIPMENT

2.1.1 Test Chamber

2.1.2 A reverberant chamber shall be used for conducting this test.

2.1.3 The chamber shall be of such shape and construction as to produce as closely as possible, a diffuse sound field. A chamber shape and relative size dimensions for this test is illustrated in Fig 4.2-1.

2.1.4 The source opening shall be small in relation to the total wall area. The volume occupied by the equipment under test shall not exceed 10 percent of the volume of the chamber. As far as possible, it shall be possible for the equipment under test to be positioned at the centre of the chamber .

2.2 Noise Source

2.2.1 The acoustic energy supplied to the test chamber should, as far as practicable, be of a random nature approximating to a normal distribution with amplitudes up to a peak value not less than three times the root mean square (r.m.s.) value.

2.3 Measuring System

2.3.1 The measuring and indicating instruments used with the microphones and the microphones themselves shall be capable of handling random noise as specified in clause 2.2.2. The measuring system shall give the root mean square value of the sound pressure when measuring a random noise.

2.4 Microphones

2.4.1 The microphones used shall be calibrated for random incidence.

2.5 Spectrum Measurements

2.5.1 The sound pressure level shall be measured in octave bands with centre frequencies and band widths as required by the relevant equipment specification.

2.6 **Tolerances**

2.6.1 The accuracy of the measuring system shall correspond to the precision grade for sound level meters.

3. TEST PROCEDURE

3.1 **Mounting**

3.1.1 The equipment shall be mounted in the test chamber in such a manner that all appropriate external surfaces are exposed to the acoustic field. The principal surfaces of the equipment shall not be parallel to any surface of the test chamber. If the equipment is long compared to its width and a single noise source is used, the equipment shall not be mounted with the long axis in line with the noise source.

3.1.2 The equipment shall be suspended in the chamber on an elastic suspension. The resonant frequency of the suspension system and the equipment combined shall be less than 25 Hz, unless otherwise stated. Care must be taken to ensure that no spurious acoustic or vibratory inputs are introduced. Where the equipment is provided with specific means of mounting, the suspension system should be attached to these points. Where no specific means of mounting is provided, the suspension system should be connected to the equipment in such a way that it does not interfere with the free movement of parts of the equipment which may move independently.

3.1.3 If cables and pipes are required to be connected to the equipment during the test as required in the relevant equipment specification, these should be arranged so as to add similar restraints and mass as in the normal installation.

3.2 **Initial Measurements**

3.2.1 The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.3 **Conditioning**

3.3.1 The equipment shall be subjected to this test in the unpacked 'and' switched off' condition and under the laboratory atmospheric conditions.

3.3.2 The overall Sound Pressure Level (SPL), required by the relevant equipment specification shall be produced in the chamber conforming to the octave band spectra given in Fig 4.2-1. The overall sound pressure levels (SPL) corresponding to typical applications are given in Table 4.1. The relevant equipment specification shall choose one or more of these levels as required.

Note : With reference to Fig 4.2-2, the optional extension of the frequency spectrum from 125 Hz to 63 Hz (shown by dotted lines) involves the assumption that the test chamber has adequate nodal density at the low frequencies. If the chamber is small, the nodal density may be inadequate to provide a continuous spectrum for the test. The capabilities of the test chamber including the test set up should be examined before specifying the lower frequency limit below 125 Hz.

3.3.3 Measuring equipment capable of resolutions better than one octave may be used. Appropriate reductions should be made to the octave band sound, pressure levels in Fig 4.2-2 to give the required overall sound pressure level. Measurements shall be made by using one microphone (or more if desired), placed in the area to be occupied by the equipment under test.

3.3.4 The equipment shall be mounted in the chamber as specified in clause 3.1 and the overall sound pressure level shall be re-established and monitored by not less than three microphones. A microphone should be located in proximity to each major dissimilar face of the equipment at a distance of 0.5 m from the face or half the distance to the nearest chamber wall whichever is lesser. When the chamber is provided with a single noise source, one microphone must be placed between the equipment and the chamber wall farthest from the noise source.

3.3.5 The overall sound pressure level (SPL) shall be adjusted until the average of the sound level at each of the monitoring points is within + 4 and -2 dB of the specified level and until the SPL at each monitoring point is also within + 4 and -2 dB. For larger or irregularly shaped equipment where it is not practicable to meet the latter requirement, its tolerance may be relaxed to ± 6 dB. When the spread of readings at the measuring positions does not exceed 5 dB, a simple arithmetical average of the decibel readings may be used. For spread exceeding 5 dB, an rms summation of the individual sound pressures (not decibel values) shall be used. The performance achieved shall be noted in the test report.

3.3.6 The equipment shall then be exposed to the above conditions for a period stipulated in the relevant equipment specification.

Note : 1 When testing missiles, the test should be related to the nominal flight time multiplied by a safety factor to be agreed between the contracting parties. In general, a maximum duration not exceeding 30 minutes should suffice. Missiles carried on aircraft may require an additional test simulating the aircraft carriage condition.

2 Equipment in aircraft is exposed to acoustic noise environments of varying amplitude during the course of its life. The more severe levels arising during take off and the application of reheat occur only for a small proportion of the life of the equipment. Lower levels of noise, invariably persist for long periods and the cumulative damage caused by the varying noise environments can, where there is an established relationship between stress and cycles to failure, be simulated by a test of reduced duration applied at a level representative of the most severe conditions. The maximum testing time should not normally exceed 10 hours.

3.3.7 The equipment should be operated either throughout the test or at appropriate phases of the test in a manner representative of the most adverse duty cycles for the equipment. A demonstration of the functional performance of the equipment should be made towards the end of the conditioning phase or if desired, at the start and at intervals throughout the conditioning phase.

Note : If this test is required to assess the survival of the equipment only, the performance check should be carried out after the noise conditioning.

3.3.8 At the conclusion of 3.3.6 above, the noise source shall be switched off and the equipment shall be removed from the chamber.

3.4 **Recovery**

3.4.1 The equipment shall then be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

3.5 **Final Measurements**

3.5.1 The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Details of Spectrum Measurements (see clause 2.5)

4.2 Initial Measurements (see clause 3.2)
4.3 The overall sound pressure levels (see clause 3.3.2 and Table 4.1)

4.4 Lower frequency limit of the test spectrum, if lower than 125 Hz (see clause 3.3.2 Note).

4.5 The duration of the test (see clause 3.3.6).

4.6 Details for operations and performance checks and the terms at which they should be made (see clause 3.3.7).

4.7 Final Measurements (see clause 3.5)

4.8 Any deviation from the normal test procedure.

TABLE 4.1 OVERALL SOUND PRESSURE LEVELS FOR TYPICAL APPLICATIONS

TYPICAL APPLICATION	SPL dB
Equipment Bays of Transport Aircraft in Locations not close to jet exhaust.	130
Internal Equipment Bays of Transport Aircraft close to Jet exhaust. Internal equipment bays remote from Jet exhaust of high performance Military Aircraft	140
Internal Equipment Bays close to Jet exhaust of Military Aircraft	150
Compartments of Missiles close to large thrust Motors. Aircraft compartments close to Gun Muzzles, reheat exhausts	160 to 165

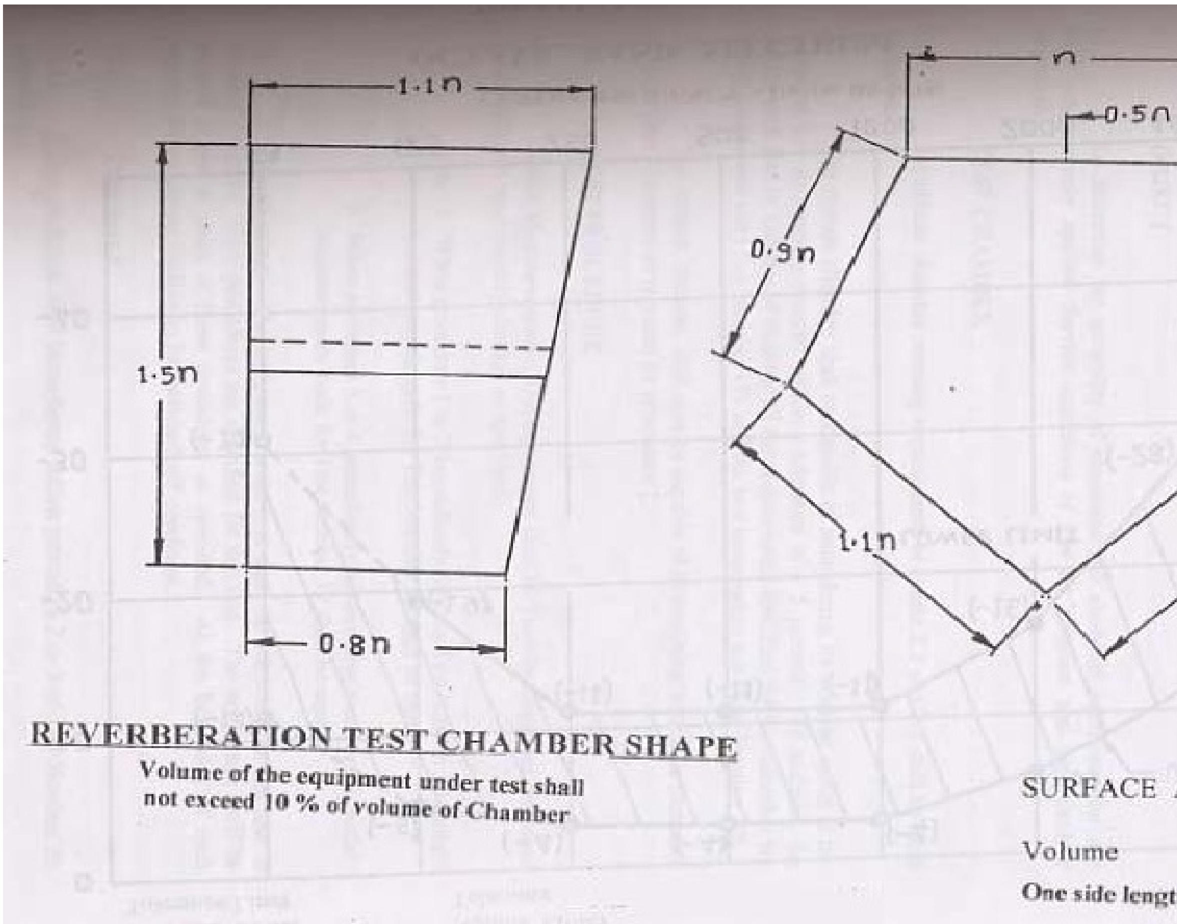


FIGURE - 4.2-1 (Clause 2.1.2)

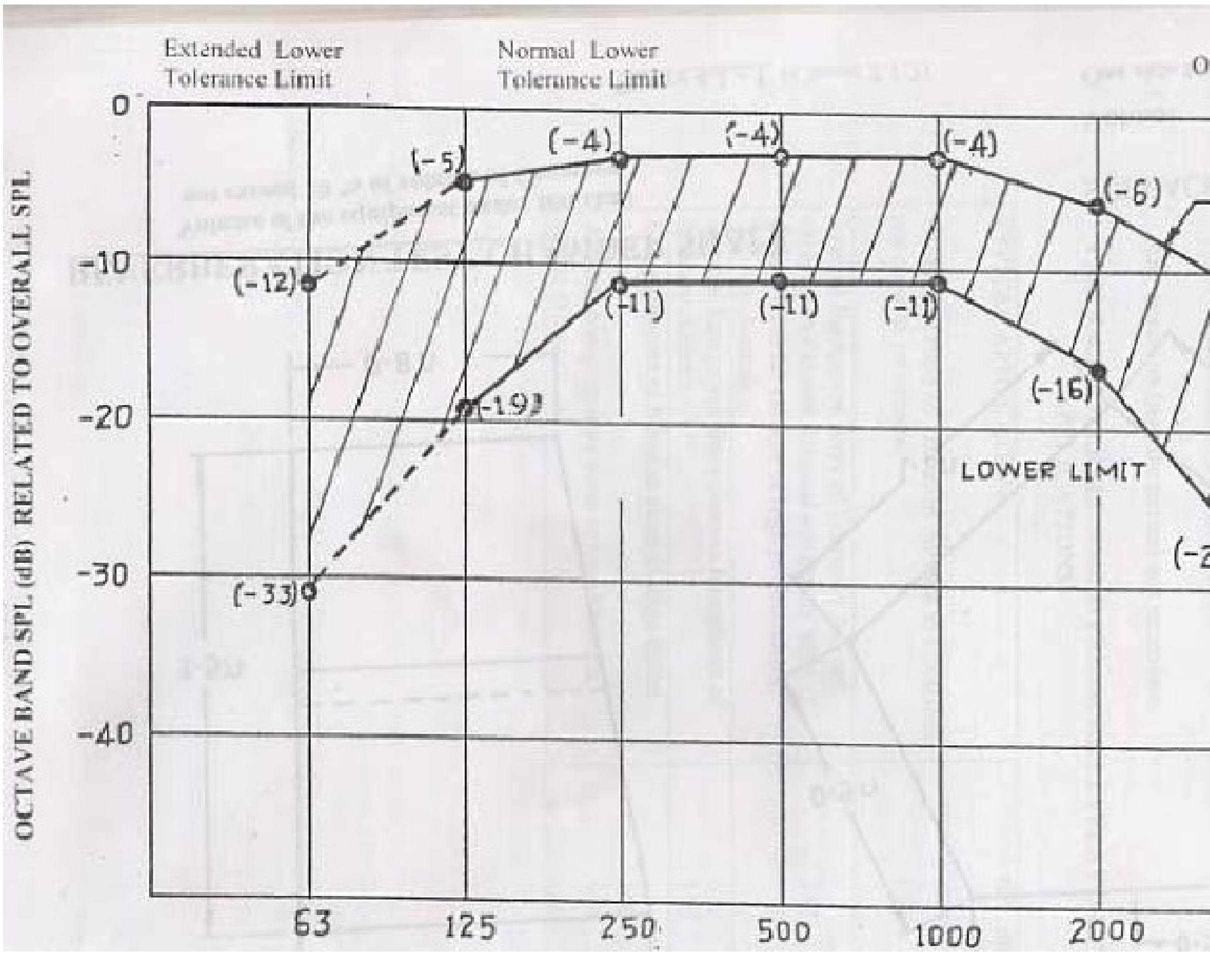


FIGURE – 4.2-2 (Clause 3.3.2)

TEST NUMBER 3
ALTITUDE

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use under simultaneously applied Service conditions of low air pressure and high or low temperature.

2. TEST CHAMBER

2.1 An altitude chamber meeting requirements of clause 2.2 and 2.3 shall be used for this test.

2.2 The altitude chamber shall be capable of maintaining its working space at the appropriate low air pressure severity within a tolerance of ± 5 percent. In addition, the chamber shall also be capable of meeting all the requirements specified for test chamber for the high temperature test (Test Number 17) and the low temperature test (Test Number 20)

2.3 The altitude chamber shall also be capable of maintaining a relative humidity of not less than 95 percent as required for procedure 2.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

Note : 1 When procedure 1 or 2 immediately follows Test Number 20 initial measurements made for Test Number 22 shall be used.

2 When procedure 3 or 4 immediately follows Test Number 17, initial measurements made for Test Number 17 shall be used.

3.2 **Conditioning** - The equipment under test shall be subjected to this test in 'unpacked' condition. Five procedures are specified for this test. The equipment shall be subjected to one or more of these procedures as specified. At the beginning of each procedure the equipment shall be in its 'switched-off' condition.

3.2.1 **Procedure 1**

3.2.1.1 This procedure shall immediately follow procedure 2 or 3 of Test Number 20, as specified.

3.2.1.2 The chamber temperature shall be adjusted to one of the following test conditions as specified:

a) Test condition L1 : -20^{o}C ± 3 degC

b) Test condition L2 : -55^{o}C ± 3 degC

3.2.1.3 The equipment shall be stabilized at the appropriate test condition stated in clause 3.2.1.2.

3.2.1.4 The air pressure inside the chamber shall then be reduced within a period of 30 minutes, to a value corresponding to one of the test conditions given in Table 4.3-1, as required

TABLE 4.3-1 TEST CONDITIONS
(Clause 3.2.1.4)

TEST CONDITION	ALTITUDE IN METRES	AIR PRESSURE IN kPa
A1	3, 000	70.0
A2	6, 100	46.5
A3	9, 100	30.0
A4	15, 200	11.5
A5	18, 300	7.2
A6	21, 300	4.4

3.2.1.5 The equipment shall then be operated as specified.

Note : 1 Equipment normally operated throughout the flight shall be operated from the start of the temperature conditioning and shall continue to operate throughout the test.

2 Equipment operated intermittently in flight shall be operated only when the required conditioning has been attained and the equipment has achieved a stable temperature.

3.2.1.6 If required, the operation of the equipment shall be stopped during the temperature/low air pressure conditioning phase, until the internal temperatures of the equipment have restabilized so that a subsequent cold `switch-on' or 'start-up' can be made.

3.2.1.7 A performance check shall be carried out on the equipment as required. The test shall continue for at least half an hour after the equipment has commenced functioning or until the performance check is completed. whichever is longer.

> Note : Ideally, all measurements shall be made simultaneously at the end of the warm up period. Where this is impracticable, characteristics that are likely to be affected by low temperature should be checked first. Should these checks take such a time that the state of equipment is no longer representative of that at the end of the warm up period, the operation of the equipment should be stopped, the temperature restabilized at the original level and the remaining performance tests continued.

3.2.1.8 The equipment shall then be subjected to the appropriate test method of procedure 2, as required.

3.2.2 **Procedure 2**- The equipment shall be subjected to one of the following test methods, as specified.

3.2.2.1 **Method A**

a) This test method shall immediately follow conditioning of procedure 1.

b) The chamber temperature shall be raised from the level of procedure 1 to 30ºC in a period of 1 to 2 hours, with the relative humidity held at or close to saturation (nominally not less than 95 percent). Visible frosting should occur on the surface of the equipment. When the mean temperature of the equipment has attained a level between 0 and 5ºC and the frost has melted, the air pressure in the chamber shall be restored to the laboratory conditions at an approximately uniform rate during a period of 15 to 30 minutes.

Note : A saturated atmosphere conforming to these requirements shall be accepted, without humidity measurement, if heating is by steam injection.

c) The equipment shall be operated and performance check shall be made, as specified.

Note : Equipment intended for operation throughout descent phase shall be operated throughout the test. Unless required, equipment normally idle during the descent phase, shall not be operated until the equipment temperature has stabilized at 30ºC.

d) The test shall continue for 1 hour after the temperature and relative humidity have stabilized at 30ºC and 95 percent respectively, or for a period sufficiently long to complete performance check, whichever is longer.

3.2.2.2 **Method B**

a) The equipment shall be subjected to the conditioning of Method A, after which it shall be reconditioned to appropriate procedure 1 levels of temperature and air pressure. This shall constitute one cycle.

b) Unless otherwise specified, the equipment shall be subjected to 4 such cycles.

c) The equipment shall be operated and performance check shall be carried out, as specified.

d) At the end of last cycle, the chamber temperature shall be restored to the laboratory atmospheric conditions, and the equipment shall be subjected to recovery conditions (see clause 3.3).

3.2.2.3 **Method C**

a) This method shall immediately follow low temperature conditions of procedure 1 of this test (see clause 3.2.1.3) or Test Number 22 (procedure 2 to 3), as specified. This test may be conducted by using two chambers or one chamber as required

Note : It is essential that whichever method is adopted condensation shall occur on the equipment.

b) Two chamber method - The equipment conditioned to appropriate low temperature level (see (a) above), shall be transferred to a humidity chamber maintained at a temperature of 30ºC and relative humidity not less than 95

percent. The transfer shall take place as quickly as possible, but in a time not exceeding 15 minutes, this period being applicable only to more complex equipment involving handling problems.

c) One chamber method - The chamber temperature shall be raised from the appropriate low temperature level (see (a) above) to 30ºC in 2 hours, by introducing required humidity and heating. During the transitional period the humidity shall be held close to saturation (nominally not less than 95 percent relative humidity).

Note : A saturated atmosphere conforming to these requirements shall be accepted, without humidity measurement, if heating is by steam injection.

d) The equipment shall be operated and performance check shall be made, as specified. The equipment operation shall continue for 1 hour after the equipment temperature has stabilized at 30ºC or for a period sufficient to complete performance check, whichever is longer.

Note : The equipment, whose operation during descent phase is important, shall be tested by one chamber method only.

3.2.3 **Procedure 3**

3.2.3.1 This procedure shall immediately follow procedure 3 or 4 of Test Number 17, as specified.

3.2.3.2 The chamber temperature shall be adjusted to one of the following test conditions, as specified.

a) Test condition H1 : 55ºC ± 3 degC
b) Test condition H2 : 85ºC ± 3 degC
c) Test condition H3 : 150ºC ± 5 degC

3.2.3.3 The equipment shall be stabilized at the appropriate test condition stated in clause 3.2.3.2.

3.2.3.4 The air pressure inside the chamber shall then be reduced, within a period of 30 minutes, to a value corresponding to test condition A2 or A3 (see Table 4.3- 1), as specified.

3.2.3.5 The equipment shall then be operated for a period of 4 hours, or any other period as required. During this period of operation, the maximum surface temperatures attained by the components or materials in the equipment shall be measured and recorded if so required.

3.2.3.6 Towards the end of the period specified in clause 3.2.3.5, a performance check shall be carried out. Unless otherwise specified, the equipment shall then be switched off and its operation shall be stopped for 5 minutes, while the chamber temperature is being maintained at the specified level. The equipment shall be switched on again. It shall then be operated for a minimum period required and a limited performance check shall be carried out only to demonstrate that the equipment is not deranged by a hot `switch-on' or `start-up'.

3.2.3.7 The equipment shall then be switched-off and immediately subjected to conditioning mentioned in procedure 4.

3.2.4 **Procedure 4**

3.2.4.1 This procedure shall immediately follow procedure 3 of this test or appropriate procedure of Test Number 17, as specified.

3.2.4.2 The conditioning under this procedure shall be as specified in clauses 3.2.3.2 to 3.2.3.6 except that the test conditions shall be chosen from those specified in clauses 3.2.4.3 and 3.2.4.4.

3.2.4.3 The temperature of the chamber shall be maintained at one of the following test conditions, as specified:

a) Test condition H1 : 5ºC ± 2 degC

b Test condition H2 : 10ºC ± 3 degC

c) Test condition H3 : 40ºC ± 3 degC

d) Test condition H4 : 55ºC ± 3 degC

e) Test condition H5 : 150ºC ± 5 degC

3.2.4.4 The air pressure inside the chamber shall be maintained at a value corresponding to one of the test conditions given in Table 4.3-1, as specified.

3.2.4.5 At the end of conditioning as in clause 3.2.3.6 the air pressure inside the chamber shall be restored to laboratory atmospheric conditions within 30 minutes. The chamber temperature shall then be restored to laboratory atmospheric conditions.

3.2.5 **Procedure 5**

3.2.5.1 The equipment under test, while being under laboratory atmospheric condition, shall be introduced into the chamber, the latter also being under the same conditions. The temperature of the chamber shall then be lowered to one of the following test conditions, as specified:

a) Test condition L1 : -40ºC ± 3 degC

b) Test condition L2 : -30ºC ± 3 degC

3.2.5.2 The air pressure inside the chamber shall then be reduced to a value corresponding to one of the test conditions, given in the Table 4.3-2 as specified.

TABLE 4.3-2 TEST CONDITIONS
(Clause 3.2.5.2)

TEST CONDITION	ALTITUDE IN METRES	AIR PRESSURE IN kPa
A1	9, 100	30.0
A2	4,160	60.0

3.2.5.3 The conditions of temperature and air pressure as specified in clauses 3.2.5.1 and 3.2.5.2 shall be maintained for a period of 16 hours.

3.2.5.4 During the last 30 minutes of the period specified in clause 3.2.5.3, the equipment shall be 'switched on' and a performance check shall be carried out, as specified.

3.2.5.5 The temperature of the chamber shall then be allowed to rise, at such a rate that it would attain laboratory atmospheric conditions in not less than one hour and not more than four hours.

3.2.5.6 When the equipment temperature has reached a value between 0 and 10º C, the air pressure inside the chamber shall be restored to laboratory atmospheric conditions within 30 minutes.

3.2.5.7 A performance check shall then be carried out as specified.

3.3 **Recovery** - The equipment shall then be removed from the chamber and shall be restored to laboratory atmospheric conditions within 30 minutes for a period of 2 to 4 hours.

Note : For procedure 1 and 3 the recovery conditions shall be applicable only

when these procedures are not immediately followed by procedure 2 or 4 respectively and final measurements at laboratory atmospheric conditions are required to be made.

3.4 **Final Measurements** - The equipment shall then be visually examined and shall be electrically and mechanically checked as specified.

Note : 1 For procedure 1 or 3 the final measurements shall be made only when the relevant equipment specification requires the performance of the equipment to be checked at the laboratory atmospheric conditions.

2 In case of procedure 2, method B, the equipment shall be completely stripped down and examined for ingress of moisture, if so required.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1).

4.2 The applicable test procedure or test procedures (see clause 3.2).

4.2.1 **For Procedure 1:**

a) The applicable test condition for temperature (see clause 3.2.1.2.)

b) The applicable test conditions for altitude (see clause 3.2.1.4),

c) The details and period of operation see clause 3.2.1.5)

d) Whether the operation of the equipment to be stopped during the temperature/low air pressure conditioning phase or not (see clause 3.2.1.6), and

e) Details of performance check (see clause 3.2.1.7).

4.2.2 **For procedure 2 :**

a) The applicable test method (see clause 3.2.2)

b) Details of operation and performance check (see clause 3.2.2.1 [c]).

c) Number of cycles, if other than 4 cycles (see clause 3.2.2.2[b]),

d) Whether the equipment should be completely stripped down for examination of ingress of moisture (see clause 3.4 Note 2),

e) Whether test method C shall follow Test Number 22 (procedure 2 or 3) or procedure 1 of this test (see clause 3.2.2.3[a]),

f) Whether one chamber or two chambers to be used (see clause 3.2.2.3[a]), and

g) Details of operation and performance check (see clause 3.2.2.3[d]).

4.2.3 **For procedure 3:**

a) The applicable test condition for temperature (see clause 3.2.3.2)

b) The applicable test conditions for altitude (see clause 3.2.3.4), and

c) The details and period of operation, if other than 4 hours (see clause 3.2.3.5),

d) Whether maximum surface temperatures attained by the components shall be measured and recorded or not (see clause 3.2.3.5.), and

e) Details of performance check (see clause 3.2.3.6).

4.2.4 **For Procedure 4:**

a) The applicable test condition for temperature (see clause 3.2.4.3),

b) The applicable test condition for altitude (see clause 3.2.4.4). and

c) Other details as required for procedure 3 [see clause 4.2.3 (c), (d) and (e)]

4.2.5 **For procedure : 5**

a) The applicable test condition for temperature (see clause 3.2.5.1.),

b) The applicable test condition for altitude (see clause 3.2.5.2), and

c) Details of performance check (see Clauses 3.2.5.4 and 3.2.5.7).

4.3 Final measurements (see clause 3.4).

4.4 Any deviation from the normal test procedure.

TEST NUMBER 4
BOUNCE

1. OBJECT

1.1 To determine the ability of electronic and electrical equipment as prepared for field use to withstand transportation when they are carried as loose cargo on a wheeled vehicle traversing irregular surface where it has some freedom, however slight, to bounce, scuff, or collide with other items of cargo or the sides of the vehicle.

2. TEST EQUIPMENT

2.1 A Bounce Tester shall be used for this test. The bounce tester shall consist of a flat table assembly coupled to two shaft driven eccentric assemblies which are mounted on a base frame.

2.2 The table assembly shall be of 25 ±1 mm plywood firmly secured by recessed fasteners to a steel frame.

2.3 The eccentrics shall produce a maximum peak to peak vertical displacement of 25+1 mm or –0.5 mm of table assembly, in the region between drive shafts.

2.4 The bounce tester when loaded with the equipment and any other necessary devices for the test shall have the characteristics specified in appropriate test procedures.

3. TEST PROCEDURE

3.1 **Initial Measurements**

3.1.1 Equipment to be tested shall be visually examined and shall be electrically and mechanically checked as specified in the relevant specification.

3.2. **Method of Mounting**

3.2.1 The equipment to be tested, prepared as for transportation shall be placed on the table centrally with respect to drive shafts.

3.2.2 The presence of the vehicle side walls or of other similar constraints shall be simulated by a rectangular arrangement of retaining barriers securely attached to the table frame. These barriers shall consist of 76 mm steel channel section faced with firmly secured 25±1 mm plywood.

3.2.3 The barriers shall be erected with an all round clearance between them and the vertical surfaces of the test specimen between 50 mm and 75 mm. The top edge of the uppermost barrier shall be 50 ± 25 mm below the top of the test specimen and not more than 600 mm from the top surface of the plywood table.

3.2.4 Where the aspect ratio of the test specimen (the ratio of its longest to its shortest) does not exceed 3:1 on each of its faces (normally 3 for a cylinder and 6 for a rectangular object) orientated with respect to the table surface as stated in the relevant specification. For packages of greater aspect ratio or weight, the test shall be carried out as required by the relevant specification.

3.2.5 Unless otherwise stated in the relevant specification whenever the package dimension and the number of specimens available for test allow, they shall be stacked to a level not exceeding one metre in height.

3.3 **Conditioning** - The specimen shall be subjected to one of the following procedures as specified in the relevant specification.

3.3.1 **Procedure 1 - Synchronous circular motion**.

3.3.1.1 The movement of the platform of the bounce machine shall be such that each point of the platform which is always in a horizontal position describes a circle with a diameter of 25.0 ±0.5 mm in the vertical plane.

3.3.1.2 The horizontal motion allowed by the barriers shall be adjusted to a total of 50 ± 5 mm, i.e. the specimen when placed at the centre of the platform in its normal position shall have a free movement in any horizontal direction of a nominal 25 mm.

3.3.1.3 The duration of test shall be as given in clause 3.4

3.3.2 **Procedure 2- Non-synchronous motion.**

3.3.2.1 The motion of the platform shall vary cyclically between a linear vertical and oscillatory motion. This motion shall be produced by a nominally vertical drive applied to the platform along two transverse lines spaced not less than 600 mm apart and not more than 1700 mm. The applied peak to peak value at the drive points shall be 25.0 ± 0.5 mm.

3.3.2.2 The relative speeds of the two drive shafts shall be in the ratio 1: 0.9 ±0.03. The higher speed shaft shall rotate at mean speed of 285 ±5 r.p.m.

3.3.2.3 The duration of test shall be as given in clause 3.4

3.4 **The Severity** - The severity is determined by the duration of the test. It shall be one of the following and it shall be as specified in the relevant specification. These are the total times.

Test condition A	:	180 minutes
Test condition B	:	60 minutes
Test condition C	:	15 minutes

3.4.1 If the relevant specification specifies a number of test attitudes (see clause3.2.4) then the total test time shall be equally divided between the specified attitudes and orientations.

3.5 **Recovery** - Tests exceeding five minutes duration must be split in to five minute test periods followed by a recovery period of five minutes or longer to prevent excessive temperature rise within the specimen.

3.6 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1) .

4.2 Specimen to be tested with or without its transport case (see clause 3.2.1)

4.3 Attitude and orientation of specimen (see clause 3.2.4)

4.4 Stacking of specimens if applicable (see clause 3.2.5)

4.5 The applicable test procedure (see clause 3.3)

4.6 The severity (see clause 3.4)

4.7 Final measurements (see clause 3.6)

4.8 Any deviation from the normal test procedure.

TEST NUMBER 5
BUMP

1. OBJECT

1.1 To determine the ability of electronic and electrical equipment to withstand repeated bumps without malfunctioning and mechanical damage.

2. TEST EQUIPMENT

2.1 **Characteristics of Bump Machine** - A bump machine shall be used for this test. When the bump machine and fixtures are loaded with the equipment and any other necessary load for the testing, the applied bump shall, at the monitoring points have the characteristics specified in clauses 2.2 to 2.5.

2.2 **Basic Pulse Shape** - The bump machine shall be capable of generating a pulse approximating to one half cycle of a sine wave as shown by dotted lines in Fig. 4.5-1. The nominal Pulse shall have a peak acceleration and duration as indicated in table under clause 3.3.2, The acceleration and time duration shall be achieved within tolerance shown by thick lines in Fig. 4.5-1 unless otherwise specified in the relevant equipment specifications.

2.3 **Repetition Rate** - The bump repetition rate shall be such that between impacts, the relative motion within the equipment shall be substantially zero and the value of the acceleration at the monitoring point shall be within the limits shown in Fig. 4.5-1.

Note : A bump repetition rate of 1 to 3 bumps per second is usually adequate to reduce secondary bumps to a minimum.

2.4 **Velocity Change** - The actual velocity change shall be within ± 20 percent of the value corresponding to the nominal pulse, i.e. 1.50 m/s. To determine the velocity change, the actual pulse should be integrated from 0.4 D before the pulse to 0.1 D beyond the pulse where D is the duration of the nominal pulse (see Fig. 4.5- 1).

2.5 **Transverse Motion** - The positive or negative peak acceleration at the monitoring point perpendicular to the intended direction of bumps shall not exceed at any time 30 percent of the nominal value of the peak acceleration in the intended direction, when determined with a measuring system conforming to clause 2.6.

2.6 **Measuring System**

2.6.1 **Monitoring** - The acceleration measuring device shall be an accelerometer placed at the monitoring point. This point shall be equipment fixing point nearest to the centre of the table surface, unless there is a fixing point having a more rigid connection to the table, in which case, the latter shall be chosen.

2.6.2 **Accuracy** - The accuracy of measuring system shall be such that it can determine the true value within the given tolerances.

2.6.3 **Frequency Characteristics** - The frequency response of the overall measuring system including the accelerometer shall be within the limits shown in Fig 4.5-2.

Note : When it is necessary to employ filters to reduce the effect of any high frequency resonances inherent in the accelerometer, it may be necessary to examine the amplitude and phase characteristics of the measuring system in order to avoid distortion of the reproduced waveform.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Mounting**

3.2.1 Equipment, in its 'unpacked' and 'switched-off' conditions shall be fastened to the bump machine, either directly or by means of a fixture. Mounting fixtures shall be such as to enable the equipment to be subjected to bumps along the various axes as specified for conditioning (see clause 3.3.1).

3.2.2 Equipment intended for use in an environment where bumping takes place (for example, in moving vehicle), shall be fastened by its normal means of attachment, unless otherwise specified.

3.2.3 Equipment intended for use with isolators should normally be tested with its isolators.

3.2.4 External connections necessary for measuring purposes shall add a minimum of restraint and mass. If cables and pipes are required to be connected to the equipment during the test, as specified, these should be arranged so as to add similar restraint and mass as in normal installation.

3.2.5 When bump test is employed to demonstrate a certain degree of robustness in an equipment which is normally protected by isolators, the equipment shall, unless otherwise specified, be mounted directly to the table and the test carried out with the isolators removed or blocked. The relevant equipment specification shall clearly state the manner of mounting and the number of bumps.

3.2.6 When the bump test is employed to ascertain the capability of an equipment to withstand transportation, other than that inherent in its Service use, the equipment shall be mounted as specified.

3.2.7 When mounting the equipment on the bump machine, stays or straps additional to those required or permitted by the relevant equipment specification shall be avoided.

3.2.8 The relevant equipment specification shall state whether the effect of gravitational force is important. In this case, the equipment shall be so mounted that the gravitational force acts in the same direction as in the normal use.

3.3 **Conditioning**

3.3.1 Where the attitude of the equipment when mounted and transported is known, and since bumps are generally of greatest significance in one direction (usually vertical), the specified number of bumps (see clause 3.3.2) shall be applied in that direction and attitude only. However, where the attitude is unknown, the specified number of bumps should be applied in each of the directions specified. In this case, three mutually perpendicular directions are usually adequate.

3.3.2 The equipment shall be subjected to test severities an per the following table:-

TABLE 4.5-1 TEST SEVERITIES
(Clause 3.3.2)

TEST SEVERITIES			APPLICATION
PEAK ACCELERA-TION (m/s^2)	**PULSE DURATION (ms)**	**NUMBER OF BUMPS**	
100	16	4000 + 10	General ruggedness test. Equipment. attached or installed in vehicles with no cross country requirement.
250	6	@4000 ± 10	Equipment attached or installed in vehicles with Full cross country requirement.
400	6	@1000 ± 10	Equipment which may be carried loose on floors of vehicles for short distances
400	6	@4000 ± 10	Equipment which may be carried loose in any type of vehicle for an indefinite period

@ These severities are usually applied to equipment of nominal mass up to 100 kg. For heavier Equipment the 100 or 50 m/s^2 severity should be considered.

3.3.3 If required, the equipment shall be operated at any stage and for the period specified. Performance check, if any, shall be carried out as specified.

3.4 **Final Measurements** - The equipment shall be visually examined for any mechanical damages and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 Details of mounting (see clause 3.2), whether isolators are to be used during the test (see clause 3.2.3) and number of bumps (see clause 3.2.5).

4.3 The attitude or directions in which the equipment to be tested (see clause 3.3.1).

4.4 Details of operation and performance check, if applicable (see clause 3.3.3).

4.5 Final measurements (see clause 3.4).

4.6 Any deviation form the normal test procedure.

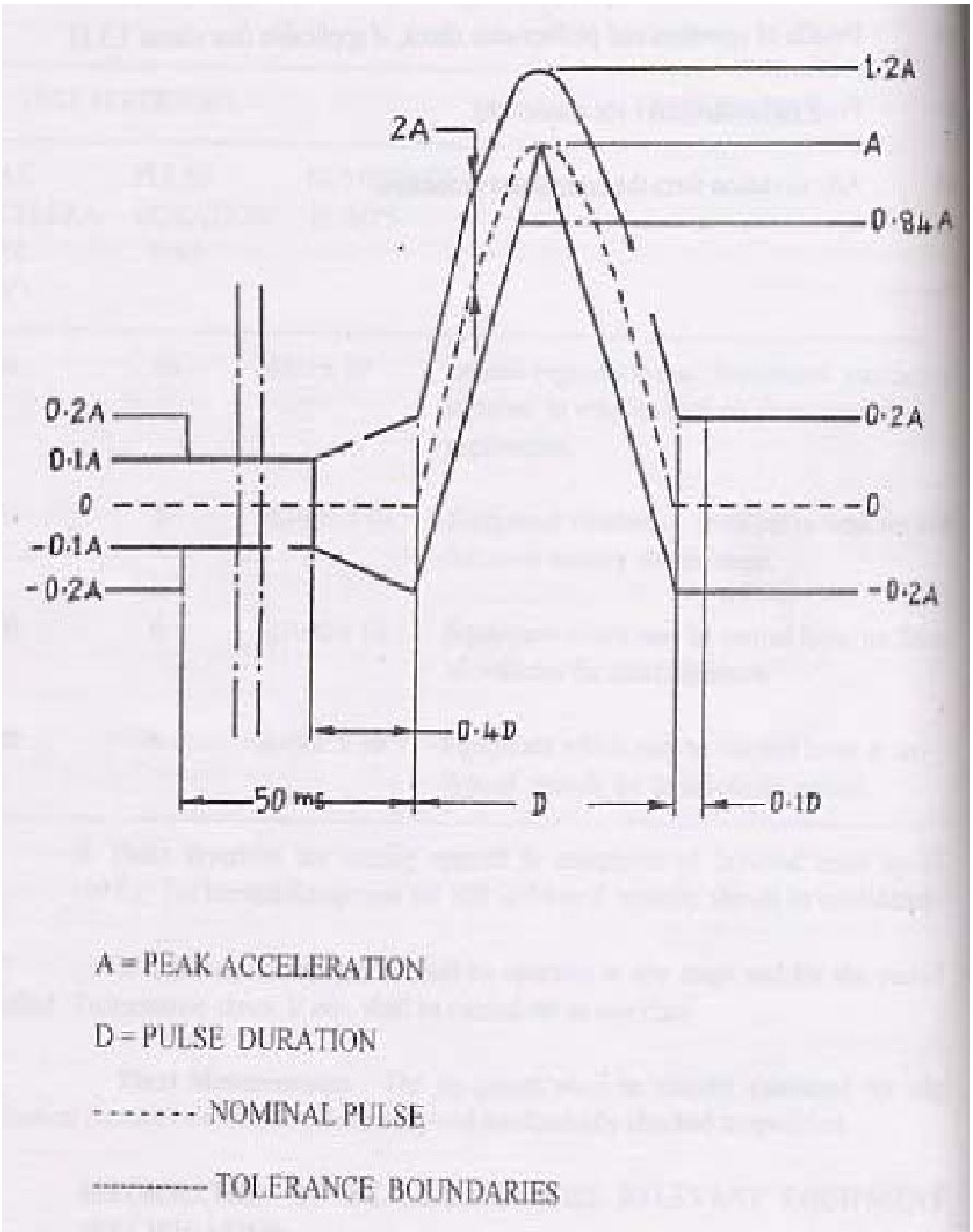
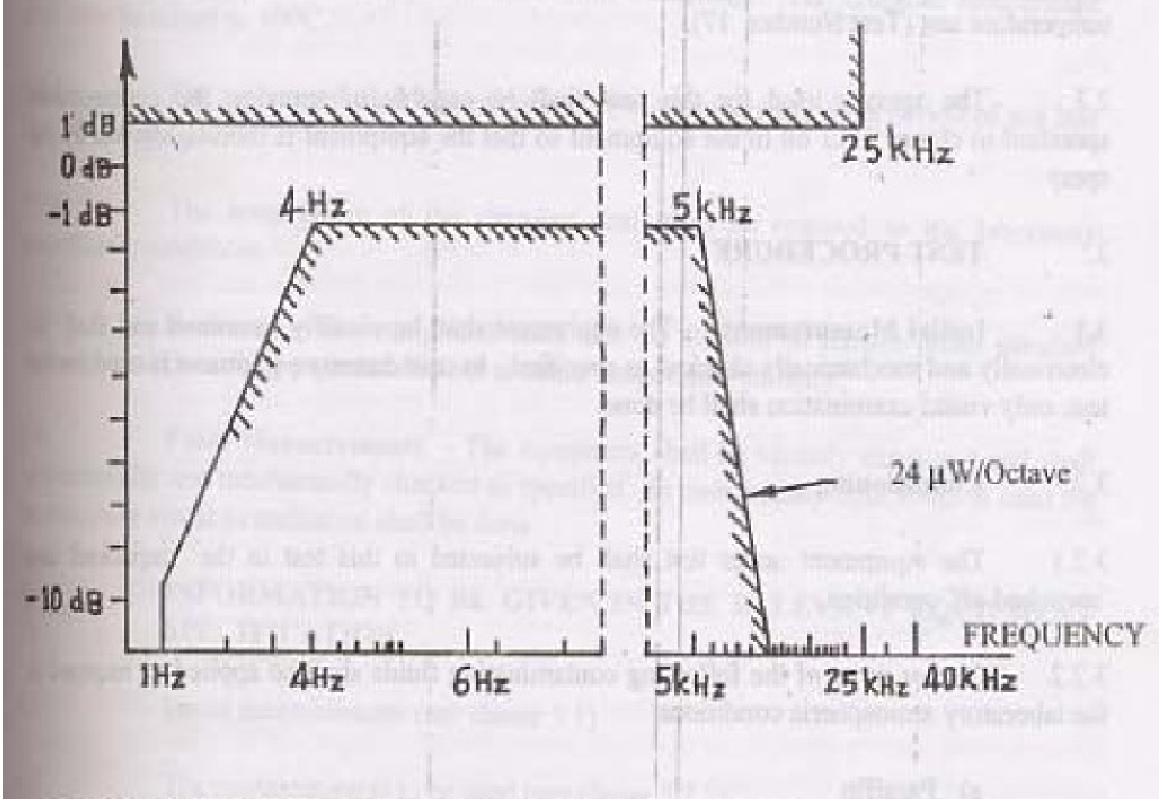


FIGURE 4.5-1 (PARA 2.2)



FREQUENCY RESPONSE OF THE MEASURING SYSTEM FOR BUMP TEST

FIGURE 4.5-2 (PARA 2.6.3)

TEST NUMBER 6
CONTAMINATION

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment to withstand contamination from fuels, oils and such other substances that may be encountered in Service use and storage.

2. TEST EQUIPMENT

2.1 A dry heat chamber and a sprayer shall be used for this test.

2.2 The dry heat chamber shall conform to the requirements specified in the high temperature test (Test Number 17).

2.3 The sprayer used for this test shall be capable of spraying the contaminants specified in clause 3.2.2 on to the equipment so that the equipment is thoroughly wet by the spray .

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

3.2 **Conditioning**

3.2.1 The equipment under test shall be subjected to this test in the `unpacked' and `switched off' condition.

3.2.2 One or more of the following contaminating fluids shall be applied as required at the laboratory atmospheric conditions:

a) Paraffin
b) Petrol
c) Lubricating oil
d) Hydraulic fluids
e) Ester based lubricating oils

Note : 1 When the equipment is to be subjected to more than one contaminants they may be applied in succession.

2 Precautions must be taken to safeguard the operators and their clothing from the effects corrosive or toxic contaminants and to avoid explosion or ignition of flammable vapours during the test.

3.2.3 The equipment shall be thoroughly wetted by the contaminating fluid or fluids which may be applied by brush, dip or spray according to the geometry of the equipment and the nature of contaminating fluid.

3.2.4 After spraying with the contaminant specified in clause 3.2.2, the equipment, while still being under the laboratory atmospheric conditions, shall be introduced into the dry heat chamber, the latter also being under the same conditions. The chamber temperature shall then be raised to 50°C.

3.2.5 The equipment shall be maintained at this temperature for a period of not less than 48 hours.

3.2.6 The temperature of the chamber shall then be restored to the laboratory atmospheric conditions.

3.3 **Recovery** - The equipment shall then be allowed to remain under standard recovery conditions for a period sufficient to attain temperature stability.

3.4 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 The contaminant (s) to be used (see clause 3.2.2)

4.3 Final measurements (see clause 3.4)

4.4 Any deviation from the normal test procedure.

TEST NUMBER 7
CORROSION (ACID)

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use and/or storage under the influence of atmospheres containing Sulphur dioxide .

2. TEST CHAMBER

2.1 A acid spray chamber meeting the requirements specified in clauses 2.2 to 2.6 shall be used for this test.

Note : The chamber used for this test is similar in all respects to the chamber specified in Test Number 8 Corrosion (Salt).

2.2 The acid spray chamber shall be constructed from materials that will not be affected adversely by the corrosive influence of the Sulphur dioxide solution used in this test.

2.3 The acid mist shall freely circulate around the equipment under test. There shall be no direct impingement of the acid mist on the equipment under test. The liquid which has come in contact with the equipment under test shall not be allowed to return to the reservoir containing the solution. Drops of liquid condensate accumulating on the walls, ceiling and other parts of the chamber shall not fall on the equipment under test.

2.4 The chamber shall be properly vented to prevent pressure build up inside the chamber.

2.5 The acid spray shall be produced by an atomiser employing compressed air which is free from impurities.

2.6 It shall be possible to adjust the air pressure for spraying of the solution in the chamber such that the quantity of acid solution sprayed per hour shall be approximately one percent of the volume of the chamber.

2.7 The acid spray chamber or a humidity chamber shall be used for storage of the equipment under test for exposure to the conditions specified in clauses 3.3.1.4 and 3.3.2.4. Whichever chamber is used for this purpose, it shall be capable of maintaining its working space at a temperature of 35ºC ± 2 degC and a relative humidity of 90 to 95 percent during the periods of storage of the equipment under test. The chamber used for this purpose shall satisfy the requirements specified for damp heat chamber in the Damp Heat Test (Test Number 10).

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

3.2 **Preparation of Acid Solution**

3.2.1 The acid solution to be sprayed shall consist of a solution of Sulphur - dioxide in distilled water. The composition of the solution shall be 0.3 percent (W/V) Sulphur dioxide in distilled water. The solution shall be prepared as per Clauses 3.2.2 to 3.2.3.

3.2.2 A small quantity of distilled water at ambient temperature shall be saturated with sulphur dioxide (use of a fume cup board is desirable). This takes about half an hour. Towards the end of this period, the temperature of the solution shall be raised to 36ºC. This will yield a stock solution containing approximately 6 percent (W/V) Sulphur dioxide in distilled water. The stock solution shall be kept in a well stoppered dark bottle in a cool place and used within 28 days. (Readily available Sulphur dioxide solution of required concentration may also be used).

3.2.3 The test solution shall be prepared by diluting 5 ml of stock solution with 95 ml of distilled water. It shall be kept in a well stoppered bottle in a cool place and used within 7 days.

> **Caution** - Sulphur dioxide and solutions of Sulphur dioxide are harmful to human beings and clothing. Operators carrying out this test must take precautions. They should not enter the chamber during spraying and the chamber should be purged with clean air to lower the concentration of Sulphur dioxide in the air of the chamber to a level acceptable to a safety limits before they enter after spraying. Rubber gloves should be used to handle equipment. If necessary, a suitable respirator should be worn.

3.3 **Conditioning** - The equipment under test shall be subjected to this test in its 'unpacked' and 'switched off' condition. Two procedures are specified for this test. The equipment shall be subjected to one of these procedures as specified.

3.3.1 **Procedure - 1.**

3.3.1.1 The equipment under test, while being under the laboratory atmospheric conditions, shall be introduced into the acid spray chamber, the latter also being under the same conditions.

3.3.1.2 The equipment shall then be exposed to the acid mist. with the spray operating for a period of 2 hours under the laboratory atmospheric conditions.

3.3.1.3 The quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

3.3.1.4 The equipment shall then be stored at a temperature of 35°C ± 2 degC and relative humidity of 90 to 95 percent for a period of 7 days.

3.3.1.5 The procedure specified in clauses 3.3.1.2 to 3.3.1.4 constitutes one cycle. The equipment shall be subjected to a total of four consecutive cycles as above.

3.3.1.6 The equipment shall then be removed from the chamber and shall be examined for corrosion and deterioration of metal parts, finishes, materials, components and contact materials.

3.3.2 **Procedure 2**

3.3.2.1 The equipment under test, while being under laboratory atmospheric conditions, shall be introduced into the acid spray chamber, the latter also being under the same conditions.

3.3.2.2 The equipment shall then be exposed to the acid mist with the spray operating for a period of 2 hours under the laboratory atmospheric conditions.

3.3.2.3 The quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

3.3.2.4 The equipment shall then be stored at a temperature of 35°C ± 2 degC and a relative humidity of 90 to 95 percent for a period of 22 hours.

3.3.2.5 The procedure specified in Clauses 3.3.2.2 to 3.3.2.4 constitutes one cycle.

The equipment shall be subjected to a total of three consecutive cycles as above.

3.3.2.6 The equipment shall then be removed from the chamber and shall be examined for corrosion and deterioration of metal parts, finishes, materials, components and contact materials.

3.4 **Recovery** - If required, the equipment may be washed in running tap water for 5 minutes, rinsed in distilled water or demineralised water, then shaken by hand or subjected to airblast to remove droplets of water and dried for 1 hour at +55ºC ± 2 degC. The equipment shall then be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

3.5 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial Measurements (see clause 3.1)

4.2 The applicable procedure (see clause 3.3)

4.3 Recovery (see clause 3.4)

4.4 Final Measurements (see clause 3.5)

4.5 Any deviation from the normal test procedure.

TEST NUMBER 8
CORROSION (ALKALINE)

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use and/ or storage under the influence of atmosphere containing Potassium hydroxide.

2. TEST CHAMBER

2.1 An alkaline spray chamber meeting the requirements specified in Clauses 2.2 to 2.6 shall be used for the test.

Note : The chamber used for the test is similar in all respect to the chamber specified in Test No. 9 Corrosion (Salt).

2.2 The alkaline spray chamber shall be constructed from materials that will not be affected adversely by the influence of Potassium hydroxide solution used in this test.

2.3 The alkaline mist shall freely circulate around the equipment under test. There shall be no direct impingement of the alkaline mist on the equipment under test. The liquid which has come in contact with the equipment under test shall not be allowed to return to the reservoir containing the solution. Drops of liquid condensate accumulating on the walls, sealing and other parts of the chamber shall not fall on the equipment under test.

2.4 The chamber shall be properly vented to prevent pressure build up inside the chamber.

2.5 The alkaline spray shall be produced by an atomizer employing compressed air which is free from impurities.

2.6 It shall be possible to adjust the air pressure for spraying of the solution in the chamber such that the quantity of alkaline solution sprayed per hour shall be approximately 1% of the volume of the chamber.

2.7 The alkaline spray chamber or a humidity chamber shall be used for storage of the equipment under test for exposure to the conditions specified in clauses 3.3.1.4 and 3.3.2.4. Whichever chamber is used for this purpose it shall be capable of maintaining its working space at a temperature of $35^{o}C \pm 2$ degC and a relative humidity of 90 to 95% during the periods of storage of the equipment under test. The chamber used for this purpose shall satisfy the requirement specified for damp heat chamber in the Damp Heat Test (Test No. 10).

3. TEST PROCEDURE

3.1 **Initial Measurements**:

The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

3.2 **Preparation of Alkaline solution.**

The alkaline solution to be sprayed shall consist of a solution of Potassium hydroxide in distilled water. The composition of the solution shall be 10% (Weight/Volume) Potassium hydroxide in distilled water.

> **CAUTION** : Potassium hydroxide and solutions of Potassium hydroxide are harmful to human beings and clothing. Operators carrying out this test must take precautions. They should not enter the chamber during spraying and the chamber should be purged with clean air to lower the concentration of Potassium hydroxide in the air of the chamber to a level acceptable to a safety limit before they enter after spraying. Rubber gloves should be used to handle equipment. If necessary, a suitable respirator should be worn.

3.3 **Conditioning.**

The equipment under test shall be subjected to this test in its 'unpacked' and 'switched off' condition. Two procedures are specified for this test. The equipment shall be subjected to one of these procedures as specified.

3.3.1 **Procedure – 1**

3.3.1.1 The equipment under test, while being under the laboratory atmospheric conditions, shall be introduced into the alkaline spray chamber, the latter also being under the same conditions.

3.3.1.2 The equipment shall then be exposed to the alkaline mist with the spray operating for a period of 2 hours under the laboratory atmospheric conditions.

3.3.1.3 The quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

3.3.1.4 The equipment shall then be stored at a temperature of 35°C $\pm$ 2 degC and relative humidity of 90 to 95 percent for a period of 7 days.

3.3.1.5 The procedure specified in Clauses 3.3.1.2 to 3.3.1.4. constitutes one cycle. The equipment shall be subjected to a total of four consecutive cycles as above.

3.3.1.6 The equipment shall then be removed from the chamber and shall be examined for corrosion and deterioration of metal parts, finishes, materials, components and contact materials.

3.3.2 **Procedure – 2**

3.3.2.1 The equipment under test, while being under laboratory atmospheric conditions, shall be introduced into the alkaline spray chamber, the latter also being under the same conditions.

3.3.2.2 The equipment shall then be exposed to the alkaline mist with the spray operating for a period of 2 hours under the laboratory atmospheric conditions.

3.3.2.3 The quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

3.3.2.4 The equipment shall then be stored at a temperature of 35°C $\pm$ 2degC and relative humidity of 90 to 95 percent for a period of 22 hours.

3.3.2.5 The procedure specified in Clauses 3.3.2.2 to 3.3.2.4. constitutes one cycle. The equipment shall be subjected to a total of three consecutive cycles as above.

3.3.2.6 The equipment shall then be removed from the chamber and shall be examined for corrosion and deterioration of metal parts, finishes, materials, components and contact materials

3.4 **Recovery**

3.4.1 If required, the equipment may be washed in running tap water for 5 minutes,

rinsed in distilled water or demineralised water, then shaken by hand or subjected to air blast to remove droplets of water and dried for 1 hour at + 55°C $\pm$ 20degC. The equipment shall then be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

3.5 **Final Measurements**

3.5.1 The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial Measurements (see clause 3.1)

4.2 The applicable procedure (see clause 3.3)

4.3 Recovery (see clause 3.4)

4.4 Final Measurements (see clause 3.5)

4.5 Any deviation from the normal test procedure.

TEST NUMBER 9
CORROSION (SALT/SALT FOG)

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use and/or storage in salt laden atmosphere. This test is intended mainly for evaluating the quality and uniformity of protective coatings.

2. TEST CHAMBER

2.1 A salt spray chamber meeting the requirements of clauses 2.2 to 2.6 shall be used for this test.

2.2 The salt spray chamber shall be constructed from material, that will not be affected adversely by the corrosive influence of the salt mist.

2.3 The salt mist shall freely circulate around the equipment under test. There shall be no direct impingement of salt mist on the equipment under test. The liquid which has come in contact with the equipment under test, shall not be allowed to return to the salt solution reservoir. Drops of liquid condensate accumulating on the walls, ceiling and other parts of the chamber shall not fall on the equipment under test.

2.4 The chamber shall be properly vented to prevent pressure build-up inside the chamber.

2.5 The salt spray shall be produced by atomiser employing compressed air which is free from all impurities.

2.6 It shall be possible to adjust the air pressure for the spraying of salt solution in the chamber such that the quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

2.7 The salt mist chamber or a humidity chamber shall be used for the storage of the equipment under test for exposure to the condition specified in clause 3.3.1.4. or 3.3.2.4. Whichever chamber is used for this purpose, it shall be capable of maintaining its working space at a temperature of 35°C ± 2 degC and relative humidity of 90 to 95 percent during the periods of storage of the equipment under test. The chamber used for this purpose shall satisfy the requirements specified for damp heat chamber in the damp heat test Test Number 10).

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

3.2 **Preparation of Salt Solution**

3.2.1 Salts, given in Table 4.9-1 shall be dissolved in distilled water for preparation of the salt solution. The proportions of the ingredients in the solution are to be within 10 percent of those given in the Table 4.9- 1.

TABLE 4.9-1 COMPOSITION OF SALT SOLUTION
(Clause 3.2.1)

INGREDIENT	QUANTITY PER 1 LITRE OF SOLUTION
Sodium chloride ($NaCl$)	26.5 g
Magnesium chloride ($MgCl_2$)	2.4 g
Magnesium sulphate ($MgSO_4$)	3.3 g
Calcium chloride ($CaCl_2$)	1.1 g
Potassium chloride (KCl)	0.73 g
Sodium bicarbonate ($NaHCO_3$)	0.20 g
Sodium bromide ($NaBr$)	0.28 g
Distilled Water	To make up 1 litre of solution

3.2.2 Fresh solution shall be used for each spray.

3.3 **Conditioning** - The equipment under test shall be subjected to this test in its "unpacked" and 'switched- off" condition. Two procedures are specified for this test. Third procedure is applicable only for Airborne Equipment, as specified in the relevant Equipment specification. The equipment shall be subjected to one of these procedures as specified

3.3.1 **Procedure 1**

3.3.1.1 The equipment under test, while being under the laboratory atmospheric conditions shall be introduced into the salt spray chamber, the latter also being under the same conditions.

3.3.1.2 The equipment shall then be exposed to the salt mist with the spray operating, for a period of 2 hours under the laboratory atmospheric conditions.

3.3.1.3 The quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

3.3.1.4 The equipment shall then be stored at a temperature of 35ºC ± 2 degC and a relative humidity of 90 to 95 percent for a period of 7 days.

3.3.1.5 The procedure specified in clauses 3.3.1.2 to 3.3.1.4 constitutes one cycle. The equipment shall be subjected to a total of four consecutive cycles as above.

3.3.1.6 The equipment shall then be removed from the chamber and shall be examined for corrosion and deterioration of metal parts, finishes, materials and components.

3.3.2 **Procedure 2**

3.3.2.1 The equipment under test, while being under laboratory atmospheric conditions shall be introduced into the salt spray chamber, the latter also being under the same conditions.

3.3.2.2 The equipment shall then be exposed to the salt mist, with the spray operating, for a period of 2 hours under the laboratory atmospheric conditions.

3.3.2.3 The quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

3.3.2.4 The equipment shall then be stored at a temperature of 35ºC ± 2 degC and a relative humidity of 90 to 95 percent for a period of 22 hours.

3.3.2.5 The procedure specified in clauses 3.3.2.2 to 3.3.2.4 constitutes one cycle. The equipment shall be subjected to a total of three consecutive cycles as above.

3.3.2.6 The equipment shall then be removed from the chamber and shall be examined for corrosion and deterioration of metal parts, finishes, materials and components.

3.3.3 **Procedure 3**

3.3.3.1 The equipment under test while being under laboratory atmospheric conditions shall be introduced into the salt spray chamber, the latter also being under the same conditions.

3.3.3.2 The equipment shall then be exposed to the salt mist with the spray operating for a period of 48 hours or as specified in the equipment specification laboratory atmospheric condition.

3.3.3.3 The quantity of solution sprayed per hour shall be approximately one percent of the volume of the chamber.

3.3.3.4 The equipment shall then be stored at standard ambient atmosphere for 48 hours or as specified in the equipment specification for drying.

3.3.3.5 At the end of drying period the equipment shall be operated and the results documented for comparison in the pre test data.

3.3.3.6 The equipment shall then be visually inspected. If necessary to aid in examination, a gentle wash in running water may be used.

3.4 **Recovery** - If required, the equipment may be washed in running tap water for 5 minutes, rinsed in distilled water or demineralised water, then shaken by hand or subjected to air blast to remove droplets of water and dried for 1 hour at 55ºC ± 2º degC. The equipment shall then be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

3.5 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified. In case dummy equipment is used for the test, only visual examination shall be done.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 The applicable procedure (see clause 3.3)

4.3 Recovery (see clause 3.4)

4.4 Final measurements (see clause 3.5)

4.5 Any deviation from the normal test procedure.

TEST NUMBER 10
DAMP HEAT

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use under conditions of high humidity.

2. TEST CHAMBER

2.1 A damp heat chamber meeting requirements of clauses 2.2 to 2.8 shall be used for this test.

2.2 The damp heat chamber shall be capable of maintaining at any point in its working space a temperature, with a tolerance of ± 0.5 degC, of any value up to 40ºC ± 2 degC with a relative humidity of not less than 95 percent.

Note : The temperature tolerance of ± 2 degC is introduced in order to take account of absolute errors in the measurements of slow change of this temperature and of temperature variation in the working space. The temperature control shall keep the short term temperature fluctuation within ± 0.5 degC.

2.3 Condensed water shall be continuously drained from the chamber and shall not be used again until it has been purified.

2.4 When the humidity conditions in the chamber are obtained by using demineralised water, this shall have a resistivity of not less than 500 ohm meters.

2.5 The temperature and relative humidity of the chamber shall be monitored by sensing devices suitably located in the working space.

2.6 The conditions prevailing throughout the working space shall be uniform and shall be as similar as possible to those prevailing in the immediate vicinity of sensing devices.

2.7 The properties of the equipment or its operation shall not appreciably influence the conditions within the working space of chamber.

2.8 Any condensed water from the walls and roof of the chamber shall not fall on the equipment.

3. TEST PROCEDURE

3.1 The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning**

3.2.1 The equipment under test shall be subjected to the test in its' unpacked' and 'switched-off' condition.

3.2.2 The equipment under test, while being under the laboratory atmospheric conditions shall be introduced into the chamber, the latter also being under the same conditions. The temperature and relative humidity of the chamber shall then be raised to 40ºC ± 2 degC and not less than 95 percent respectively, over a period of not less than one hour.

3.2.3 The equipment shall be conditioned under these conditions for a period of 16 hours.

3.2.4 During the last 30 minutes of the period, specified in clause 3.2.3, the equipment shall be switched on and a performance check, as specified, shall be carried out.

Note : In the case equipment having high heat dissipation and requiring large volume of fresh air intake for cooling purposes, the performance check will be done at the nearest possible, specified test conditions depending on the limitations of the chamber.

3.2.5 The temperature of the chamber, shall then be restored to the laboratory atmospheric conditions in not less than an hour. Saturation of the chamber atmosphere with water vapour shall occur during this period. The equipment shall then be exposed to these conditions for a period of not less than 3 hours.

3.3 **Recovery** - The equipment shall be recovered from the chamber and shall be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

Note : The relevant equipment specification may specify whether removal of condensed moisture is required and recommended method of removal, before final measurements.

3.4 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1).

4.2 Details of performance check (see clause 3.2.4)

4.3 Final measurements (see clause 3.4)

4.4 Any deviation from the normal test procedure.

TEST NUMBER 11
DRIP PROOF

1. OBJECT

1.1 To determine the suitability of unsealed electronic and electrical equipment in service to water droplets falling on it.

2. TEST EQUIPMENT

2.1 One or more dispensers fitted with nozzles of the type shown in Fig. 4.11-1 shall be used for conducting this test.

2.2 The number of dispenser units employed shall be sufficient to cover the area of the equipment surface under test. In case of large areas, it may be acceptable for sections to be conditioned sequentially. In this case the areas must overlap and each is to be conditioned for specified duration.

2.3 The water used for the test shall be clean tap water. The water from the nozzle shall fall vertically downwards on to the surface of the equipment from a height of one metre. The water level in dispenser shall be maintained constant by adjusting the water flow to the dispenser.

2.4 Distance between two dispensers shall be 25 mm and distance between water level and dispenser level shall be 76 $\pm$ 1.6 mm. Total level of water shall be 300 mm.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning** - The equipment shall be subjected to this test in its unpacked condition.

3.2.1 The equipment under test, while being under the laboratory atmospheric conditions shall be positioned below the drip dispenser in its normal operational attitude.

3.2.2 Unless otherwise specified, any removable covers of the equipment shall be fixed in position as in normal operations. Sockets, terminal boxes, pipe and other entries shall be protected either by fitting the normal connectors and pipes or equivalent sealing blocks.

3.2.3 The equipment shall be subjected to this test for a period of 15 minutes.

3.2.4 The equipment shall be operated during this test.

3.2.5 At the conclusion of the test, the equipment shall be visually examined for ingress of water.

3.3 **Recovery** - Unless otherwise specified, all the external surfaces of the equipment shall be dried by wiping or by applying a clean blast of air at room temperature.

3.4 **Final Measurements** - The equipment shall then be visually examined and electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial Measurements (see clause 3.1)

4.2 Details of operation (see clause 3.2.4)

4.3 Final measurements (see clause 3.4)

4.4 Any deviation from the normal test procedure.

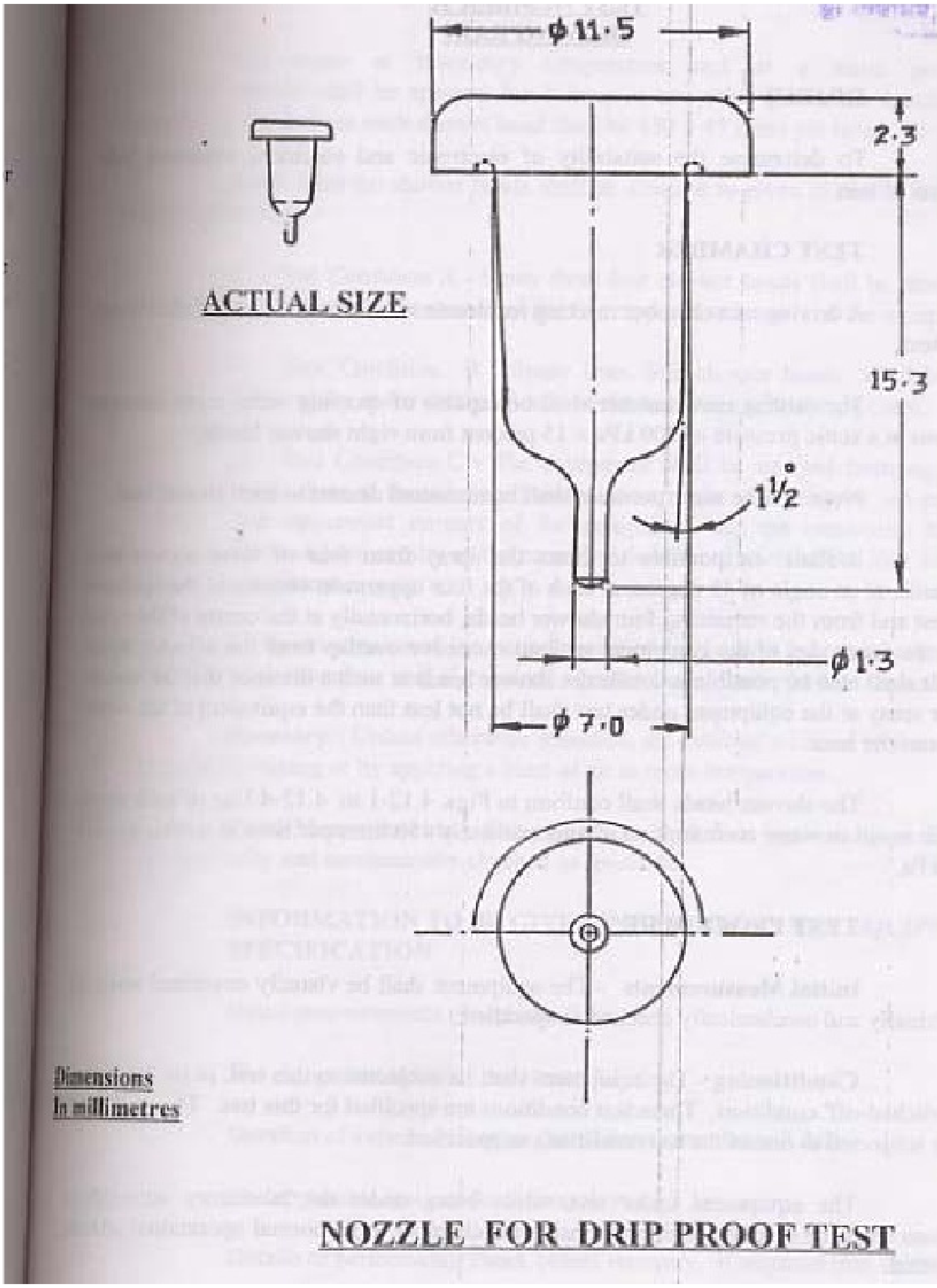

ϕ11·5
2·3
ACTUAL SIZE
15·3
1½°
ϕ1·3
ϕ7·0
Dimensions
In millimetres
NOZZLE FOR DRIP PROOF TEST

FIGURE 4.11-1

TEST NUMBER 12
DRIVING RAIN

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment under conditions of rain.

2. TEST CHAMBER

2.1 A driving rain chamber meeting requirements of clause 2.2 to 2.4 shall be used for this test.

2.2 The driving rain chamber shall be capable of spraying water under laboratory conditions at a static pressure of 200 kPa ± 15 percent from eight shower heads.

Note : The static pressure shall be measured nearest to each shower head.

2.3 It shall be possible to direct the spray from four of these shower heads downwards, at an angle of 45 degree, at each of the four uppermost corners of the equipment under test and from the remaining four shower heads, horizontally at the centre of the area of each of the four sides of the equipment without excessive overlap from the adjacent shower heads. It shall also be possible to locate the shower heads at such a distance that the intensity of water spray at the equipment under test shall be not less than the equivalent of the rainfall of 250 mm per hour.

2.4 The shower heads shall conform to Figs. 4.12-1 to 4.12-4 Use of such shower head will result in water consumption of approximately 450 litres per hour at a static pressure of 200 kPa.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning** - The equipment shall be subjected to this test, in its `unpacked' and `switched-off' condition. Three test conditions are specified for this test. The equipment shall be subjected to one of the test conditions as specified.

3.2.1 The equipment under test, while being under the laboratory atmospheric conditions shall be suitably positioned inside the chamber in its normal operational attitude as specified.

3.2.2 Tap water at laboratory temperature and at a static pressure of 200 kPa ±15 percent shall be sprayed for 1 hour or any other period as specified. The consumption of water from each shower head shall be 450 ± 45 litres per hour.

3.2.3 Spray from the shower heads shall be directed as given in one of the three test conditions given below:

a) Test Condition A - Spray from four shower heads shall be directed at an angle of 45 degree at each of the four uppermost corners of the equipment.

b) Test Condition B - Spray from four shower heads shall be directed horizontally at the centre of each of the four sides of the equipment.

c) Test Condition C - The equipment shall be sprayed from eight shower heads, four of them being directed at an angle of 45 degree on each of the four uppermost corners of the equipment and the remaining four being directed horizontally at the centre of the area of each of the four sides of the equipment.

3.2.4 At the conclusion of the period specified in clause 3.2.2, the equipment shall be removed from the chamber and, if, required a performance check shall be carried out.

3.3 **Recovery** - Unless otherwise specified, the external surfaces of the equipment shall be dried by wiping or by applying a blast of air at room temperature.

3.4 **Final Measurements** - The equipment shall then be visually examined and shall be electrically and mechanically checked as specified

4. <u>INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION</u>

4.1 Initial measurements (see clause 3.1)

4.2 The equipment attitude (see clause 3.2.1)

4.3 Duration of exposure, if other than 1 hour (see clause 3.2.2)

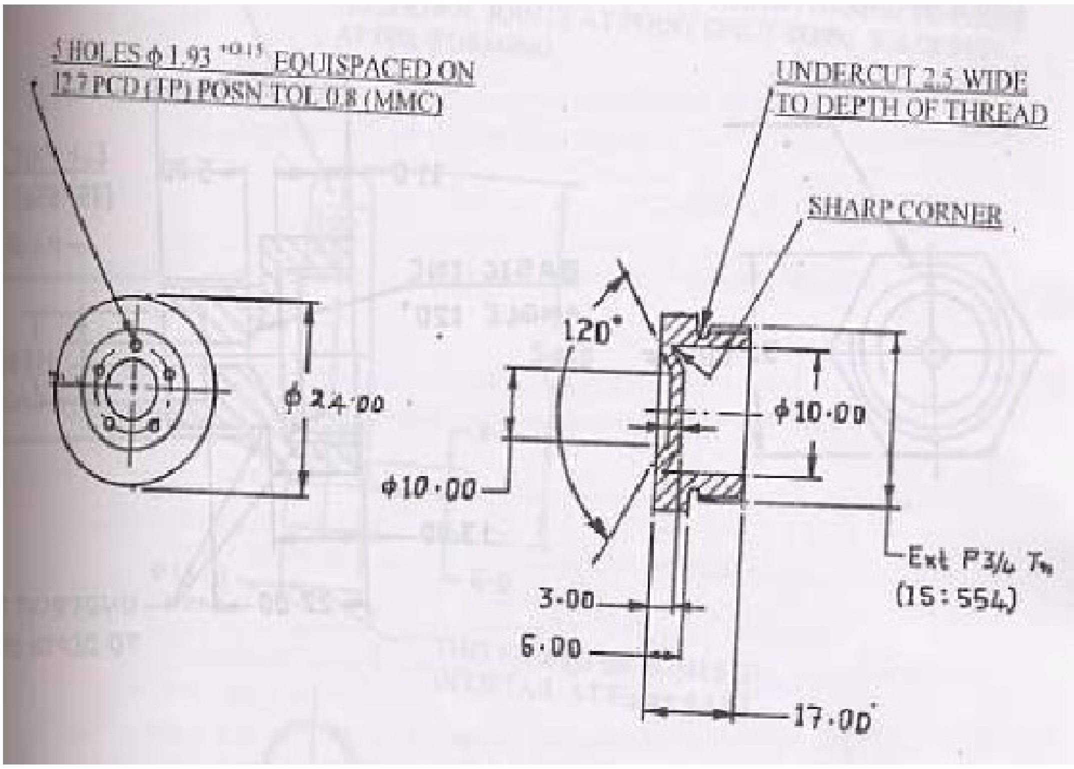
4.4 The applicable test condition (see clause 3.2.3)

4.5 Details of performance check before recovery, if required (see clause 3.2.4).

4.6 Final measurements (see clause 3.4).

4.7 Any deviation from the normal test procedure.

FIGURE 4.12-1



Notes 1: MATERIAL BRASS

2: DIMENSIONS ARE IN MILLIMETRES
TOLERANCES ±0.15 UNLESS STATED OTHERWISE

3: ALL BURRS TO BE REMOVED. EXTERNAL EDGES TO BE RADIUSED OR CHAMFERED 0.25 Min. INTERNAL CORNERS TO BE RADIUSED OR CHAMFERED 0.5 Max.

4: M/C SURFACE ROUGHNESS $^{3.2}\surd$ UNLESS OTHERWISE STATED

FIGURE 4.12-2

SPRAY

Notes

1: MATERIAL BRASS

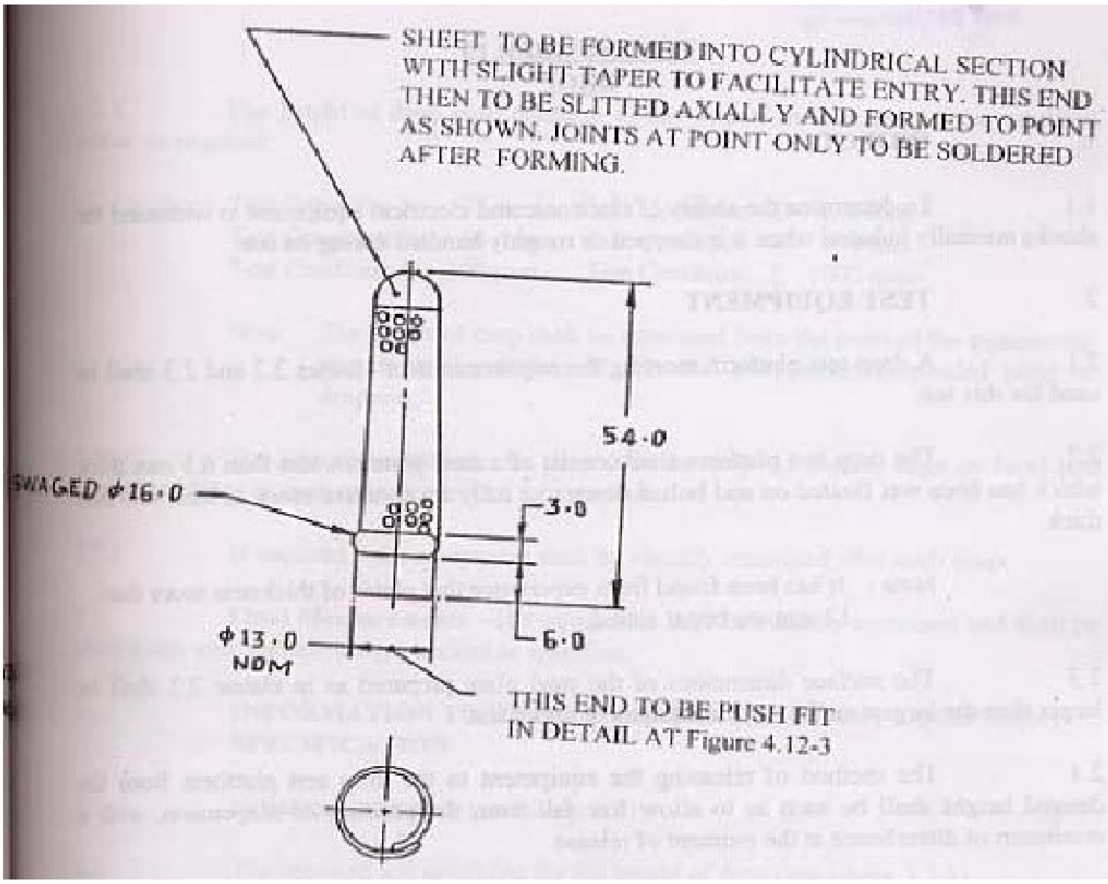
2: DIMENSIONS ARE IN MILLIMETRES
TOLERANCES ±0.15 UNLESS STATED OTHERWISE

3: ALL BURRS TO BE REMOVED. EXTERNAL EDGES TO BE RADIUSED OR CHAMFERED 0.25 Min. INTERNAL CORNERS TO BE RADIUSED OR CHAMFERED 0.5 Max.

4: M/C SURFACE ROUGHNESS $^{3.2}\surd$ UNLESS OTHERWISE STATED

FIGURE 4.12-3

NUT



Notes 1: MATERIAL 1mm COLD ROLLED BRASS SHEET PERFORATED 0.8 DIA HOLES ON STAGGERED PITCHES 1.5 APPROXIMATELY.

2: DIMENSIONS ARE IN MILLIMETRES
TOLERANCES ±0.4 UNLESS STATED OTHERWISE

3: ALL BURRS TO BE REMOVED. EXTERNAL EDGES TO BE RADIUSED OR CHAMFERED 0.25 Min. INTERNAL CORNERS TO BE RADIUSED OR CHAMFERED 0.5 Max.

4: M/C SURFACE ROUGHNESS $^{3.2}\surd$ UNLESS OTHERWISE STATED

FIGURE 4.12-4

TEST NUMBER 13
DROP

1. OBJECT

1.1 To determine the ability of electronic and electrical equipment to withstand the shocks normally induced when it is dropped or roughly handled during its use.

2. TEST EQUIPMENT

2.1 A drop test platform meeting the requirements of clauses 2.2 and 2.3 shall be used for this test.

2.2 The drop test platform shall consist of a steel plate not less than 6.5 mm thick which has been wet floated on and bolted down to a fully set concrete block at least 460 mm thick.

Note : It has been found from experience that plates of thickness more than 12 mm are better suited

2.3 The surface dimensions of the steel plate prepared as in clause 2.2 shall be larger than the largest surface of the equipment under test.

2.4 The method of releasing the equipment to the drop test platform from the desired height shall be such as to allow free fall from the position of suspension, with a minimum of disturbance at the moment of release.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning**

3.2.1 The equipment under test shall be subjected to this test in its `unpacked' and `switched-off' condition.

3.2.2 The equipment shall be allowed to fall freely on the drop test platform.

3.2.3 The height of drop shall conform to any one of the test conditions specified below as required:

Test Condition A	25 mm	Test Condition D	250 mm
Test Condition B	50 mm	Test Condition E	500 mm
Test Condition C	100 mm	Test Condition F	1000 mm

Note : The height of drop shall be measured from the point of the equipment, nearest to the surface of the steel plate, when suspended prior to dropping.

3.2.4 The equipment attitude for drop (that is, drop on corner, edge or face) and number of drops in each attitude shall be as specified.

3.2.5 If required, the equipment shall be visually examined after each drop.

3.3 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 The required test condition for the height of drop (see clause 3.2.3).

4.3 The equipment attitude (s) and number of drops in each attitude (see clause 3.2.4)

4.4 Whether visual examination is required at the end of each drop (see clause 3.2.5)

4.5 Final measurements (see clause 3.3)

4.6 Any deviation from the normal test procedure.

TEST NUMBER 14
DUST

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use and/or storage under dust laden environment.

2. TEST CHAMBER

2.1 A dust chamber meeting requirements of clauses 2.2 and 2.3 shall be used for this test.

2.2 The dust chamber shall be capable of circulating dust in its working space in such a manner as to produce a dust concentration sufficient to deposit requisite quantity of dust in the dust measuring device as specified in clause 2.6.

Note : Fig. 4.14-1 indicates a suggested layout the dust inducing components in the dust chamber.

2.3 The chamber shall also be capable of maintaining its working space at a temperature of 40ºC ± 3 degC with a relative humidity not exceeding 50 percent. In all other respects, the chamber shall satisfy the requirements specified for the test chamber in high temperature test (Test Number 17).

2.4 The dust used for this test shall be dry. It shall be heated to 40ºC ± 3 degC before the agitation of the dust in the chamber is commenced. Sufficient quantity of dust shall be made available in the chamber originally, in order to give the specified dust concentration throughout the chamber.

2.5 The dust shall conform to the following requirements.

2.5.1 **Physical Characteristics**

a) 100 percent dust shall pass through 150 Micron IS Sieve.

b) 98 ± 2 percent dust shall pass through 106 Micron IS Sieve.

c) 90± 2 percent dust shall pass through 75 Micron IS Sieve .

d) 75 ±2 percent dust shall pass through 45 Micron IS Sieve.

2.5.2 **Chemical Composition** - The chemical composition of the dust shall be as indicated in Table 4.14-1

TABLE 4.14-1 CHEMICAL COMPOSITION OF DUST
(Clause 2.5.2)

SUBSTANCE	PERCENTAGE BY WEIGHT
SiO_2	97 to 99
Fe_2O_2	0 to 2
Al_2O_2	0 to 1
TiO	0 to 2
MgO	0 to 1
Ignition losses	0 to 1

2.6 A dust measuring device is shown in Fig. 4.14-2. The device shall be kept at any place within the dust chamber. The air shall be circulated for 5 minutes and the dust shall be allowed to settle down. The amount of dust collected in the device shall be 25 $\pm$ 5 grams.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning** - The equipment shall be subjected to this test in its `unpacked' and `switched - off' condition.

3.2.1 The equipment under test, shall be introduced into the chamber, under the laboratory atmospheric conditions, the chamber also being under the same conditions.

3.2.2 The temperature of the chamber shall then be raised to a value of 40ºC ± 3 degC. The relative humidity shall be maintained at a value not exceeding 50 percent.

3.2.3 After temperature stability has been attained, the equipment shall then be subjected to a stream of dust laden air for a period of one hour. During this period the dust concentration shall be maintained as in clause 2.2.

3.2.4 If required, equipment shall be switched on and a performance check shall be carried out at any time during the period specified in clause 3.2.3.

3.2.5 The circulation of dust shall then be discontinued and the temperature of the chamber shall be restored to the laboratory atmospheric conditions.

3.3 **Recovery** - The equipment shall be removed from the chamber and allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

3.4 **Final Measurements**. - The equipment shall be visually examined as specified, and any local accumulation of dust shall be noted. If required, the equipment shall then be electrically and mechanically checked.

Note : The accumulated dust shall be removed before electrical and mechanical checks are made. The dust shall be removed by brushing, wiping or shaking. Under no circumstances shall the dust be removed by an air blast or by vacuum cleaning.

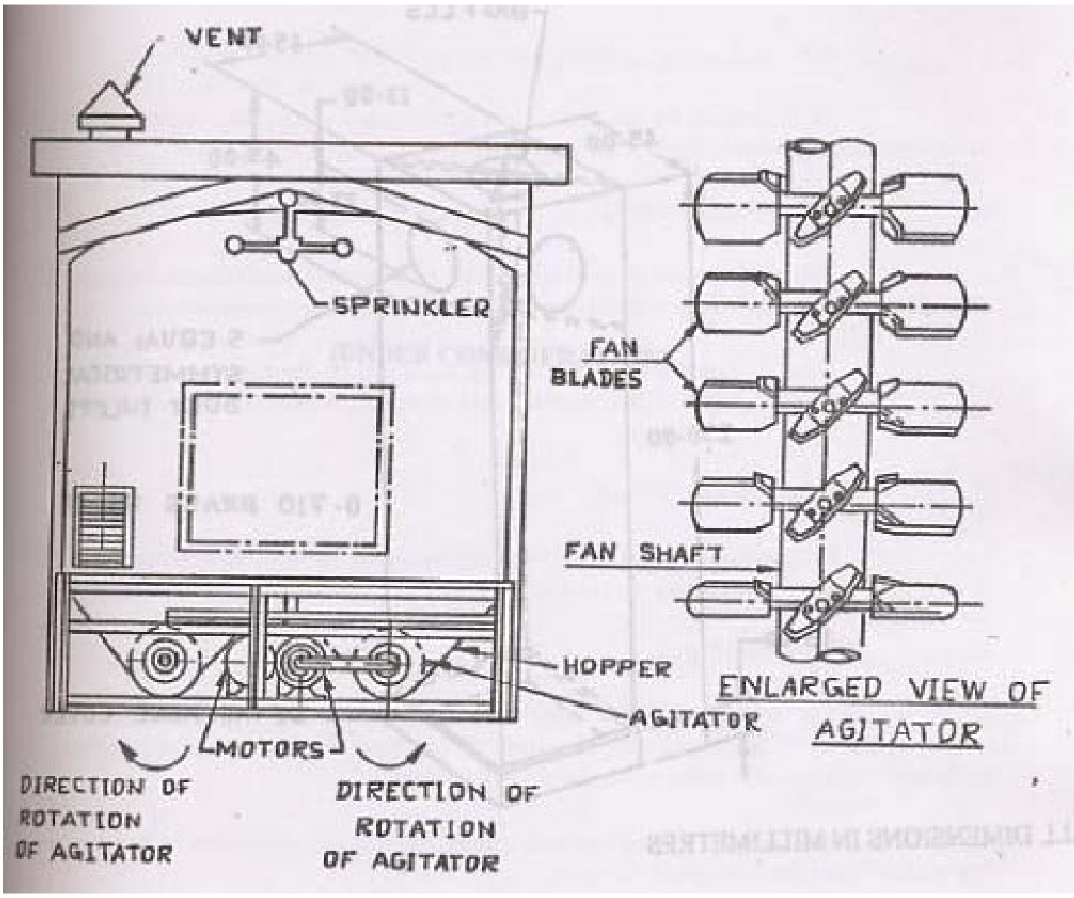
4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 Performance checks required (see clause 3.2.4)

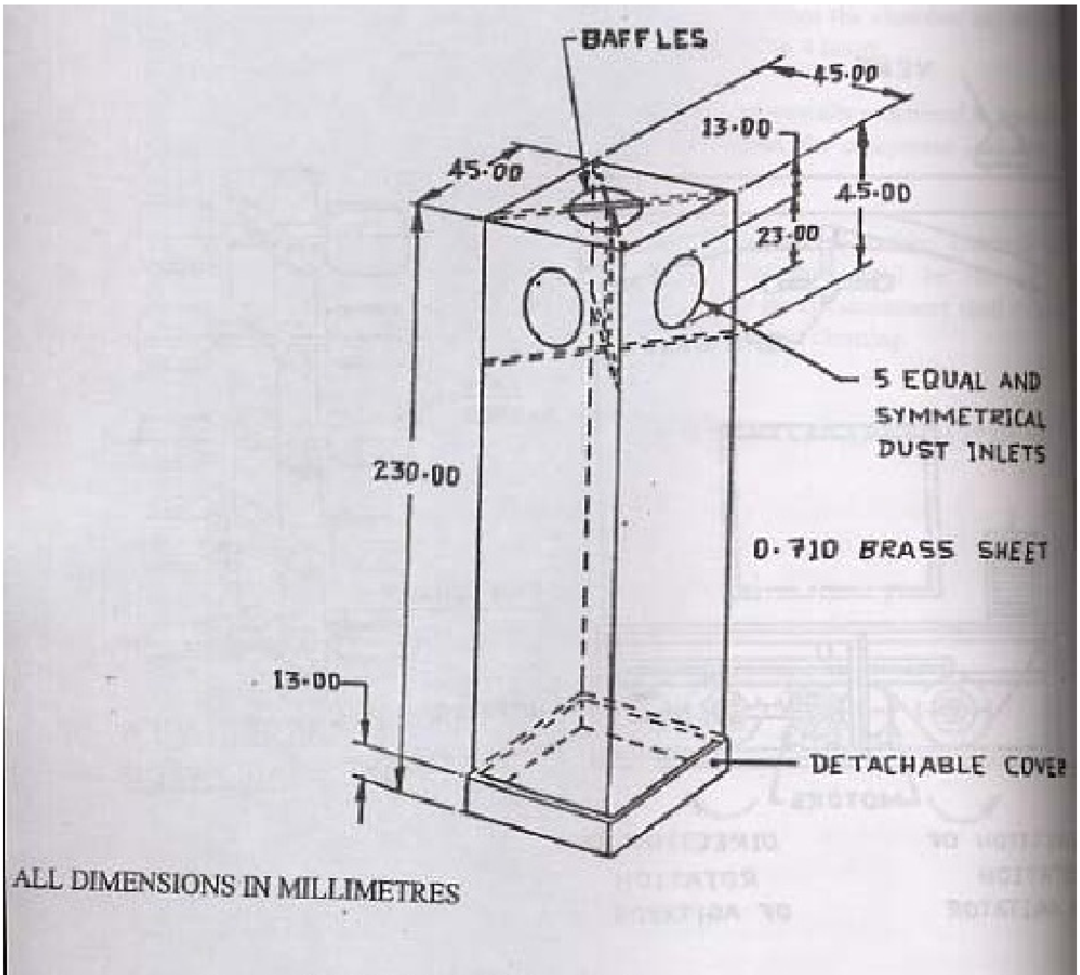
4.3 Final measurements (see clause 3.4

4.4 Any deviation from the normal test procedure.



~~**DUST CHAMBER**~~

FIGURE 4.14-1



DUST MEASURING DEVICE

FIGURE 4.14-2

TEST NUMBER 15
EXPLOSION

(UNDER CONSIDERATION)

TEST NUMBER 16
FINE MIST

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use when exposed to the conditions of fine mist of water.

2. TEST EQUIPMENT

2.1 The equipment used for this test shall be an enclosure of adequate size capable of producing a fine mist of tap water under laboratory atmospheric conditions.

Note : Fine mist of water may be generated by directing an air jet across the top of a fine jet connected to a pipe, immersed in or connected to a water supply.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified

3.2 **Conditioning**

3.2.1 The equipment under test, while being under the laboratory atmospheric conditions and in its `unpacked' and `switched-off' condition shall be introduced into the test enclosure, the latter also being under the same conditions.

3.2.2 The equipment, in its normal operational attitude, shall then be exposed to a fine mist of water for a period of one hour.

3.2.3 If required by the relevant equipment specification, the equipment shall be operated and a performance check carried out during the last 30 minutes of the period specified in clause 3.2.2.

3.2.4 The equipment shall be removed from the test enclosure and examined for ingress of water.

3.3 **Recovery** - The equipment shall be allowed to remain under standard laboratory conditions for a period of 2 to 4 hours.

3.4 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 Performance checks required (see clause 3.2.3).

4.3 Final measurements (see clause 3.4).

4.4 Any deviation from the normal test procedure.

TEST NUMBER 17
HIGH TEMPERATURE

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use and/or storage at specified high ambient temperature conditions.

2. TEST CHAMBER

2.1 A dry heat chamber meeting the requirements stated in clauses 2.2 to 2.7 shall be used for this test.

2.2 The chamber shall be capable of maintaining its working space at the appropriate high temperature severity, within the following tolerances:

a) ± 3 degC for temperatures less than 100ºC.

b) ± 5 degC for temperatures equal to or greater than 100ºC.

2.3 The relative humidity shall not exceed 50 percent.

2.4 The high temperature conditions in the chamber shall be achieved by circulating hot air and these conditions shall be maintained uniformly, throughout the working space of the chamber.

2.5 The heating elements of the chamber shall be baffled to prevent direct radiation on the equipment under test.

2.6 The temperature within the chamber shall be monitored by a temperature sensing device suitably located in its working space.

2.7 The design and construction of the chamber shall be such that any heat dissipated by the equipment during testing shall not appreciably influence the conditions within the chamber.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified

3.2 **Conditioning** - The equipment under test shall be subjected to this test in `unpacked' conditions. Six procedures are specified for this test. The equipment shall be subjected to one or more of these procedures as specified. At the beginning of each procedure the equipment shall be in its `switched-off' condition.

3.2.1 **Procedure 1**

3.2.1.1 The equipment under test, while being under laboratory atmospheric conditions, shall be introduced into the chamber, the latter also being under the same conditions. The temperature of the chamber shall then be raised to 85ºC ± 3 degC.

3.2.1.2 The equipment shall then be exposed to this temperature, either for a period sufficient to allow the equipment temperature to stabilize and then for a further period of 2 hours, or for a total period of 6 hours, whichever is less. If possible, the equipment shall be visually examined towards the end of this period to determine whether deterioration likely to impair future performance has occurred.

3.2.1.3 If the relevant equipment specification requires, performance check at the laboratory atmospheric conditions, the chamber temperature shall be restored to these conditions. The equipment shall then be subjected to recovery conditions (see clause 3.3) and final measurements (see clause 3.4) shall be made as specified in the relevant equipment specification.

3.2.1.4 At the end of clause 3.2.1.2 or 3.2.1.3 as applicable, the equipment shall be immediately subjected to conditioning in procedure 2.

3.2.2 **Procedure 2**

3.2.2.1 The chamber temperature shall be adjusted to one of the following test condition, as required.

a) Test condition A: 70ºC ± 3 degC
b) Test condition B 85ºC ± 3 degC

Note :1 When procedure 2 immediately follows conditions in clause 3.2.1.2 and test conditions B is applicable, the equipment may be directly subjected to conditions in clauses 3.2.2.3 to 3.2.2.5.

2 When procedure 2 follows conditions stated in clause 3.2.1.3 the equipment shall be reintroduced into the chamber, while the latter also is at laboratory atmospheric conditions. The chamber temperature shall then be gradually raised to that of the test conditions A or B.

3.2.2.2 The equipment temperature shall be stabilised at the appropriate test conditions stated in clause 3.2.2.1.

3.2.2.3 The equipment shall then be operated and a performance check shall be carried out as required. The equipment shall be operated for 30 minutes or for a period sufficiently long to complete the performance check, whichever is longer.

Note : 1 When the performance check takes longer than 30 minutes and the temperature rise of the equipment is excessive, the test may be divided into groups; the tests in each group to be carried out after the equipment temperature has restabilised at the chamber temperature.

2 Where practicable, temperature sensors should be fitted to all components and assemblies that are known to be near their limiting temperatures. The temperatures at these locations should be monitored and recorded throughout the test.

3.2.2.4 Unless otherwise specified, after completion of conditioning specified in clause 3.2.2.3 and while the chamber temperature is being maintained at the specified test condition, the equipment shall be switched off and its operation shall be stopped for 5 minutes after which the equipment shall be again switched on. The equipment shall then be operated for a minimum period required and a limited performance check shall be carried out only to demonstrate that it is not deranged by a hot switch-on or start-up.

3.2.2.5 The equipment shall then be switched off and immediately subjected to conditioning specified in procedure 3.

3.2.3. **Procedure 3**

3.2.3.1 The chamber temperature shall be adjusted to one of the following test conditions as required:

a) Test condition C : 55ºC $\pm$ 3 degC

b) Test condition D : 70ºC + 3 degC

3.2.3.2 After the equipment has attained the temperature stability, it shall be operated for a period of 4 hours (see Note 2 in clause 3.2.2.3).

3.2.3.3 Towards the end of the period specified in clause 3.2.3.2 preferably after internal temperatures have re- stabilised, a performance check shall be carried out.

3.2.3.4 Unless otherwise specified, the equipment, while the chamber temperature is being maintained at the specified test condition, shall then be switched off and its operation shall be stopped for 5 minutes. The equipment shall be switched on again, It shall then be operated for a minimum period required and a limited performance check shall be carried out only to demonstrate that the equipment is not deranged by hot `switch-on' or `start-up'.

3.2.3.5 The equipment shall then be immediately subjected to procedure 4 or Test Number 3 (procedure 4) as specified.

3.2.4 **Procedure 4**

3.2.4.1 The chamber temperature shall be adjusted to one of the following test conditions as required.

a) Test condition E : 70ºC $\pm$ 3 degC

b) Test condition F :100ºC $\pm$ 5 degC

3.2.4.2 The equipment temperature shall be stabilized at the appropriate test condition stated in clause 3.2.4.1.

3.2.4.3 The equipment shall then be operated for a period of 1 hour or for any other period as specified

3.2.4.4 At the end of the period specified in clause 3.2.4.3 performance check shall be carried out, If necessary, the duration specified in clause 3.2.4.3 shall be extended to allow the performance check to be completed.

3.2.4.5 Unless otherwise specified, the equipment, while the chamber temperature is being maintained at the specified test condition, shall be switched off and its operation shall be stopped for 5 minutes. The equipment shall be switched on again. The equipment shall then be operated for a minimum period required and a limited performance check shall be carried out only to demonstrate that the equipment is not deranged by hot `switch-on' or `start- up'.

3.2.4.6 The equipment shall then be immediately subjected to conditioning specified in procedure 3 or 4 of Test Number 3 as specified.

3.2.5 **Procedure 5**

3.2.5.1 The equipment under test while being under the laboratory atmospheric conditions, shall be introduced into the chamber, the latter also being under the same conditions. The chamber temperature shall then be raised to one of the following test conditions as required:

a) Test condition G: 55ºC + 3 degC

b) Test condition H: 70ºC + 3 degC

c) Test condition J: 80ºC + 3 degC

3.2.5.2 The equipment shall be exposed to this temperature for a period of 16 hours.

3.2.5.3 If required, the equipment shall be switched on and operated for the specified duration at any time during this period of exposure to high temperature. The maximum surface temperature attained by the components or materials in the equipment shall be measured and recorded, if required .

3.2.5.4 During the final hour of the period specified in clause 3.2.5.2, a performance check shall be carried out on the equipment as required.

Note : Performance check is required to be conducted after equipment internal temperatures have stabilised. For the purpose a period longer than 16 hours (see clause 3.2.5.2) is permitted, when necessary.

3.2.5.5 The temperature of the chamber shall then be restored to the laboratory atmospheric conditions.

3.2.6 **Procedure 6**

3.2.6.1 The equipment shall be subjected to one of the following test conditions, as required.

a) Test condition K : Operation at 55ºC ± 3 degC followed by storage at 70ºC ± 3 degC

b) Test condition M : Operation at 55ºC ± 3 degC followed by storage at 85ºC ± 3 degC

3.2.6.2 The equipment under test, while being under the laboratory atmospheric conditions shall be introduced into the chamber, the latter also being under the same conditions. The temperature of the chamber shall then be raised to 55ºC ± 3 degC. the equipment shall be exposed to this temperature for a period of 16 hours.

3.2.6.3 If required, the equipment shall be switched on and operated for the specified duration at any time during this period of exposure to high temperature. Unless otherwise specified, the maximum surface temperatures attained by the components or materials in the equipment shall be measured and recorded .

3.2.6.4 During the final hour of the period specified in clause 3.2.6.2 a performance check shall be carried out on the equipment as required (see Note in clause 3.2.5.4).

3.2.6.5 The temperature of the chamber shall then be raised to storage temperature corresponding to test condition K or M as specified. The equipment shall be exposed to this temperature for a period of 16 hours.

3.2.6.6 At the end of this period, the temperature of the chamber shall be restored to the laboratory atmospheric conditions.

3.3 **Recovery** - The equipment shall be removed from the chamber and shall be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

Note : For procedures, 1,2,3 and 4 the recovery conditions shall be applicable only when these procedures are not immediately followed by another procedure of the test or Test Number 3 and final measurements at laboratory atmospheric conditions are required to be made.

3.4 **Final Measurements** - The equipment shall then be visually examined and shall be electrically and mechanically checked as specified.

Note : For procedures 1,2,3, and 4, the final measurements shall be made only when the relevant equipment specification requires the performance of the equipment to be checked at the laboratory atmospheric conditions.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 The applicable procedure or procedures (see clause 3.2)

4.3 For procedure 1:

a) Applicable test conditions (see clause 3.2.1.1)
b) Details of operation and performance check (See clause 3.2.1.3)

4.4 **For procedure 2:**

a) Applicable test condition (see clause 3.2.2.1)
b) Details of operation and performance checks (see clause 3.2.2.3), and
c) Details and period of operation (see 3.2.2.3), and details of limited performance check (see clause 3.2.2.4).

4.5 **For procedure 3:**

a) Applicable test conditions (see clause 3.2.3.1)
b) Details of operation (see clause 3.2.3.2)
c) Details of performance check (see clause 3.2.3.3), and
d) Details and period of operation and details of limited performance check (see clause 3.2.3.4).

4.6 **For procedure 4:**

a) Applicable test conditions (see clause 3.2.4.1)
b) Period and details of operation (see clause 3.2.4.3)
c) Details of performance check (see clause 3.2.4.4), and
d) Details and period of operation and details of limited performance check (see clause 3.2.4.5).

4.7 **For procedure 5:**

a) Applicable test conditions (see clause 3.2.5.1)
b) Duration of operation of equipment and the time at which this operation should commence (see clause 3.2.5.3)
c) If measurement of surface temperature of components or materials is required (see clause 3.2.5.3), and
d) Details of performance check (see clause 3.2.5.4).

4.8 **For procedure 6:**

a) Applicable test conditions (see clause 3.2.6.1)
b) Duration of operation of equipment and time at which such operation should commence (see clause 3.2.6.3), and
c) Details of performance check (see clause 3.2.6.4), and

4.9 Final measurements (see clause 3.4)

4.10 Any deviation from the normal test procedure.

TEST NUMBER 18
ICING

1. OBJECT

1.1 To determine the effect of various icing conditions on the performance of Airborne Electronic and Electrical Equipment.

Note : Icing test is specified to simulate the effect that occurs when an aircraft flying in a cold atmosphere encounters free water or descends through clouds into a moist atmosphere near the ground. Ice may build up on the equipment immediately, or frosting or condensation may occur and freeze to Ice. Such tests also simulate the converse effect when water which may have been trapped or condensed inside an equipment or may have collected on pockets on the outside either through wet conditions on the ground or through accumulation of moisture by frosting and subsequent melting of frost, freezes as the aircraft ascends.

2. TEST CHAMBER

2.1 A chamber conforming to the requirements of altitude test (Test Number 3) shall be used for Icing as per Test Procedures 1,2, and 3.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined electrically and /or mechanically checked, as required by the relevant equipment specification.

3.2 **Conditioning -** The equipment to be tested shall in all cases, be in a condition representative of operational use. Unrepresentative coatings and contaminants such as oils grease and dirt, which could affect the adhesion between the Ice and the surface of the equipment, shall be removed before commencing the test.

3.2.1 The operation of the equipment shall be checked at the most adverse phase of the test which for most applications would be a switch on and brief functional checks under Icing conditions. Excessive operation of equipment which generates heat shall be avoided.

3.2.2 **Procedure 1**

3.2.2.1 The chamber temperature shall be raised from the level of procedure 1 of Altitude Test (Test No. 3) to 30ºC in a period of 1 to 2 hours with relative humidity held at or close to saturation (nominally not less than 95 percent). Visible frosting should occur on the surface of the equipment (Refer procedure 2 clause 3.2.2.1(b) of Altitude Test).

3.2.2.2 When the temperature of equipment has risen to -5ºC ± 3 degC and before the restoration of the chamber pressure to normal atmospheric conditions, a functional test shall be conducted to check for satisfactory operation.

Note : 1 If in the case of vented equipment, there is a possibility of the vent holes being closed by the presence of Ice, the test procedure shall be amended so that pressure is restored before the Ice has melted.

2 The relevant equipment specification shall specify whether it is permissible during the functioning tests for more than one attempt to be made to obtain satisfactory operation.

3.2.3 **Procedure 2**

3.2.3.1 The equipment shall be conditioned to a temperature not higher than -20ºC until temperature stabilisation has been achieved.

3.2.3.2 The chamber pressure shall then be reduced to that used in the Altitude Test (Test No.3) Procedure 1 (clause 3.2.1) but not lower than 15200 metres. After a period of not less than 10 minutes, the temperature of the chamber shall be raised at a rate not exceeding 3ºC per minute and humidified so that the chamber humidity is held at or close to saturation. The chamber temperature shall not exceed 30ºC.

3.2.3.3 When the equipment temperature has reached above 0ºC and after a period which would allow all frost or Ice to melt, the pressure shall be increased to that corresponding to normal atmospheric conditions at a uniform rate, in a period of 15 to 30 minutes. At the completion of repressurisation the next cycle shall be commenced.

3.2.3.4 A total of twenty five such cycles should be made consecutively. If it becomes necessary to interrupt this sequence, the interruption shall take place whilst the equipment is held in low temperature conditions.

3.2.3.5 A functional check shall be made in the final cycle as required in the relevant equipment specifications at the lowest temperature in the cycle i.e. -20ºC.

3.2.4 **Procedure 3**

3.2.4.1 The equipment shall be conditioned in a low temperature chamber as specified in low temperature Test No.20 until its temperature has stabilised at level determined by previous experiments, that will permit hard clear Ice to form on the item when water is sprayed upon it. The optimum temperature is likely to be between -1 to -10ºC depending upon the thermal mass of the item. A homogeneous layer of hard clear Ice (not white or Air pocketed) shall be produced on the relevant surfaces of the item, to the required thickness and distribution by hand spraying/atomizer with a fine mist of water the temperature of which is close to freezing (say +2ºC).

3.2.4.2 When the Ice accretion has reached the level specified in the relevant equipment specifications, spraying shall be stopped and the test temperature restabilised unless otherwise stated, at the relevant temperature of the Altitude Test (Test No. 3) Procedure 1. (clause 3.2.1) before making the performance check required by the relevant equipment specification.

3.3 **Recovery**: - The temperature of the chamber shall then be restored to the laboratory atmospheric conditions.

3.4 **Final Measurements**: - For tests demonstrating survival of the equipment only, the equipment shall be operated and a performance evaluation made when the temperature and humidity have returned to standard laboratory conditions.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATIONS

4.1 Initial Measurements (see clause 3.1)

4.2 The applicable test procedure or test procedures (see clauses 1.1, 3.2.2, 3.2.3 and 3.2.4).

4.3 Permissible number of attempts to operate (see clause 3.2.2.2 Note 2).

4.4 Final Measurements (see clause 3.4)

4.5 Any deviation from the proposed procedures.

TEST NUMBER 19
IMMERSION

1. OBJECT

1.1 To determine the water tightness of electronic and electrical equipment when subjected to immersion under stated conditions of pressure and time.

2. TEST CHAMBER

2.1 An immersion tank or a high pressure water chamber shall be used for this test.

2.2 When an immersion tank is used, the specified depth of water shall be measured above the top most point of the equipment.

2.3 When a high pressure water chamber is used, the excess pressure shall be adjusted to the value specified.

3. TEST PROCEDURE

3.1 **Preconditioning** - Preconditioning of the equipment and seals shall be carried out, as required.

3.2 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified. All sealing features shall be checked to ascertain that they have been correctly mounted .

3.3 **Conditioning** - The equipment shall be subjected to this test in its `unpacked' and `switched-off' condition.

3.3.1 The water used for this test shall be at a temperature between 15ºC and 35ºC.

3.3.2 The equipment temperature shall be 5 to 10ºC above the temperature of the water, immediately before the start of the test.

3.3.3 The equipment shall be placed in the attitude specified and shall be completely immersed in the water. The depth of immersion or excess pressure shall be adjusted to any of the severities specified in clause 3.3.4, as required.

Note : Sea water may be used in case of severities G,H or J (see Table 4.19-1).

3.3.4 The depth of immersion or excess pressure shall be corresponding to one of the test conditions listed in Table 4.19-1.

3.3.5 The duration of the immersion, under condition of clause 3.3.4, shall be 2 hours. Unless otherwise specified, during immersion, the equipment under test shall not be in operating condition but shall be switched off and its movable parts shall be at rest.

3.3.6 At the end of period specified in clause 3.3.5, the equipment shall be removed from the immersion tank or high pressure water chamber and its external surfaces shall be thoroughly dried by wiping or by applying a blast of air at room temperature, unless otherwise specified.

3.4 **Recovery** - The equipment shall then be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

3.5 **Final Measurements** - The equipment shall be visually examined for any ingress of water and shall be electrically and mechanically checked as specified.

TABLE 4.19-1 SEVERITIES FOR IMMERSION TEST
(Clause 3.3.4)

SEVERITY	DEPTH OF WATER (m)	CORRESPONDING EXCESS PRESSURE AT 25ºC (kPa)
Test condition A	0.15	1.47
Test condition B	0.4	3.91
Test condition C	1.0	9.78
Test condition D	1.5	14.7
Test condition E	4	39.1
Test condition F	6	58.7
Test condition G	10	97.8
Test condition H	15	147.0
Test condition J	265	2591.7

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Preconditioning (see clause 3.1).

4.2 Initial measurements (see clause 3.2).

4.3 Equipment attitude (see clause 3.3.3).

4.4 Applicable test condition (see clause 3.3.4).

4.5 Final measurements (see clause 3.5).

4.6 Any deviation from the normal test procedure.

TEST NUMBER 20
LOW TEMPERATURE

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use and/or storage at specified low ambient temperature conditions.

2. TEST CHAMBER

2.1 A cold chamber meeting the requirements stated in clauses 2.2 to 2.5 shall be used for this test.

2.2 The chamber shall be capable of maintaining its working space within ± 3 degC of the appropriate low temperature severity.

2.3 The low temperature conditions in the chamber shall be achieved by circulating cold air and these conditions shall be maintained uniformly throughout the working space of the chamber.

2.4 The temperature within the chamber shall be monitored by a temperature sensing device suitably located in its working space.

2.5 The design and construction of the chamber shall be such that any heat dissipated by the equipment during testing, shall not appreciably influence the conditions within the chamber.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning**- The equipment under test shall be subjected to this test in `unpacked' condition. Four procedures are specified for this test. The equipment shall be subjected to one or more of the procedures as specified. At the beginning of each procedure the equipment shall be in its `switched-off' condition.

3.2.1 **Procedure 1**

3.2.1.1 The equipment under test, while being under laboratory atmospheric conditions, shall be introduced into the chamber, the latter also being under the same conditions. The temperature of the chamber shall then be lowered to one of the following test conditions, as required:

a) Test condition A : -40ºC ± 3 degC.

b) Test condition B : -60ºC ± 3 degC.

3.2.1.2 After the equipment has attained temperature stability, it shall be maintained at the appropriate test condition for a period of 2 hours. If possible, the equipment shall be visually examined at the end of this period, to determine whether deterioration likely to impair future performance of the equipment has occurred.

3.2.1.3 If the relevant equipment specification requires performance check and visual examination at laboratory atmospheric conditions, the chamber temperature shall be restored to these conditions. The equipment shall then be subjected to recovery conditions (see clause 3.3) and final measurements (see clause 3.4) shall be made, as specified.

3.2.1.4 At the end of clause 3.2.1.2 or after final measurements, as applicable the equipment shall be immediately subjected to the conditioning specified in procedure 2.

3.2.2 **Procedure 2**

3.2.2.1 The chamber temperature shall be adjusted to one of the following test conditions as required.

a) Test condition C : -40ºC ± 3 degC.

b) Test condition D : -55ºC ± 3 degC.

Note : 1 When procedure 2 immediately follows conditions in clause 3.2.1.2 and test condition C is applicable, the equipment may be directly subjected to conditions in clause 3.2.2.6.

2 When it is not convenient to subject the equipment to procedure 2 immediately after clause 3.2.1.2, or when procedure 2 follows conditions as stated in clause 3.2.1.3, the equipment shall be reintroduced in the chamber while latter also is at laboratory atmospheric conditions. The chamber temperature shall then be gradually raised to that of the test condition C or D.

3.2.2.2 The equipment shall be stabilized at the appropriate test condition stated in clause 3.2.2.1.

3.2.2.3 If required, the equipment shall then be switched-on and allowed to warm up.

Note : The relevant equipment specification shall state any warm up procedure, acceptable warm up time and whether short term derangement is acceptable.

3.2.2.4 During and after the warm up period, the equipment shall be operated as specified.

3.2.2.5 At the end of the warm up period, a performance check shall be carried out. Unless otherwise specified, the conditioning shall continue for 30 minutes or until the completion of performance check, whichever is longer.

Note : 1 In some instances, the performance of the airborne equipment grades A,B,C,D,Q,R and S (see sub section 5.20.1) outside the stated tolerances may be acceptable at the lowest temperature, provided such characteristics are reversible and satisfactory performance is achieved when tested in accordance with procedure 3.

2 Ideally, all measurements should be made simultaneously at the end of the warm up period. Where this is impracticable, characteristics that are likely to be affected by low temperature should be checked first. Should these checks take such a time that the state of the equipment is no longer representative of that at the end of warm up period, the operation of the equipment should be stopped, the temperature restabilized at the original level and a further test cycle or cycle, as specified above, repeated and the remaining performance tests continued.

3.2.2.6 The equipment shall then be switched off and immediately subjected to the conditioning specified in procedure 3.

Note : Satisfactory performance of the equipment tested to procedure 2 may obviate need of testing in accordance with procedure 3. In such cases the equipment may be directly subjected to Test Number 3. The relevant equipment specification shall clearly state whether procedure 3 is applicable.

3.2.3 **Procedure 3**

3.2.3.1 The chamber temperature shall be adjusted to one of the following test conditions as required:

a) Test condition E : -20ºC ± 3 degC.

b) Test condition F : -40ºC ± 3 degC.

c) Test condition G : -55ºC ± 3 degC.

3.2.3.2 The equipment shall be stabilized at the appropriate test conditions stated in clause 3.2.3.1.

3.2.3.3 The equipment shall be switched-on and if required shall be allowed to warm up for the period as specified.

3.2.3.4 The equipment shall then be operated for a period of 4 hours at its minimum duty cycle. If required, the operation of the equipment shall continue beyond this period, until all internal temperatures are stable.

3.2.3.5 The equipment shall then be switched off and immediately subjected to conditioning in procedure 1 or 2 of Attitude Test Number 3, as required.

3.2.4 **Procedure 4**

3.2.4.1 The equipment under test, while being at the laboratory atmospheric conditions, shall be introduced into the chamber, the latter also being under the same conditions. The temperature of the chamber shall then be lowered to one of the following test conditions as required

a) Test condition H : -10ºC ± 3 degC.
b) Test condition J : -20ºC ± 3 degC.
c) Test condition K : -30ºC ± 3 degC.
d) Test condition L : -40ºC ± 3 degC.
e) Test condition M : 0ºC

3.2.4.2 The equipment shall be exposed to this temperature for a period of 16 hours after the temperature of the equipment has stabilized.

3.2.4.3 If required, equipment shall be switched on and a performance check shall be carried out during the last 30 minutes of the period specified in clause 3.2.4.2.

3.2.4.4 The temperature of the chamber shall then be restored to the laboratory atmospheric conditions.

3.3 **Recovery** - The equipment shall be removed from the chamber and shall be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

Note : For procedures 1,2 and 3 the recovery condition shall be applicable, only when these procedures are not immediately followed by another procedure of this test or Test Number 3 and final measurements at laboratory atmospheric conditions are required to be made.

3.4 **Final Measurements** - The equipment shall then be visually examined and shall be electrically and mechanically checked as specified.

Note : For procedures 1,2 and 3 the final measurement shall be made only when the relevant equipment specification requires the performance of the equipment to be checked at the laboratory atmospheric conditions.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 The applicable procedure or procedures (see 3.2)

4.3 For procedure 1 :

a) Applicable test condition (see clause 3.2.1.1),

b) Whether visual examination is required (see clause 3.2.1.2), and

c) Whether visual examination and performance check are required at laboratory atmospheric conditions and if applicable details of performance check (see clause 3.2.1.3).

4.4 **For Procedure 2:**

a) Applicable test condition (see clause 3.2.2.1), and
b) Warm up procedure and time. Whether short term derangement is acceptable (see clause 3.2.2.3)

c) Details of operation (see clause 3.2.2.4), and

d) Details of performance check (see clause 3.2.2.5)

4.5 For Procedure 3:

a) The applicable test condition (see clause 3.2.3.1)

b) Whether warm up is required and the period of warm up (see clause 3.2.3.3), and

c) Details of operation and whether the operation of the equipment is to be continued beyond 4 hours (see clause 3.2.3.4).

4.6 **Procedure 4:**

a) The applicable test condition (see clause 3.2.4.1), and

b) Details of performance check (see clause 3.2.4.3).

4.7 Final measurements (see clause 3.4).

4.8 Any deviation from the normal test procedure.

TEST NUMBER 21
MOULD GROWTH (FUNGLE)

1. OBJECT

1.1 To determine the resistance of electronic and electrical equipment against mould growth.

2. TEST CHAMBER

2.1 A humidity chamber meeting requirements of clauses 2.2 to 2.4 shall be used for this test.

2.2 The chamber shall have a well sealed door to prevent exchange of atmosphere between inside and outside.

2.3 The chamber shall be capable of maintaining its working space at a temperature of 29ºC $\pm$ 1 degC.

2.4 Any periodic change of temperature shall not exceed a rate of 1ºC per hour.

2.5 The relative humidity shall be maintained at a value greater than 90 percent by exposing a large area of water slurry of Potassium sulphate (K_2SO_4).

Note : The chamber shall be fitted with a suitable fan to provide a gentle circulation of air to all parts of the working space to aid rapid transfer of moisture to or from the salt solution. The speed of circulating air must not be too high, otherwise small drops of water or grains of salt, on the walls of the tray holding the slat solution, may be carried over into the atmosphere. It should also be ensured that the spores are not detached from the equipment under test by the air circulation.

2.6 The door of the chamber shall be opened for a few minutes, once a week, to renew the oxygen supply and to add further water to the slurry.

Note : If the chamber becomes contaminated it is desirable to clean it. The preferable method is to heat it to a temperature of 120ºC, in a moisture saturated atmosphere for 1 hour. An alternative and allowed method, when the heating cannot be tolerated, is to dry it and fumigate it with Propylene oxide, finally washing it with water containing a detergent and ventilating it well to remove all oxide fumes.

3. TEST PROCEDURE

3.1 Cultures

3.1.1 The cultures used for this test shall be obtained from an official mould research station.

Note : Owing to a large number of generations in the genetic history of the standard cultures, it is possible for them to suffer variation in their ability to attach retain materials. The assessment of the ability requires a high degree of mycological skill and the research station supplying these cultures for the test purposes should certify that they are as suitable for this test as those previously supplied and considered acceptable.

3.1.2 The following cultures shall be used together for performing this test:

	Culture	Strain
a)	Aspergillus niger	V. Tleghem
b)	Aspergillus terrcus	Thom
c)	Aureobasidium pullulans	(De Barry) Arnaud
d)	Paecilomyces varioti	Bainier
e)	Pencillium Furiculosum	Thom.
f)	Pencillium ochro-chloron	Biourge
g)	Scopulariopsis brevicaulis	(Sace) Bain Var, Glabra Thom
h)	Trichoderma viride	Pers. ex Fr

3.1.3 The cultures shall be supplied as spores on agar medium in glass containers with cotton plugs or as considered appropriate by the mycological institute supplying them.

3.1.4 The cultures shall be stored in a refrigerator at a temperature between 5ºC and 10ºC. The cultures shall be used for preparing the test suspension when they are between 14 and 21 days old. The stoppers shall not be removed until the mould suspension is about to be made and only one suspension shall be made from the opened container. A fresh unopened container shall be used for each batch of suspension.

3.2 **Preparation of Mould Suspensions**.

3.2.1 The mould suspension shall be prepared in distilled water to which has been added 0.05 percent of a non- fungicidal wetting agent. An agent based on N-methyl taurid, (Igepon) or on Dicotyl Sodium Sulphosuccinate is suitable.

3.2.2 Ten millimetres of water and the required wetting agent shall be added gently to each phial or tube. A platinum or a nichrome wire shall be sterilized by heating it to red hot state in a flame and allowed to cool. This wire shall be used to scrape gently the surface of the culture to liberate the spores. The liquid shall be gently agitated to disperse the spores without detaching mycelical fragments and the mould suspension shall then be gently decanted into a flask.

3.2.3 All the eight dispersions shall be shaken vigorously together in a flask to mix thoroughly and to break up any clumps of spores.

3.2.4 The spore suspension thus prepared shall be used on the same day on which it is prepared and shall not be stored for future use.

3.3 **Control Strips**

3.3.1 The control strips called for in this test shall consist of strips of pure white filter paper soaked with a nutrient salt solution as described in clause 3.3.2.

3.3.2 The nutrient salt solution shall consist of a solution of the following materials in distilled water. The quantities listed are mass of salt per litre of water.

a) Potassium dihydrogen orthophosphate (KH_2PO_4)	0.7 g
b) Potassium monohydrogen orthophosphate (K_2HPO_4)	0.3 g
c) Magnesium sulphate ($MgS_2O_4,7H_2O$)	0.5 g
d) Sodium nitrate ($NaNO_3$)	2.0 g
e) Potassium chloride (KC1)	0.5 g
f) Ferrous sulphate ($Fe\ SO_4,\ 7H_2O$)	0.01 g
g) Sucrose	30 g

3.3.3 The control strips shall be placed in a small glass dish and covered with the nutrient salt solution. The strip shall be removed from this solution and allowed to drain free of drips immediately before use.

3.3.4. The control strips and the nutrient salt solution shall be freshly prepared on the same day on which they will be used for the test.

3.4 **Preconditioning** - The equipment shall not normally receive any special cleaning treatment.

Note : When required, it is permissible to clean the equipment in ethanol or in water containing a detergent before testing, so that mould growth caused by unsuitable materials can be distinguished from that due to surface contamination.

3.5 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.6 **Conditioning**

3.6.1 The equipment and three control strips shall be sprayed with the mixed spore suspension prepared as in clause 3.2. The spray shall be generated by a nozzle large enough not to be blocked by the fragments of mycellum. The spray shall impinge on all exposed surfaces of the equipment.

3.6.2 Within 15 minutes of spraying the equipment and the control strips shall be introduced into the chamber whose working space is maintained at a temperature of 29ºC ± 1 degC and a relative humidity of not less than 90 percent.

3.6.3 The equipment and the control strips shall not be unduly disturbed except for opening the chamber door each week until completion of the test.

3.6.4 If no mould growth is visible on any one of the control strips when the chamber door is opened for the first time after 7 days of starting the test, the test shall be considered void and shall be recommenced.

3.6.5 Provided that the mould growth on the control strips indicates that the conditions are suitable and the moulds viable, the equipment shall be exposed in the chamber continuously for a total period of 28 days.

3.6.6 The equipment shall be removed from the chamber after the 28 days of exposure and examined immediately under 10 power magnification .

Note : This microscopic examination shall be completed within a very short period as the mould growth begins to dry and changes in appearance rapidly when exposed to the laboratory conditions.

3.6.7 Unless otherwise specified, there shall be no mould growth when examined as clause in 3.6.6.

3.7 **Recovery** - The equipment shall then be allowed to remain under standard recovery conditions for 2 to 4 hours.

3.8 **Final Measurements** - The equipment shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.5).

4.2 Whether cleaning of the equipment is required before conditioning (see clause 3.4).

4.3 The criteria for failure if other than that specified (see clause 3.6.7).

4.4 Final measurements (see clause 3.8).

4.5 Any deviation from the normal test procedure.

TEST NUMBER 22
RAPID TEMPERATURE CYCLING
(THERMAL SHOCK)

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment to withstand rapid changes of temperature in air, as may be encountered during storage, transportation and use.

2. TEST CHAMBER

2.1 The following chambers shall be used. The location of chambers shall be such as to allow a rapid transfer of equipment from one chamber to other.

2.1.1 A dry heat chamber conforming to the requirements of the high temperature test (Test Number 17).

2.1.2 A cold chamber conforming to the requirement of the low temperature test (Test Number 20).

2.1.3 A damp heat chamber conforming to the requirements of the damp heat test (Test Number 10).

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning** - The equipment shall be subjected to this test, in its `unpacked' and `switched-off' conditions, in accordance with procedure 1 or 2, as specified.

3.2.1 **Procedure 1**

3.2.1.1 The equipment, while being under laboratory atmospheric conditions, shall be introduced into the dry heat chamber maintained at a temperature of 55°C ±3 degC and relative humidity not exceeding 30 percent.

3.2.1.2 The equipment shall be maintained at this temperature for a period of 3 hours. The relative humidity during this period shall not exceed 30 percent.

3.2.1.3 The equipment shall then be transferred to a cold chamber which is maintained at -40ºC ± 3 degC.

3.2.1.4 The duration allowed for transfer from the dry heat chamber to the cold chamber shall be that corresponding to one of the test conditions given below, as required.

Test condition A : 2 to 3 minutes.

Test condition B : Not exceeding 15 minutes.

3.2.1.5 The equipment shall be maintained at -40ºC ±3 degC for a period of 3 hours.

3.2.1.6 The conditioning stated in clauses 3.2.1.1 to 3.2.1.5 Constitutes one cycle. When relevant equipment specification requires conditioning for more than one cycle, the equipment shall be retransferred (see clause 3.2.1.4) to dry heat chamber maintained at conditions stated in clause 3.2.1.1 and conditioning in Clauses 3.2.1.2 to 3.2.1.5 shall be repeated for stated number of cycles.

3.2.1.7 At the end of last cycle the equipment shall be removed from the cold chamber and shall be subjected to recovery conditions (see clause 3.3).

3.2.2 **Procedure 2**

3.2.2.1 The equipment while being at laboratory atmospheric conditions, shall be introduced in a damp heat chamber, maintained at a temperature of 40ºC ±3 degC and relative humidity of not less than 95 percent.

3.2.2.2 The equipment shall be kept under these conditions for a period of 3 hours.

3.2.2.3 The equipment shall then be transferred to the cold chamber, maintained at -40ºC ±3 degC, and shall be maintained at this temperature for a period of 3 hours,

3.2.2.4 The period of transfer from one chamber to other shall not exceed 15 minutes.

3.2.2.5 The conditioning stated in clauses 3.2.2.1 to 3.2.2.4 constitutes one cycle. When relevant equipment specification requires conditioning for more than one cycle, the equipment shall be retransferred (see clause 3.2.2.4) to damp heat chamber maintained at conditions stated in clause 3.2.2.1 and the conditioning in clauses 3.2.2.2 to 3.2.2.4 shall be repeated for the stated number of cycles.

3.2.2.6 At the end of last cycle the equipment shall be removed from the cold chamber and shall be subjected to recovery conditions (see clause 3.3).

3.3 **Recovery** - The equipment shall be allowed to remain under the standard recovery conditions for a period of 2 hours.

3.4 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 The applicable procedure (see clause 3.2).

4.3 Transfer time (see clause 3.2.1.4)

4.4 Number of cycles (see clause 3.2.1.6 and 3.2.2.6).

4.5 Final measurements (see clause 3.4).

4.6 Any deviation from the normal test procedure.

TEST NUMBER 23
SEALING

1. OBJECT

1.1 To determine effectiveness of sealing of electronic and electrical equipment.

2. TEST EQUIPMENT

2.1 **For Procedures 1 and 2** - The test set up shall consist of the following items:

2.1.1 A dry heat chamber conforming to requirements of the high temperature test (Test Number 17).

2.1.2 A cold chamber conforming to requirements of the low temperature test (Test Number 20).

2.1.3 A vacuum pump capable of producing vacuum equivalent to an air pressure of 25 kPa.

2.1.4 A sensitive pressure gauge capable of reading air pressure accurately to less than 0.7 kPa.

2.1.5 A source of compressed dry air or dry nitrogen at the required pressure.

2.1.6 An air flow meter.

2.1.7 Nozzle and inter-connecting hoses.

2.2 **For Procedure 3**

2.2.1 A high air pressure chamber capable of attaining pressure differentials specified in Table 4.23-1 shall be used for this procedure. The chamber shall be capable of maintaining the required pressure for the duration specified in clause 3.3.5.

2.2.2 The chamber shall also be capable of maintaining its working space at the temperatures of -20°C ±3 degC and 70°C ±3 degC, and for this purpose shall meet the requirements specified in low temperature (Test Number 20) and high temperature (Test Number 17) tests.

2.3 **For Procedures 4 and 5**

2.3.1 A low air pressure chamber capable of attaining pressures specified in Table 4.23-2, at rates specified in Clauses 3.4.5 and 3.5.5, shall be used for this procedure. The chamber shall be capable of maintaining the required pressure for the duration specified in clauses 3.4.6 and 3.5.6.

2.3.2 The chamber shall also be capable of maintaining its working space at the temperatures of -20ºC ±3 degC and 40ºC ±3 degC and for this purpose shall meet the requirements specified in low temperature (Test Number 20) and high temperature (Test Number 17) tests.

3. TEST PROCEDURE

3.1 The equipment shall be subjected to this test in its `unpacked' and `switched-off' `condition. Five procedures are specified. The equipment shall be subjected to one or more of these procedures as required.

Note : For procedure 1 or 2 of this test to be possible a suitable nozzle should be available on the equipment for providing connection to vacuum pump/gas source and pressure gauge etc.

3.1.1 **Procedure 1 - Sealing Test (Vacuum)**

3.1.2 The equipment nozzle shall be connected to a vacuum pump (see clause 2.1.3) and a pressure gauge.

3.1.3 The equipment temperature shall then be stabilized at 20ºC ±2 degC.

3.1.4 The equipment shall then be evacuated until a vacuum corresponding to one of the following test conditions, as required, is achieved:

Test condition A : Air pressure equal to 25 kPa

Test condition B : Air pressure equal to 50 kPa

3.1.5 The equipment shall then be sealed off from the pump and allowed to stand for 30 minutes, after which the reading in pressure gauge shall be noted.

3.1.6 For equipment sealing to be satisfactory, the air pressure reading at the end of 30 minutes period should not have fallen by more than 10 kPa.

3.2 **Procedure 2 - Sealing Test (Pressure)**

3.2.1 This procedure includes three methods. Method A and B are applicable to equipment which are `statically' pressurized, that the equipment is pressurized and sealed initially and the pressure within the equipment is not maintained during operation. Method C is applicable to the equipment within which constant pressure is maintained.

3.2.2 This test shall be conducted at one or more of the following temperatures, as required.

a) At 20ºC ±2 degC.

b) At the highest operating temperature of the equipment.

c) At the lowest operating temperature of the equipment.

3.2.3 **Method A**

3.2.3.1 This method shall be used for determination of leakage time constant, which is the time taken for the pressure within the equipment to fall by a ratio of 2.718.

3.2.3.2 The equipment nozzle shall be connected to a pressure gauge and a source of pressurized dry air or dry nitrogen.

3.3.3.3 The equipment temperature shall then be stabilized at the value specified (see clause 3.2.2).

3.2.3.4 The pressure within the equipment shall be adjusted accurately to an initial value specified and time shall be noted.

3.2.3.5 The pressure shall be recorded at measured time intervals, a correction being applied, if necessary, for any variation in temperature at the time of reading the pressure. The test shall be continued for at least half the value of time constant.

3.2.3.6 The leakage time constant shall be determined graphically by extrapolation assuming an exponential fall in pressure.

3.2.4 **Method B**

3.2.4.1 This method shall be used for determination of the leakage rate.

3.2.4.2 The equipment shall be connected to a source of pressurized dry air or dry nitrogen and a sensitive pressure gauge.

3.2.4.3 The equipment temperature shall be stabilised at the value specified (see clause 3.2.2).

3.2.4.4 The pressure within the equipment shall be adjusted accurately to a value specified and time shall be noted.

3.2.4.5 The rate of fall of pressure shall be determined. Correction for change in temperature shall be made where necessary. Generally the test shall be continued until the pressure has fallen by at least 1.4kPa.

3.2.5 **Method C**

3.2.5.1 This method shall be used for determination of leakage rate of the equipment where constant pressure is maintained during operation by measurement of rate of flow of the dry air/nitrogen required to maintain the pressure.

3.2.5.2 The equipment shall be connected to a source of pressurized dry air or dry nitrogen through a suitable flow meter and a pressure gauge (see clause 2.1.4).

Note : The gas source shall be maintained at a pressure slightly in excess of that specified for the equipment.

3.2.5.3 The equipment temperature shall be stabilized at the value specified (see clause 3.2.2).

3.2.5.4 The rate of flow of air into the equipment shall be determined, a correction being applied as necessary for variation of temperature.

3.3 **Procedure 3 - Excess Pressure Test**

3.3.1 Equipment normally pressurised or evacuated shall have the internal pressure adjusted to the most adverse design limit that would be experienced at ground level.

3.3.2 The equipment shall be placed in the test chamber and oriented into its normal attitude if this is significant, as required

3.3.3 The test chamber shall be conditioned for a period sufficient to allow the equipment to stabilize at one of following temperatures, as required

a) Temperature corresponding to standard testing conditions.
b) -20ºC ± 3 degC
c) 70ºC ± 3 degC

Note : The pressure shall be applied initially at temperature corresponding to (a) above, and additionally at -20ºC or 70ºC, or both, if temperature is likely to contribute to failure.

3.3.4 The pressure within the chamber shall then be increased by the appropriate differential test pressure given in Table 4.23-1 as required in a period of not less than 5 minutes and not greater than 15 minutes.

TABLE 4.23-1 PRESSURES FOR EXCESS PRESSURE TEST
(Clause 3.3.4)

RELEVANT EQUIPMENT GRADE (see Note 1)	MAXIMUM PRESSURE DIFFERENTIAL (kPa) (see Note 2)	DIFFERENTIAL TEST PRESSURE (kPa) + 5 PERCENT -0 (see Note 3)
A	76	86
B	36	41

Note : 1 The equipment grades stated here and the relevant class of aircraft correspond with those given in sub-section 5.20.1

2 In the test conditions stated above, the pressurization level for ground testing has been assumed equal to the maximum level occurring in flight for the particular class of aircraft.

3 The test pressure is based on a proof test concept and is the maximum pressure differential multiplied by 1.125.

3.3.5 The pressure shall be maintained at this level for a period of not less than 30 minutes, and shall finally be restored to laboratory conditions in a period of not less than 5 minutes and not greater than 15 minutes.

3.3.6 The equipment shall be subjected to this test in its idle or inert condition, unless it is a functional part of the aircraft during a pressurization check. In this event the equipment should be operated and made to function in the representative manner as required.

3.4 **Procedure 4 - Rapid Decompression Test**

3.4.1 Equipment normally pressurized or evacuated shall have the internal pressure adjusted to the most adverse design limit that would be experienced at ground level.

3.4.2 The equipment shall be placed in the test chamber and orientated into its normal attitude if this is significant, as required.

3.4.3 The test chamber shall be conditioned for a period sufficient to allow the equipment to stabilize at one of the following temperatures as required:

a) Temperature corresponding to standard testing conditions.

b) -20ºC ±3 degC.

c) 40ºC ± 3 degC.

Note: The test shall be applied initially at temperature corresponding to (a) above, and, additionally at -20ºC or 40ºC, or both, if temperature is likely to contribute to failure.

3.4.4 The pressure within the chamber shall then be reduced to the appropriate pressurization level stated in Table 4.25-2 as required and shall be maintained at this level for a period of not less than 5 minutes.

TABLE 4.23-2 PRESSURES FOR RAPID DECOMPRESSION TESTS
(Clause 3.4.4)

RELEVANT EQUIPMENT GRADE (see Note 1)	USE IN AIRCRAFT CLASS (see Note 1)	PRESSURIZATION LEVEL kPa ABSOLUTE (see Note 2) + 5 PERCENT - 0	TEST PRESSURE RELATED TO MAXIMUM FLIGHT ALTITUDE kPa ABSOLUTE + 5 PERCENT
	II	87.5	11.5
A	IV	80.5	4.5
	II	51.5	11.5
Q	III	47.0	7.0
	IV	44.5	4.5

Note : 1 The equipment grades stated here and the relevant class of air craft correspond with those given in sub-section 5.20.1

2 The test condition stated above are based upon a pressurization where the differential is 76 kPa for Grade A equipment and 36 kPa for grade Q

equipment. In the latter case the Fig has been increased to 40 kPa to allow for suction effects.

3.4.5 The pressure shall then be further reduced to that corresponding to the appropriate maximum flight altitude stated in Table 4.25-2 in a period not exceeding one minute, or if allowed by the relevant equipment specification at the maximum rate of change obtainable from the test chamber (see sub section 5.23 also).

3.4.6 The pressure shall then be maintained at this level for a period of not less than 10 minutes, or for any other period specified.

3.4.7 The relevant equipment specification may require the temperature to be changed to simulate temperature levels resulting from pressurization failure, and/or the pressure to be increased to simulate descent to a more acceptable flight altitude. The relevant equipment specification shall state the conditioning required.

3.4.8 The equipment, unless the test is being made with equipment in its idle or inert state, shall be operated and its performance checked at the phases of the test specified.

3.5 **Procedure 5 - Explosive Decompression Test**

3.5.1 Equipment which is normally pressurized or evacuated shall have the internal pressure adjusted to the most adverse design limit that would be experienced at ground level.

3.5.2 The equipment shall be placed in the test chamber and orientated into its normal attitude if this is significant, as required.

3.5.3 The test chamber shall be conditioned for a period sufficient to allow the equipment to stabilize at one of the following temperatures as required:

a) Temperature corresponding to standard testing conditions.

b) -20ºC ±3 degC.

c) 40ºC ±3 degC.

Note : The test shall be applied initially at temperature corresponding to (a) above, and additionally at -20ºC or 40ºC, or both, if temperature is likely to contribute to failure.

3.5.4 The pressure within the chamber shall then be reduced to the appropriate pressurization level stated in Table 4.23-3 as required and shall be maintained at this level for a period of not less than 5 minutes.

TABLE 4.23-3 PRESSURES FOR EXPLOSIVE DECOMPRESSION TEST (Clause 3.5.4)

RELEVANT EQUIPMENT GRADE (see Note 1)	USE IN AIRCRAFT CLASS (see Note 2)	PRESSURIZATION LEVEL kPa ABSOLUTE (see Note 2) + 5 PERCENT - 0	TEST PRESSURE RELATED TO MAXIMUM FLIGHT ALTITUDE kPa ABSOLUTE ± 5 PERCENT
Q	II	51.5	11.5
	III	47.0	7.0
	IV	44.5	4.5

Note : 1 The equipment grades; stated here, and the relevant class of aircraft correspond with those given in subsection 5.20.1.

2. The test conditions stated above are based upon a pressurization differential of 36 kPa which has been increased to 40 kPa to allow for suction effects.

3.5.5 The pressure shall then be further reduced to that corresponding to the appropriate maximum flight altitude in a period not exceeding 100 ms.

3.5.6 The pressure shall then be maintained at that level for a period not less than 10 minutes, or for any other period as specified.

3.5.7 The relevant equipment specification may require the temperature to be changed to simulate temperature levels resulting from pressurization failure and/or the pressure to be increased to simulate descent to a more acceptable flight altitude. The relevant equipment specification shall state the conditioning required.

3.5.8 The equipment, unless the test is being made with equipment in its inert or idle state, shall be operated and its performance checked at the phases of the test specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Applicable procedure (see clause 3.1).

4.2 For procedure 1: applicable test condition (see clause 3.1.4).

4.3 **For procedure 2:**

a) Applicable test method (see clause 3.2.1)

b) Temperature (s) at which test is to be conducted (see clause 3.2.2),

c) Initial pressure (see clauses 3.2.3.4, 3.2.4.4 and 3.2.5.2), and

d) Acceptable leakage time constant or leakage rate (see clauses 3.2.3.6, 3.2.4.5 and 3.2.5.4).

4.4 **For procedure 3:**

a) Mounting of equipment in the chamber (see clause 3.3.2),

b) Test temperature (s) (see clause 3.3.3),

c) Test pressure (see clause 3.3.4), and

d) Details of operation and performance check, if required (see clause 3.3.6).

4.5 **For procedure 4:**

a Mounting of equipment in the chamber (see clause 3.4.2)

b) Test temperature (s) (see clause 3.4.3.)

c) Pressurization level (see clause 3.4.4.)

d) Test pressures related to maximum flight altitude (see clause 3.4.5.)

e) Whether a rate of change lower than 1 minute is allowed (see clause 3.4.5)

f) Duration of maximum flight altitude (see clause 3.4.6.)

g) Conditioning following decompression phase, stating temperature and pressure (see clause 3.4.7.) and

h) Details of operation and performance check (see clause 3.4.8.).

4.6 **For procedure 5 :**

a) Mounting of equipment in the chamber (see 3.5.2)

b) Test temperature (s) (see clause 3.5.3)

c) Pressurization level (see clause 3.5.4.)

d) Pressure related to maximum flight altitude (see clause 3.5.5.)

e) Duration of pressure related to maximum flight altitude (see clause 3.5.6.)

f) Conditioning following decompression phase, stating temperature and pressure (see clause 3.5.7.) and

g) Details of operation and performance check (see clause 3.5.8)

4.7 Any deviation from the normal test procedure.

TEST NUMBER 24
SHOCK OR IMPACT

1. OBJECT

1.1 To determine the structural integrity and performance of electronic and electrical equipment when they are subjected to non-repetitive mechanical shocks.

2. TEST EQUIPMENT

2.1 An impact machine, as described below, shall be used for conducting the test in accordance with procedure 1.

2.1.1 The impact machine shall be capable of imparting shock of the required intensity to equipment and supporting brackets, together weighing up to a maximum of 275 kg.

2.1.2 The impact machine shall be fitted with a target plate to which the equipment under test is secured.

2.1.3 The impact machine shall be capable of applying impacts up to 2712 Joules to the target plate along each of its three mutually perpendicular axes.

2.1.4 The intensity of the mechanical shock delivered to the target plate by the impact machine, shall be measured by a copper crusher gauge or by any other approved means. The intensity of shock is related to the change in length of the copper as a result of the blow. After a vertical blow, the length of the copper must not exceed 4.6 mm and after a lateral blow, it shall not exceed 5.3 mm. If the length of the crusher exceeds this Fig after the blow, the height of fall of the weight shall be increased until compliance with the above limit is obtained. If, however, the length of the crusher is less than the maximum limit after the blow, the height of fall of the weight shall not be decreased until compliance with the above limit is obtained but not below 1.5 meters.

2.2 A shock machine, as described below, shall be used for conducting the test in accordance with procedure 2.

2.2.1 **Characteristics of the Shock Machine** - When the equipment together with its supporting brackets and any other load for test purposes are mounted on the shock machine, the applied shocks shall, at the monitoring point, have the following characteristics.

Note : In certain cases, for instance, for highly reactive loads, the relevant equipment specification may allow tolerances less severe than those specified below:

2.2.1.1 **Basic Pulse Shapes** -The shock machine shall be capable of generating a pulse approximating to one of the following nominal acceleration versus time curves:

a) Half-sine curve which is one half cycle of a sine wave as shown by the dotted line in Fig. 4.24-1.

b) Final-peak saw tooth curve which is an asymmetrical triangle with a short fall time as shown by dotted line Fig. 4.24-2.

The true value of the actual pulse shall be within the limit of tolerance as shown by the solid lines in the relevant Fig.

2.2.1.2 **Velocity Change Tolerance** - For all pulse shapes, the actual velocity change shall be within ±10 percent of the value corresponding to the nominal pulse. To determine the velocity change, the actual pulse should be integrated from 0.4 D before the pulse to 0.1D beyond the pulse, where D is the duration of the nominal pulse (see Fig. 4.24-1 and 4.24-2)

2.2.1.3 **Transverse motion** - The positive or negative peak acceleration at the monitoring point, perpendicular to the intended shock direction, shall not exceed at any time 30 percent of the value of the peak acceleration of the nominal pulse in the intended direction, when determined with a measuring system as described in clause 2.2.2.

2.2.2 **Measuring System**

2.2.2.1 **Monitoring** - The shock pulse shall be measured by an accelerometer placed at the monitoring point. This point shall be the equipment fixing point nearest to the centre of the table surface, unless there is a equipment fixing point having a more rigid connection to the table, in which case this point shall be chosen.

2.2.2.2 **Accuracy** - The accuracy of the measuring system shall be such that it can be determined that the true value is within the given tolerances.

2.2.2.3 **Frequency Characteristics** - The frequency response for the overall measuring system, including the accelerometer, shall be within the limits shown in Fig. 4.24-3.

Note : When it is necessary to employ filters to reduce the effects of any high frequency resonance inherent in the accelerometer, it may be necessary, to avoid distortion of the reproduced waveform, to examine the amplitude and the phase characteristics of the measuring system.

3. TEST PROCEDURE

3.1 Two procedures are specified. Procedure 1 is intended for ship borne equipment which are to be tested on machine specified in clause 2.1. Procedure 2 is intended for ground and airborne Equipment to be tested on machine specified in clause 2.2.

3.1.1 **Method of Mounting**

3.1.2 **For Procedure 1**

3.1.3 The equipment shall be rigidly mounted through its normal points of attachment in the normal operational attitude on the target plate. The equipment intended to be used with shock and vibration isolators shall be normally mounted on these for the test.

3.1.4 When an equipment weighs more than 275 kg, it should be dismantled, if practicable into sub-assemblies of convenient weight. If such sub-assemblies are to be used only with the remainder of the main equipment, the impact machine shall have weights, mounted on the target plate to bring the total load being tested to approximately 275 kg. If any of the sub-assemblies may be used as separate equipment, the test is to be carried out without additional weights on the target plate.

3.2 **For Procedure 2**

3.2.1 The equipment shall be fastened to the shock machine by its normal means of mounting, either directly or by means of a fixture. Any additional stays or straps shall be avoided as far as practicable.

3.2.2 The mounting fixtures, if any used, shall be such as to enable the equipment to be submitted to shocks along the various axes as specified in conditioning (see clause 3.3.2).

3.2.3 External connections necessary for measuring purposes shall add a minimum of restraint and mass. If cables pipes, etc. are required to be connected to the equipment during the test as specified these should be arranged as to add similar restraint and mass as in normal installation.

3.2.4 Equipment intended for use with isolators shall normally be tested with its isolators. In exceptional cases, if impossible to carry out the shock test using the correct isolators, for example, if the equipment is mounted with other Equipment in a common mounting system, then the relevant equipment specification may permit a shock test of the stated severity on the single specimen using isolators specified for this case.

3.2.5 **Gravitational effect** - The relevant equipment specification shall state whether the effect of gravitational force is important. In this case, the equipment shall be so mounted that the gravitational force acts in the same direction as it would in use. Where the effect of gravitational force is not important, the equipment may be mounted in any attitude.

3.2.6 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.3 **Conditioning**

3.3.1 **Procedure 1** - The equipment shall be subjected to test Method A or B as required.

3.3.1.1 **Test Method A** - With the equipment in its `switched- off' condition, the target plate carrying the equipment, shall be subjected to a series of blows as specified below:

a) Two vertical blows from a mass of 184 kg. falling vertically from a height of 1.5 meters,

b) Two lateral blows from a mass of 184 kg. at a radius of 1.5 meters, falling through an angle of 60 degrees, and

c) Two end blows from a mass of 184 kg, at a radius of 1.5 meters, falling through an angle of 60 degrees.

3.3.1.2 **Test Method B** - This shall be carried out in two steps as follows:

a) Step 1 - With the equipment fully operating, the target plate carrying the equipment shall be subjected to a series of blows as specified below:

   i) Two vertical blows from a mass of 184 kg falling vertically from a height of 1.5 metres,

   ii) Two lateral blows from a mass of 184 kg, at a radius of 1.5 metres, falling through an angle of 60 degrees, and

iii) Two end blows from a mass of 184 kg., at a radius of 1.5 metres, falling through an angle of 60 degrees.

b) Step 2 - With the equipment in its `switched-off' condition, the target plate carrying the equipment shall be subjected to a series of blows as specified below:

i) One vertical blow from a mass of 184 kg., falling vertically from a height of 1.5 meters,

ii) One lateral blow from a mass of 184 kg, at a radius of 1.5 meters, falling through an angle of 60 degrees, and

iii) One end blow from a mass of 184 kg., at a radius of 1.5 meters, falling through an angle of 60 degrees.

3.3.2 **Procedure 2** - The equipment shall be subjected to one or more of the following test methods, as required

3.3.2.1 **Test Method A** - Basic design test

a) This test method shall be used for testing equipment of medium size, including equipment which are mounted on vibration isolators and equipment racks (see clause 3.1.2.4).

Note : This test method may also be used for ship borne equipment. In such cases the relevant equipment specification shall clearly state the applicable details as required in (b) and (c) below (that is, pulse shape, amplitude, duration and direction and axes of application).

b) The equipment shall be subjected to three shocks in each direction, along each of the three mutually perpendicular axes (i.e. total of 18 shocks). The amplitude and duration of shock pulse shall be as given in Fig. 4.24-1 or Fig. 4.24-2 for the respective pulse shapes. The applicable pulse shape shall be specified in the relevant equipment specification.

For equipment fitted in ships and submarines the test severities in vertical direction are to be selected from Table-4.24.1 When the equipment is likely to be mounted with different orientation in different ships, the severities of vertical direction will apply for transverse and longitudinal directions also. When the equipment orientation is always fixed on boards, then the multiplication factors given in Table 4.24.2 be applied to determine the test severities in different directions.

c) If required, the equipment shall be operated during the conditioning and performance check shall be carried out as specified.

3.3.2.2 **Test Method B** - Crash safety test

a) This test method shall normally be used for determining structural integrity of equipment mounting means.

b) The equipment or dummy load shall be subjected to two shocks in each direction along each of the three mutually perpendicular axes (i.e. total of 12 shocks). The amplitude and duration of the shock shall be as given in Fig. 4.24-1 or Fig, 4.24-2 for the respective pulse shape The relevant equipment specification shall specify the applicable pulse shape.

c) There shall be no failure of the mounting attachment and the equipment or the dummy load shall remain in place and not create a hazard. However, bending and duration shall be permitted.

3.3.2.3 **Test Method C -** High intensity test

a) The test method shall be used for testing equipment under the conditions of high acceleration, short time duration shock excitation.

b) The equipment shall be subjected to two shocks in each direction along each of the three mutually perpendicular axes, making a total of 12 shocks. The amplitude and duration of the shock pulse shall be as given in Fig. 4.24-1 or Fig. 4.24-2 for the respective pulse shapes. The relevant equipment specification shall specify the applicable pulse shape.

3.4 **Final Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.2.6).

4.2 The applicable test procedure (see clause 3.1).

4.3 **For procedure 1:**

a) The applicable test method (see clause 3.3.1).

b) Details of operation (see clause 3.3.1.2 (a).

4.4 **For procedure 2:**

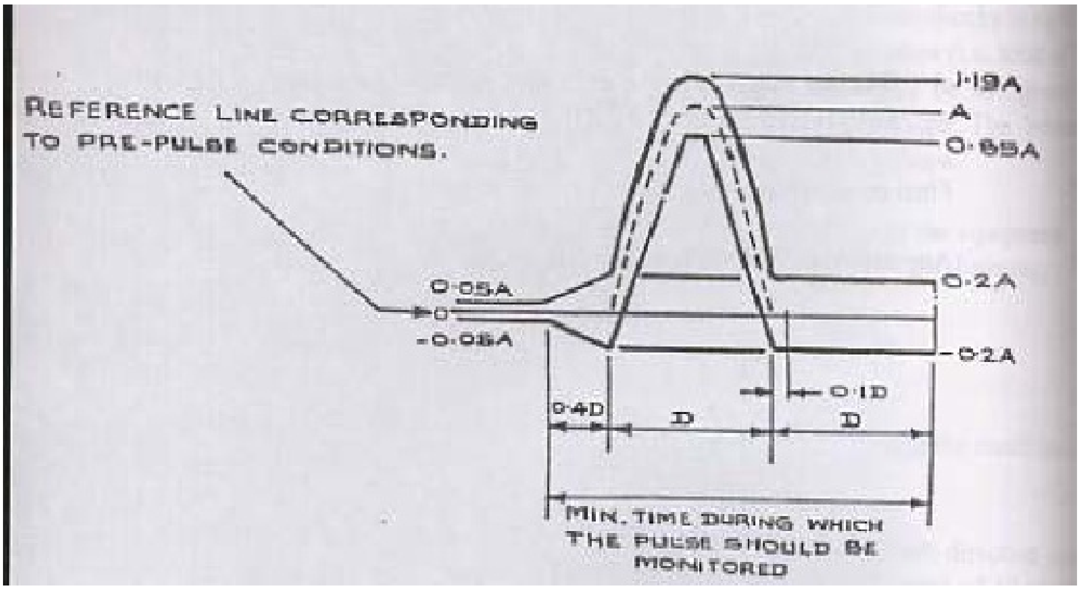
a) The applicable test method (see clause 3.3.2) and pulse shape.

b) Whether the equipment shall be operating during the test method A and details of operation and performance check (see clause 3.3.2.1 (c)), and

c) Whether a dummy load is to be used instead of the equipment for test method B (see clause 3.3.2.2 (b)).

4.5 Final measurements (see clause 3.4).

4.6 Any deviation from the normal test procedure.



---------NORMAL PULSE

______TOLERANCES BOUNDERIES

D = DURATION OF NOMINAL PULSE
A = PEAK ACCELERATION OF NOMINAL PULSE

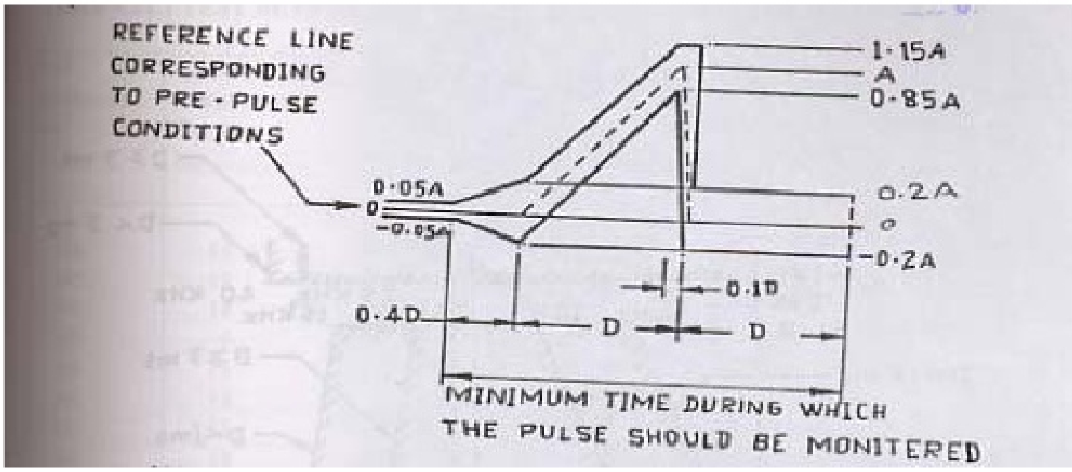
THE REFERENCE LINE SHALL NOT DIFFER MORE THAN ±0.05 A OR ±10 m/s^2, WHICHEVER IS GREATER FROM ZERO ACCELERATION

TEST METHOD	PEAK ACCELERATION (A) (m/s^2)		PULSE DURATION (D) (ms)	
	AIR BORNE EQUIPMENT	GROUND EQUIPMEN-T	AIR BORNE#1 EQUIPMENT	GROUND EQUIPMEN-T
A-Basic Design	150	400#2	11	18
B-Crash Safety	300	700	11	11
C- High Intensity	1000	1000	6	6

#1 RECOMMENDED FOR EQUIPMENT SHOCK MOUNTED OR WEIGHING 140 Kg OR MORE

#2 FOR EQUIPMENT INSTALLED ONLY IN TRUCKS OR SEMI TRAILERS PEAK ACCELERATINO OF 200 m/s^2 MAY BE SPECIFIED

FIG. 4.24-1 HALF SINE PULSE



---------NORMAL PULSE

______TOLERANCES BOUNDERIES

D = DURATION OF NOMINAL PULSE
A = PEAK ACCELERATION OF NOMINAL PULSE

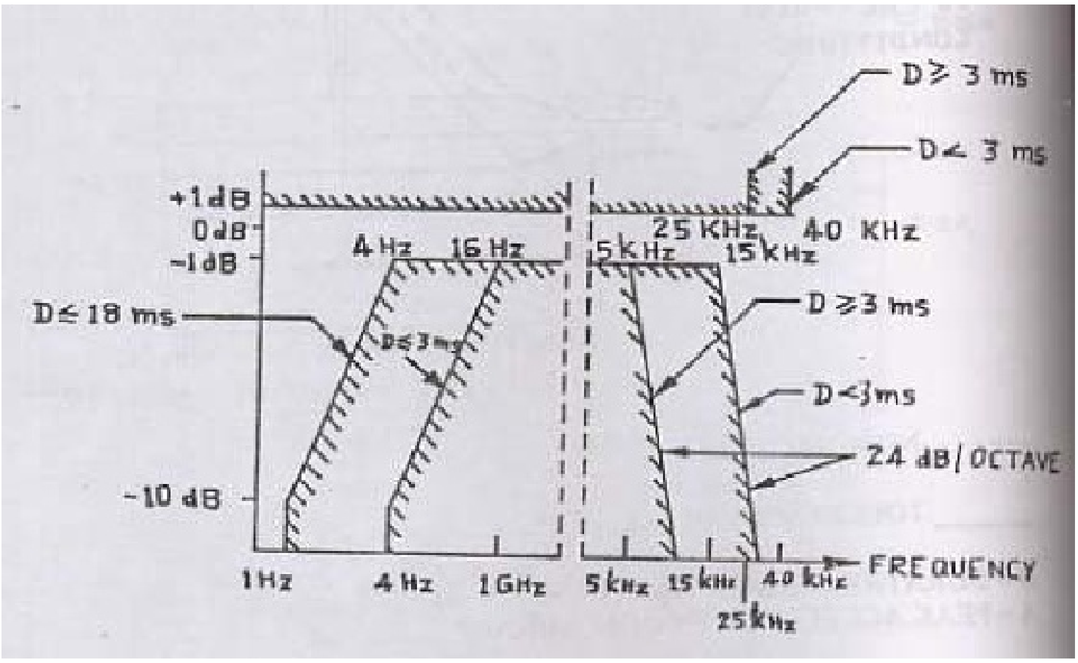
THE REFERENCE LINE SHALL NOT DIFFER MORE THAN ±0.05 A OR ±10 m/s^2, WHICHEVER IS GREATER FROM ZERO ACCELERATION

TEST METHOD	PEAK ACCELERATION (A) (m/s^2)		PULSE DURATION (D) (ms)	
	AIR BORNE EQUIPMENT	GROUND EQUIPMEN-T	AIR BORNE#1 EQUIPMENT	GROUND EQUIPMEN-T
A-Basic Design	200	400#2	11	18
B-Crash Safety	400	760	11	11
C- High Intensity	100	1000	6	6

#1 RECOMMENDED FOR EQUIPMENT SHOCK MOUNTED OR WEIGHING 140 Kg OR MORE

#2 FOR EQUIPMENT INSTALLED ONLY IN TRUCKS OR SEMI TRAILERS PEAK ACCELERATINO OF 200 m/s^2 MAY BE SPECIFIED

FIG. 4.24-2 FINAL PEAK SAW TOOTH PULSE



DURATION OF PULSE (ms)	**LOW FREQUENCY CUT OFF (Hz)**		**HIGH FREQUENCY CUT-OFF kHz (-1 dB)**	**FREQUENCY BEYOND WHICH THE RESPONSE MAY RISE ABOVE +1 dB kHz**
	-1dB	-10 dB		
A-Basic Design	16	4	15	40
B-Crash Safety	16	4	5	25
C- High Intensity	4	1	5	25

FIG. 4.24.2 FRQUENCY RESPONSE OF THE MEASURING SYSTEM

TABLE 4.24-1 TEST SEVERITIES FOR SHOCK TEST IN VERTICAL DIRECTION

Peak Acceleration (m/s^2)	Corresponding Duration of pulse ms	Final Peak Saw Tooth (m/s^2)	Corresponding Half sine m/s	Velocity change: Trapezoidal m/s
150	11	0.83	1.05	1.49
200	11	1.10	1.40	1.98
200	18	1.80	2.29	3.24
300	6	0.90	1.15	1.62
300	11	1.65	2.10	2.97
300	18	2.70	3.41	4.86
400	11	2.20	2.80	3.96
400	18	3.60	4.57	6.48
500	11	2.75	3.50	4.95
750	6	2.25	2.86	4.05
750	11	4.13	5.25	7.43
1000	6	3.00	3.82	5.40
3000	11	5.50	7.00	9.90
2000	6	6.00	7.64	10.80

TABLE 4.24-2 MULTIPLICATION FACTORS

Direction	**Vertical**	**Transverse**	**Longitudinal**
Ships	1	0.5	0.4
Submarine	1	1	0.7

Notes : 1 Underlined values are preferred values normally (Not on outer shell/hull) selected for equipment mounted internally. For equipment. directly mounted on hull and for special crafts like MMV, shock values with a velocity change greater than the preferred values may be selected.

2 Pulse duration of 6 ms are to be used for equipment of mass < 45 kg directly mounted without shock mounts.

3 Equipment, sub assemblies/panels with a total mass of > 500 kg. are to be tested with pulse width of 18 ms.

4 he preferred pulse shape should be half sine for all the severities as mentioned in Table 4.24.1 above.

TEST NUMBER 25
SOLAR RADIATION

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use under conditions of solar radiation.

2. TEST EQUIPMENT

2.1 A dry heat chamber conforming to requirements specified in high temperature test (Test Number 17) shall be used.

2.2 The chamber shall be provided with means of obtaining simulated solar radiation of an irradiance of 1.20 ± 0.10 kW/m^2. The simulated radiation shall have the following spectral distribution:

a) 540 to 775 W/m^2 of infrared (radiation of wavelengths above 780 nm).

b) 40 to 75 W/ m^2 of ultra-violet (radiation of wavelengths below 380 nm).

c) Balance visible radiation.

Note : One of the following radiation sources may be used:

(a) Mercury vapour lamps [internal reflector type only],

(b) Combination of incandescent spot lamps [including infra-red filters] together with tubular type mercury vapour lamps with external reflectors [with filters as required],

(c) Combination of incandescent spot lamps [including infra-red filters] together with mercury vapour lamps with internal reflectors [with filters as required,],

(d) Carbon arc lamps with suitable reflectors, or

(e) Mercury-xenon arc lamps with suitable reflector [with filters as required].

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning**

3.2.1 The equipment shall be subjected to this test in its `unpacked' and `switched-off' conditions.

3.2.2 The equipment while being under the laboratory atmospheric conditions, shall be introduced into the chamber, the latter also being under the same conditions.

3.2.3 The temperature of the chamber shall be adjusted to 30°C ±3 degC and shall be maintained at this temperature for a period of 9 hours. The relative humidity during this period shall not exceed 50 percent.

3.2.4 The temperature of the chamber shall then be raised to 55°C ± 3 degC at an approximately linear rate, over a period of 5 hours.

3.2.5 The chamber shall be maintained at 55°C ± 3 degC for a period of 5 hours.

3.2.6 The temperature of the chamber shall then be lowered to 30°C ± 3 degC at an approximately linear rate, over a period of 5 hours.

3.2.7 During the conditioning specified in clauses 3.2.4 to 3.2.6, simulated solar radiation from a parallel source shall be applied on all equipment surfaces, liable to receive direct solar radiation in normal use, in accordance with procedure 1 or 2, as required.

3.2.7.1 **Procedure 1**

a) The radiant energy shall be increased uniformly from zero level to the maximum (see clause 2.2) during the last three hours of period specified in clause 3.2.4.

b) The radiant energy shall be maintained at the maximum level (see clause 2.2) during the period specified in clause 3.2.5.

c) Starting at the end of period specified in clause 3.2.5, the radiant energy level shall be uniformly reduced to zero over the first three hours of the period specified in clause 3.2.6.

3.2.7.2 **Procedure 2**

a) One hour before beginning of period specified in clause 3.2.5, the radiant energy shall be increased to the maximum level (see clause 2.2), as a step function.

b) The radiant energy shall be maintained at the maximum level for a period of 7 hours, at the end of which it shall be reduced to zero level, as step function

Note : Procedure 1 shall be preferred.

3.3 **Recovery** - The equipment shall then be removed from the chamber and shall be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

3.4 **Final Measurements** - The equipment shall then be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1)

4.2 Applicable procedure (see clause 3.2.7)

4.3 Final measurements (see clause 3.4)

4.4 Any deviation from the normal test procedure.

TEST NUMBER 26
TOPPLING

1. OBJECT

1.1 To determine the ability of electronic and electrical equipment to withstand the shocks encountered during servicing.

2. TEST EQUIPMENT

2.1 A solid horizontal wooden bench top similar to that used for normal servicing operations, shall be used for this test. The bench top shall be at least 40 mm thick.

Note : Any hard wood available locally may be used for manufacturing the bench top.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning**

3.2.1 The equipment under test shall be subjected to this test in its `unpacked' and `switched-off' condition. The chassis and front panel assembly of the equipment shall be removed from its enclosure, as for servicing.

3.2.2 The equipment, as in clause 3.2.1 shall be placed in a suitable position on the wooden bench top described in clause 2.1.

3.2.3 Using one edge as a pivot, the opposite edge of the chassis shall be lifted until one of the following condition occurs (whichever occurs first).

a) The chassis forms an angle of 45 degrees with the horizontal bench top.

b) The lifted edge of the chassis has been raised 100 mm above the horizontal bench top.

c) The lifted edge of the chassis is just below the point of perfect balance.

3.2.4 The chassis shall then be allowed to drop back freely to the horizontal wooden bench top.

3.2.5 The procedure given in clauses 3.2.3 and 3.2.4 shall be repeated using other practical edges of the same horizontal face of the chassis as pivot points for a total of four drops.

3.2.6 The procedure given in clauses 3.2.3 to 3.2.5 shall be repeated with the chassis of the equipment resting on other faces until it has been dropped for a total of four times on each face on which the chassis of the equipment could be practicably placed during servicing.

3.3 **Final Measurements** - The equipment shall then be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1).

4.2 Final measurements (see clause 3.3)

4.3 Any deviations from the normal test procedure.

TEST NUMBER 27
TROPICAL EXPOSURE

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment for use and storage under conditions of high humidity when combined with cyclic temperature changes.

2. TEST CHAMBER

2.1 A damp heat chamber meeting requirements of clauses 2.2. to 2.10 shall be used for this test.

2.2 The damp heat chamber shall be capable of controlling and varying cyclically the temperature of the working space between 20° C ± 5 degC and 35°C ± 2 degC.

2.3 The chamber shall be capable of achieving in its working space, the rate of change of temperature as required in clause 3.2.2 and 3.2.4.

2.4 The chamber shall be capable of maintaining 95 percent relative humidity during the period of high temperature and not less than 95 percent relative humidity during the rest of the cycle.

2.5 Condensed water shall be continuously drained from the chamber and shall not be used again until it has been purified.

2.6 When humidity conditions in the chamber are obtained by using demineralised water, this shall have a resistivity of not less than 500 ohm - metre.

2.7 The temperature and relative humidity of the chamber shall be monitored by sensing devices suitably located in the working space.

2.8 The conditions prevailing throughout the working space shall be uniform and shall be as similar as possible to those prevailing in the immediate vicinity of the sensing devices.

Note : In case of damp heat chambers employing steam injection, the air velocity at the point accessible to the wet bulb thermometer shall be not less than 3 m/s.

2.9 The properties of the equipment or its operation shall not appreciably influence the conditions within the working space of the chamber.

2.10 Any condensed water from the walls and roof of the chamber shall not fall on the equipment.

3. TEST PROCEDURE

3.1 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.2 **Conditioning**

3.2.1 The equipment under test, shall be subjected to this test, in the `unpacked' and `switched-off' condition.

3.2.2 The equipment under test while being under the laboratory atmospheric conditions shall be introduced into the chamber maintained at a temperature of 20°C ±5 degC.

3.2.3 The temperature and relative humidity of the chamber shall then be raised to 35°C ±2 degC and 95 percent respectively over a period of 3 hours.

3.2.4 The above conditions shall be maintained for a period of 12 hours.

3.2.5 The temperature of the chamber shall then be lowered to 20°C ± 5 degC over a period of 3 hours. Saturation of the chamber atmosphere with water vapour shall occur during this period.

> Note : Condensation may occur during the cooling period but water shall not drip onto the equipment from the roof of the chamber.

3.2.6 The temperature of the chamber shall then be maintained at 20° C ± 5 degC for a period of 6 hours.

3.2.7 The above procedure from Clauses 3.2.2 to 3.2.6 constitutes one cycle. The total number of cycles shall correspond to one of the following test conditions, as required.

a) Test condition A - 7 cycles

b) Test condition B - 14 cycles

c) Test condition C - 28 cycles

d) Test condition D - 56 cycles

Note : The Equipment shall be normally subjected to the test condition C. If required, the relevant equipment specification may extend the test duration to 56 cycles. corresponding to test conditions D, in case of fully exposed equipment. Test conditions A and B may be specified for protected and partially protected Equipment.

3.2.8 If required, the equipment shall be switched on and operated during the first two hours of the 35°C period of each seventh cycle.

3.2.9 In case of test condition C or D, at the completion of 14 cycles the equipment shall be visually examined and performance check shall be carried out as required

3.3 **Recovery** - The equipment shall be removed from the chamber and shall be allowed to remain under standard recovery conditions for a period of 2 to 4 hours.

Note : The relevant equipment may specify method of removal of surface moisture.

3.4 **Final Measurements** - the equipment shall be visually examined and shall be electrically and mechanically checked as specified.

4. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

4.1 Initial measurements (see clause 3.1).

4.2 Number of cycles (see clause 3.2.7).

4.3 Details of operation if required (see clause 3.2.8)

4.4 Final measurements (see clause 3.4).

4.5 Any deviation from the normal test procedure.

TEST NUMBER 28
VIBRATION

1. OBJECT

1.1 To determine the suitability of electronic and electrical equipment to withstand specified severities of vibration.

2. TEST EQUIPMENT

2.1 Sinusoidal Vibration System

2.2.1.1 **Required Characteristics** - The characteristics required of the vibration generator and fixture when loaded for the conditioning process shall be as follows:

2.1.1.1 **Basic Motion** - The basic motion shall be sinusoidal and such that all the fixing points of the equipment are moving substantially in phase and in straight parallel lines, except as in clause 2.1.1.2 below.

2.1.1.2 **Transverse Motion** - The maximum vibration amplitude at the fixing points of the equipment in any direction normal to the intended (including that due to rocking, torsional vibration, etc.) shall not exceed 25 percent of the specified amplitude.

Note : In some cases, for example, for large Equipment, it may be difficult to maintain a limit of 25 percent. In such cases, the value shall be noted and stated in the test report.

2.1.1.3 **Distortion**- The total rms harmonic content of the acceleration, at the fixing point of the equipment, shall not exceed 25 percent of the actual acceleration corresponding to the specified amplitude at the fundamental drive frequency, unless compensated for by increasing the driving amplitude so as to restore the amplitude at the fundamental frequency to the specified value. In such cases, the distortion value shall be noted and stated in the test report. The distortion measurements shall cover the frequency range up to 5000 Hz or five times the driving frequency, whichever be the greater.

2.1.2 Tolerances

2.1.2.1 **Amplitude** - The actual vibration amplitude in the required direction shall be equal to the specific value, within the following tolerances:

a) At the reference point, (which may be specified by the relevant specification) (see clause 3.2.3):

i) in the frequency range where displacement amplitude is specified: ± 15 percent.

ii) in the frequency range where acceleration amplitude is specified: ± 10 percent.

b) At each specified control point (see clause as given in Table 4.28-1.

TABLE 4.28-1 VIBRATION AMPLITUDE TOLERANCES
(Clause 2.1.2.1 [b])

FREQUENCY RANGE	TOLERANCE ON	
	Displacement Amplitude	Acceleration Amplitude
Up to 150 Hz	± 25 percent	± 15 percent
Above 150 Hz	___	± 25 percent

Note : In some cases, for example, for large Equipment and/or at high frequencies, it may be difficult to achieve the tolerances given above at some discrete frequencies within the frequency range. In such cases a concession should be agreed with the responsible authority on he tolerances that are acceptable at these particular frequencies; the result achieved shall be stated in the test report.

2.1.2.2 **Frequency**

a) Measurement of frequency for resonance determination shall be made with a tolerance of ± 0.5 percent or ± 0.5 Hz, whichever be the greater.

b) Frequency tolerances in other cases shall be ± 1 Hz for frequencies up to 50 Hz and ± 2 percent for frequencies above 50Hz.

2.1.2.3 **Driving Force** - When required, control of vibration amplitude shall be supplemented by a limitation of the driving force applied to the vibrating system. The method of force limitation (for example, based on measured driving current or force transducer) shall be as stated. Unless otherwise specified the peak driving force shall be limited to a level not less than ma Newtons, where;

m = mass in kilograms of the complete moving assembly (that is vibration table, drive coil, jig or fixture and equipment under test, etc.).

a = the required acceleration level in m/s^2

2.2 **Random Vibration System**

2.2.1 **Required Characteristic** - The characteristic required of the vibration generator when loaded for test shall be as follows:

2.2.1.1 **Basic Motion** - The basic motion of the fixing points of the equipment shall be recetilinear and of a stochastic nature with a normal (gaussian) distribution of instantaneous values. They shall also have substantially identical motion.

2.2.1.2 **Distribution** - The instantaneous acceleration, values of the vibration applied to the measuring points shall have a nominal gaussian distribution, but the peak to rms acceleration ratio shall be not less than 2.5:1. Unless otherwise specified the Acceleration Spectral Density Acceleration (ASD) at the lower frequencies may be reduced so that the displacement utilizes the maximum capability of the test facility, but the peak to rms acceleration ratio shall not exceed 3:1. Any enforced reduction of ASD shall be stated in the test report.

2.2.2 **Tolerances**

2.2.2.1 **Acceleration Spectral Density (ASD)**

a) When a single control point is allowed, the ASD in the intended direction shall be within ± 3 dB of the specified level as determined by an analyser having a bandwidth not wider than 1/3 octave above 100 Hz and a bandwidth not wider than 20Hz below 100 Hz.

b) When two or more control points are used, the ASD at each control point in the intended direction, analysed as above, should as far as practicable be within ± 3 dB of the specified level or as otherwise agreed by the responsible authority. With large complex equipment it will be difficult to achieve this tolerance. In such cases the revised value shall be agreed and recorded in the test report.

c) The ASD level in the transverse direction at the control point shall be within ± 5 dB of the specified value in the intended direction.

2.2.2.2 **Acceleration** - The total rms acceleration at each control point shall be within ± 2 dB of the specified value.

2.2.2.3 Confirmation to these tolerances shall be made with an analyser providing statistical accuracies corresponding to a BT product not less than 50 where :

B is the bandwidth of the analyser in Hz.

T is the effective sampling time in seconds.

3. TEST PROCEDURE

3.1 Mounting

3.1.1 The equipment, with or without isolator, shall be fastened to the vibration table, either directly or by means of mounting fixtures, by its normal means of attachment or as otherwise stated in the relevant equipment specification. The use of any additional stays or straps shall be avoided. Any connections to the equipment (such as cable, pipes, wires, etc.) shall be so arranged that they impose no more restraint or mass than they would when the equipment is installed in its operational position.

3.1.2 The mounting fixtures shall be such as to enable the specimen to be vibrated along the various axes specified for conditioning.

3.1.3 If it is necessary to provide brackets in order to connect the equipment (or normal means of attachment of the equipment) to the vibration table the brackets shall be designed to be effectively rigid within the frequency range to be covered by vibration test.

3.1.4 An equipment intended for use with vibration isolators should normally be tested with its isolators. When it is not practicable to carry out vibration test with the appropriate isolators, for example, when the equipment is mounted with other Equipment in a common mounting system, or if the dynamic characteristics of the isolators are very variable (for example, temperature dependent); it may be tested without isolators at a different vibration severity, as specified. This severity shall be determined by multiplying the normal vibration level by the most adverse transmissibility factor of the isolator system in each axis. The transmissibility factor shall be as stated or as given by generalized curves of Fig. 4.28-1 (see guidance clause 1.7 also).

> Note : The relevant equipment specification may require an additional test on equipment with the external isolators removed in order to demonstrate the minimum structural resistance to vibration.

3.1.5 The relevant equipment specification shall state whether the effect of gravitational force is important. In this case the equipment shall be so mounted that the force acts in the same direction as it would in use. Where the effect of gravitational force is not important, the equipment may be mounted in any attitude.

3.1.6 The relevant equipment specification shall state whether the influence of stray magnetic field is significant, and if so, the maximum level of magnetic interference to which the equipment may be subjected.

3.2 **Control** - The test is controlled by measurements made at reference point and control points related to the fixing points of the equipment.

3.2.1 **Fixing Point**- A fixing point is part of the equipment in contact with the fixture or vibration table at a point where the equipment is normally fastened in service. If a part of real mounting structure is used as the fixture, the fixing point shall be taken as those of mounting structure and not of the equipment.

3.2.2 **Control Point** - A control point is normally a fixing point. It shall be as close as possible to the fixing point and in any case shall be rigidly connected to the fixing point. If four or less fixing points exist, each shall be used as a control point. If more than four fixing points exist, four representative points shall be selected and specified for use as control points.

Note: For large and /or complex equipment, the control points should be defined in the relevant equipment specification.

3.2.3 **Reference Point** - The reference point is the single point from which the reference signal is obtained to confirm the test requirement and is taken to represent the motion of the equipment. It may be a control point, or a fictitious point created by a manual or automatic processing of the signals from the control points. Unless otherwise specified, the signals from the reference point shall be the average of signals from the control points. The relevant equipment specification shall state the point to be used or how it should be chosen. It is recommended that for large and/or complex equipment a fictitious point be used.

3.3 **Initial Measurements** - The equipment shall be visually examined and shall be electrically and mechanically checked as specified.

3.4 **Conditioning**

3.4.1 Test sequence (see clause 3.4.2) for conditioning consists of the following three distinct stages.

3.4.1.1 **Initial Resonance Search** (see clause 3.4.5) - The equipment is vibrated (sinusoidal motion) over the complete frequency range specified. It is checked functionally and examined for any frequency dependent effects, such as mechanical resonances and malfunctioning. These vibration characteristics, their frequencies and the levels at which they occur are noted.

3.4.1.2 **Functional** (see clause 3.4.1.1) - The equipment is vibrated (sinusoidal motion) over the complete frequency range, specified and operated throughout this test.

3.4.1.3 **Endurance** - One of the following methods, as specified, shall be employed:

a) Sinusoid with frequency sweep (see clause 3.4.6) - Sinewave sweeps of specified level, sweep rate, frequency range and duration.

b) Sinusoid at fixed frequencies (see clause 3.4.7) - Vibration at one or more frequencies (or at narrow band of frequency) as specified and/or at the frequencies determined in initial resonance search test. The amplitude and duration shall be as specified.

c) Wide band random motion (see clause 3.4.8) - Random vibration of specified spectrum level, frequency range, amplitude distribution and duration.

d) Narrow band random motion (see clause 3.4.9) - Narrow band random sweeps of specified level, bandwidth, amplitude, distribution, sweep rate, frequency range and duration.

3.4.1.4 **Final Resonance Search** (see clause 3.4.10) - After the endurance stage, the specimen is re-tested functionally and re-examined for vibration characteristic as in initial resonance search. The frequency for each effect, determined in initial and later in the final resonance search is compared. The relevant equipment specification may state the action to be taken if any change of frequency occurs.

3.4.2 **Test Sequence** - The relevant equipment specification shall specify one of the following test sequences :

a) Initial resonance search
Endurance by sinusoid with frequency sweep
Final resonance search

b) Initial resonance search
Endurance at fixed frequencies
Final resonance search

c) Endurance by sinusoid with frequency sweep

d) Initial resonance search
Endurance by wide band random vibration
Final resonance search

e) Initial resonance search
Endurance by narrow band random vibration

Final resonance search

f) Initial resonance search
Functional
Endurance at fixed frequencies

Note : 1 During initial resonance search under test sequence (f),only step (b) of clause 3.4.5.2 shall be carried out.

2 Endurance at fixed frequencies includes the resonance frequencies (see clause 3.4.7.1 (a)).

g) Functional
Endurance by sinusoid with frequency sweep

Note : For equipment either completely or partially modularised, hermetically sealed or fully inaccessible to carry out mechanical resonance search, test sequence c) shall be applied.

3.4.3 Unless otherwise specified the equipment shall be vibrated in three mutually perpendicular axes in turn, which shall be so chosen that faults are most likely to be revealed.

3.4.4 If the relevant equipment specification requires initial and final resonance search, the complete test sequence including resonance search shall be performed in one axis and repeated for other axes. If necessary, the sequence may be varied by the relevant equipment specification so as to allow resonance search to be carried out in more than one direction before starting the endurance conditioning.

3.4.5 **Initial Resonance Search**

3.4.5.1 The complete sweep of the frequency range shall be carried out in order to study the behavior of the equipment under vibration, to determine resonance frequencies and to obtain information for final resonance search. Endurance conditioning, if applicable, is carried out on these resonance frequencies. Normally, the initial resonance search shall be carried out at the same amplitude as for the endurance conditioning but

the vibration amplitude may be decreased below the specified value, if, thereby a more precise determination of resonance characteristics can be obtained. For ground and ship borne equipment the vibration amplitude and frequency range are given in Table 4.28-2. For airborne equipment the initial resonance search shall be carried out at the vibration level corresponding to the most severe category of the endurance test (see clause 4.2.2.2).

Note : The build up of a resonance, as the excitation passes through the resonance frequency, is a function of the frequency sweep rate, the Q of the resonance and its frequency. If the sweep rate is too great, the resonance may be only partially excited, or in extreme cases may even escape detection. This is more likely at low frequency with high - Q resonances. For this reason the rate of sweep may be decreased during the resonance search test.

3.4.5.2 During this procedure, the equipment shall be examined in order to determine frequencies at which :

a) Equipment malfunctioning and/or deterioration of performance are exhibited which depend on vibration:

b Mechanical resonances occur.

All frequencies and amplitudes at which these effects occur shall be noted for comparison with those found in the final resonance search and/or carrying out endurance test, if required. The relevant equipment specification shall also specify whether steps (a) and (b) both are required or only one of them is required.

Note : For airborne equipment all resonances at frequencies less than 10 Hz shall be eliminated or, if impossible to eliminate, shall be declared. The resonance search test level at frequencies less than 10 Hz shall be equal to the amplitude levels at 10 Hz.

3.4.5.3 The equipment shall be functioning during the resonance search if required by the relevant equipment specification. When the mechanical vibration characteristics cannot be assessed because the equipment is functioning, an additional resonance search with the equipment not functioning shall be carried out. Any arrangements made to detect the effect of vibration upon internal parts of the equipment shall not substantially change the dynamic behaviour of the equipment as a whole.

3.4.6 Endurance by Sinusoid with Frequency Sweep

3.4.6.1 The frequency sweep is traverse of the specified frequency range once in both directions, for example 10 Hz to 1000 Hz to 10 Hz. The sweeping shall be continuous and logarithmic, and the sweep rate shall be approximately one octave per minute. A linear sweeping approximation may be used, provided the actual sweep rate does not exceed one octave per minute at any time and the duration of passage through each octave above 60 Hz is approximately the same as with the logarithmic sweep.

Note : If in the course of initial resonance search low frequency high - Q resonances have been found a check should be made that the sweep rate of one octave per minute is not too great. The maximum permissible sweep rate is given by:

$$\text{Sweep Rate (octave per minute)} = 1.443 \log_e \frac{23.6f}{Q2} + 1$$

Where f is the natural frequency in Hz

3.4.6.2 The frequency increase from the minimum to the maximum of the appropriate frequency range followed by decrease to the minimum frequency constitutes one sweep. A number of sweeps in each axis may be required to make up the specified duration. Unless otherwise specified the duration shall be equally divided on all axes.

Note : For airborne equipment, the total time of sweeping in each category shall be equal to the corresponding wide band random motion test when the frequency range is 10 to 1 000 Hz. It shall be 0.6 of the corresponding wide band random motion test when the frequency range is 60 to 1 000 Hz and 0.4 when the frequency range is 10 to 60 Hz.

3.4.6.3 It is permissible to cover the frequency range in stages provided the sweep time in each stage is appropriate to the band width of the stage.

3.4.6.4. The amplitude for ground and ship borne equipment shall be as given in Table 4.28-2, for airborne equipment the amplitude shall be as given in Fig. 4.28-7 and Fig. 4.28-8.

3.4.6.5 If required, the equipment shall be operated and checked during this test for such proportion of the total duration as may be specified.

3.4.7 **Endurance at Fixed Frequencies**

3.4.7.1 Vibration shall be applied at the frequencies at which failure, malfunctioning or other undesirable effects are likely to occur during the equipment life. These frequencies shall be selected from the following and specified in relevant equipment specification:

a) Frequencies at which mechanical resonances occur.

b) Frequencies at which equipment malfunctioning and/or deterioration of performance, have been noticed.

c) Predetermined frequencies.

Note : In the case of an equipment mounted on isolators, the relevant equipment specification shall state whether or not the fundamental resonance frequencies of the equipment on its isolators should be chosen for this endurance conditioning.

3.4.7.2 It is expected that the number of frequencies at clause 3.4.7.1 (a) and (b) will be small and normally not exceed four. If the number exceeds four, the conditioning by sweep (see clause 3.4.6) would be preferred.

3.4.7.3 While carrying out test at resonance frequencies, the driving frequency shall be so adjusted that the reasonance is always fully excited.

3.4.7.4 The duration of the test and the amplitude shall be as specified and shall be selected from severities given in clause 4. Unless otherwise specified, the total duration shall be equally divided for vibration at each frequency in each of the three axes of the equipment.

3.4.7.5 The following shall apply for testing airborne equipment only:

a) At each resonance frequency of the equipment, the time in each category, for which the excitation is applied, shall be 0.025 of the corresponding wide band random motion test.

b) If the dynamic magnification factor Q appropriate to each resonance has not been measured during the initial resonance search, the amplitude level to be applied in the test shall be that appropriate to the natural frequency and category, and is given in Fig. 4.28-6 and 4.28-7.

c) If values of Q have been measured, the amplitude level to be applied shall be calculated from:

$$d = 118.4\,(S/Qf^{3})^{1/2}$$

Where d is the applied displacement (half amplitude in mm),

S is the acceleration spectral density $(m/s^2)^2/Hz$ appropriate to the category, and Q is the measured dynamic magnification factor for resonance at frequency f in Hz.

3.4.8 **Endurance by Wide Band Random Vibration**

3.4.8.1 Equalization - Prior to the application of the random vibration conditioning at the specified level, a preliminary random excitation of the actual equipment under test may be necessary at a lower level for equalization and preliminary analysis. This equalization may be done in one or more stages: for example, first at 10 dB below the specified level and then at 6 to 3 dB below the specified level. It is important that at this time the level and time of application of the vibration be kept to a minimum. The permitted set up times are as follows:

a) at 25 percent of the specified level, no time limit;

b) at 25 to 50 percent of the specified level - 1.5 times the specified test duration;

c) at 50 to 100 percent of the specified level - 10 percent of the specified test duration.

Note : 1 These set up times shall not be subtracted from the specified duration of conditioning.

2 Minor adjustments may be effected during the conditioning.

3.4.8.2 The equipment shall be subjected to the wide band random motion severity selected from clause 4.2.2 and specified in the relevant equipment specification.

3.4.8.3 During the entire conditioning period (see clause 4.2.3) the total rms acceleration with the specified frequency range shall be measured and controlled.

3.4.8.4 Unless otherwise specified, equipment shall be functioning during the conditioning in order to determine functional as well as mechanical effects. Performance check shall be made as specified. The relevant equipment specification shall also specify the stage at which these performance checks are to be made.

3.4.9 **Endurance by Narrow Band Random Vibration** - when facilities exist for making a frequency sweep with a narrow band random input, this may be used as an alternative test. Since the conditions governing such a test will depend to a great extent on the capabilities of the test equipment, this specification does not give precise requirements for the conduct of such a test. It will, therefore, be necessary for the authority requiring this test to approve a test schedule which should be drawn up on the basis that the tests under the schedule will cause fatigue damage equal to that of the wide band random motion test.

3.4.10 **Final Resonance Search** - The final resonance search shall be performed in the same manner as the initial resonance search (see clause 3.4.5)

Note : 1 Prior to final resonance search test it may be necessary to provide a period of time in which to allow the equipment to attain the same conditions as existed at the commencement of the initial resonance search; for example, as regards temperature.

2 The final resonance search is not applicable.

3.4.11 **Functional**

3.4.11.1 The equipment shall be subjected to this test with its shock or vibration mounts, if any, in position. The equipment shall be vibrated over the range of frequencies and at amplitudes corresponding to the appropriate category specified in Table 4.28-2.

3.4.11.2 The frequency of vibration shall be varied continuously (or in steps, if so required by the relevant equipment specification) over the specified range at such a rate that any performance deterioration can be detected. The rate of change of frequency shall not exceed one octave per minute. The equipment shall be operated throughout this test and checked for satisfactory performance by carrying out a quick performance check (involving only one or two important/significant parameters as required).

3.5 **Final Measurement** - The equipment shall be visually examined and electrically and mechanically checked as specified.

4. SEVERITIES

4.1 Sinusoidal Vibration

4.1.1 A vibration severity is given by the combination of frequency range, vibration amplitude and endurance duration. The relevant equipment specification shall choose the appropriate values from those listed in clause 4.1.3 and 4.1.4.

4.1.2 The vibration amplitudes are specified in terms of constant displacement or constant velocity or constant acceleration. The term amplitude is used in the wider sense of peak value of an oscillating quantity. Each value of displacement amplitude is associated with corresponding value of velocity or acceleration amplitude, the relationship is as follows :-

$$\text{Acceleration } (m/s^2) = \frac{4\ \ {}^2f^2}{1000} \text{ displacement (mm)}$$

$$\text{Velocity } (m/s) = \frac{2\ f}{1000} \text{ displacement (mm)}$$

Where f is frequency in Hz.

Note : For any combination of displacement and acceleration or displacement and velocity amplitude, a crossover frequency can be calculated from the above relationship, so that the magnitude of vibration is same at this frequency. Hence, a frequency range may be swept continuously, changing from constant displacement to constant acceleration (or constant velocity) and vice versa at the Crossover frequency.

4.1.3 Frequency Range and Amplitudes

4.1.3.1 The frequency range and amplitudes applicable to ground and shipborne equipment are given in Table 4.28-2.

TABLE 4.28-2 FREQUENCY RANGE AND AMPLITUDES FOR VARIOUS CLASSIFICATION OF GROUND AND SHIPBORNE EQUIPMENT
(Clause 4.1.3.1)

Sl No	CLASSIFICATION OF EQUIPMENT	FREQUENCY RANGE	AMPLITUDE
1.	Ground Equipment		
	a) Equipment Installed in Tracked Vehicles		
	Level 1	5 to 13 Hz	±6 mm constant displacement
		13 to 500 Hz	±40 m/s² constant acceleration
	Level 2	5 to 13 Hz	±6 mm constant displacement
		13 to 142 Hz	±40 m/s² constant acceleration
		142 to 201 Hz	±0.05 mm constant displacement
		201 to 2000 Hz	±80 m/s² constant acceleration
	b) Equipment installed in Wheeled Vehicles and Trailers	5 to 8 Hz	±6 mm constant displacement
		8 to 500 Hz	±15 m/s² constant acceleration
2.	Shipborne Equipment a) Equipment Installed in Major Warships (see Fig. 4.28-2)		
	Mast head region	5 to 14 Hz	±1.25 mm constant displacement
		14 to 23 Hz	±0.45 mm constant displacement
		23 to 33 Hz	±0.125 mm constant displacement
	After region	5 to 23 Hz (see Note 2)	±0.45 mm constant displacement
		23 to 33 Hz	±0.125 mm constant displacement
	Main region	5 to 33 Hz (see Note 2)	±0.125 mm constant displacement
	b) Equipment Installed		

Sl No	CLASSIFICATION OF EQUIPMENT	FREQUENCY RANGE	AMPLITUDE
	Minor Warships (see Fig. 4.28-2)		
	After region	7 to 300 Hz	± 0.4 mm constant displacement or ± 60 mm/s constant velocity, whichever is the lesser
	Main region	7 to 300 Hz	± 0.2 mm constant displacement or ± 30 mm/s constant velocity, whichever is the lesser
	c) Equipment Installed in Submarines	5 to 33 Hz (see Note 2)	± 0.125 mm constant displacement
3.	Equipment Transported by Vehicle, Ship and/ or Aircraft		
	a) Up to and Including75 kg	5 to 350 Hz	± 6 mm constant displacement or ± 20 m/s^2 constant acceleration whichever is the lesser
	b) Over 75 kg (see Note 3)	5 to 150 Hz	± 6 mm constant displacement or ± 20 m/s^2 constant acceleration whichever is the lesser

Note : 1 Where equipment are installed in both tracked and wheeled vehicles, the levels appropriate to tracked vehicles shall apply.

2 For general test purposes the low frequency limit of 5 Hz is acceptable. In the instance where the equipment and its isolators (if used) may have an unacceptable response (for example, a low frequency resonance) at a lower frequency, then the frequency range should be extended down to 2 Hz. The test level at frequencies less than 5 Hz shall be equal to the amplitude level at 5 Hz.

3 For equipment of mass over 75 kg and which have a designated base, the vibration conditioning shall be applied only in plane normal to the base.

4.1.3.2 For airborne equipment the frequency range shall be derived as in the random vibration test (see clause 4.2.2.2) depending upon the flight conditions and equipment region (see Table 4.28-5) specified in the relevant equipment specification.

4.1.4 **Duration**

4.1.4.1 **Ground Equipment** - The total duration for endurance conditioning shall be based upon the estimated vehicle movement. This shall be subject to a minimum of 50 hours for equipment used in tracked vehicles, and a maximum of 10 hours for equipment used in wheeled vehicles and trailers. Subject to these maximum limits, the duration shall be calculated as follows:

a) Equipment used in tracked vehicles : 2 hours duration per 1600 km of estimated movement.

b) Equipment used in wheeled vehicles and trailers : 2 hours duration per 8000 km of estimated movement.

Note : 1 For equipment used in wheeled vehicles and trailers the duration of endurance at any one resonant frequency shall be limited to two hours. Any residual of the duration obtained after subjecting the equipment to endurance at resonance frequencies as above, shall be made up by subjecting the equipment to vibration at frequencies of 50 Hz and 100 Hz applied for equal duration in each of the three mutually perpendicular axes at both these frequencies. For equipment used in tracked vehicles, the duration of endurance at any one resonance frequency shall be limited to 10 hours.

2 When the estimated vehicle movement details are not available, the total duration of endurance shall be limited to 20 hours in the case of equipment used in tracked vehicles.

3 When a fundamental resonance frequency of an isolator is chosen for endurance conditioning, the duration of endurance at the frequency shall not exceed five minutes.

4.1.4.2 **Shipborne Equipment** - 1 hour endurance conditioning at each resonance frequency or frequency specified.

Note : If a resonance occurs in rubber shock or vibration mounting at or below 8 Hz, the duration of test at resonance should not exceed 5 minutes.

4.1.4.3 Equipment transported by vehicle, ship or aircraft - Total duration 6 hours for endurance by frequency sweep.

4.1.4.4 **Airborne Equipment** - The duration for endurance test shall correspond to that specified for the wide band random vibration test. It shall be calculated as given in note below clause 3.4.6.2 or as in clause 3.4.7.5 (a).

4.2 **Random Vibration**

4.2.1 For this test a vibration severity is given by the combination of frequency range, ASD level and endurance duration. For each parameter the relevant equipment specification shall choose the appropriate values from those given in clause 4.2.2. and 4.2.3 .

4.2.2 **Frequency range and ASD Level**

4.2.2.1 **Equipment Installed in Vehicles** - The Frequency range and ASD levels applicable to equipment installed in vehicles are given in Table 4.28-3.

TABLE 4.28-3 FREQUENCY RANGE AND ASD LEVELS
(Clause 4.2.2.1)

EQUIPMENT INSTALLED IN	ASD LEVEL AND FREQUENCY RANGE
Tracked Vehicles	
a) Level 1	10 $(m/s^2)^2$/Hz; 20 to 500 Hz
b) Level 2	10 $(m/s^2)^2$/Hz; 20 to 500 Hz falling to 1 $(m/s^2)^2$Hz at 2000 Hz (see Fig. 4.28-3)
Wheeled Vehicles	20 $(m/s^2)^2$/Hz; 20 to 50 Hz falling to 0.1 (m/s^2)/Hz at 500 Hz (see Fig. 4.28-4)

Note : 1 The low frequency range may need extending below 20 Hz for those equipment which have a low frequency response and for tests where an isolator system is included with the equipment. The ASD appropriate to 20 Hz shall be maintained subject to the amplitude limitation of clause 2.2.1.2. Alternatively, random vibration test may be supplemented by a low frequency sinusoidal test.

2 In tracked vehicles, vibration sometime severe, is excited at frequencies associated with track patter. Where levels in excess of the severities specified in Table 4.28-3 are anticipated, the wide random vibration test may need to be supplemented by a sinusoidal or narrow band random vibration test over the appropriate part of the frequency band.

4.2.2.2 **Airborne Equipment** - The ASD level for airborne equipment shall correspond to one of the categories specified in Table 4.28-4, depending upon the equipment location and flight conditions (see Table 4.28-5). The frequency range shall be defined by frequency limits f_1 and f_2 which are determined for any category by the flight conditions and the equipment location as given in Table 4.28-5.

a) **Equipment Location** - There are four equipment regions A,B,C and D as follows:

Region A - The extremities of aircraft, and any part in which equipment is mounted close to the aircraft skin so that transmission paths from the structure to the equipment are short.

Region B - The central fuselage of the aircraft, but excluding parts of the central fuselage in which equipment is in Region A.

Region C - Equipment racks and instruments packs designed to hold a number of units.

Region D - Close proximity to a main power plant, but excluding direct contact with the power plant (which is not covered by this specification).

b) **ASD Categories** - These are five categories for Region A and B, each of which is associated with a flat ASD level between lower and upper frequency limits f_1 and f_2 respectively (see Fig. 4.28-5), these are given in Table 4.28-4.

TABLE 4.28-4 ASD CATEGORIES
(clause 4.2.2.2 [b])

CATEGORY	ASD IN $(m/s^2)^2/Hz$
1	0.1
2	0.5
3	1
4	2
5	5

c) **Frequency Range** - As given in Table 4.28-5.

TABLE 4.28-5 FREQUENCY RANGE
(Clause 4.2.2.2 [c])

FLIGHT CONDITION		EQUIPMENT REGION A			EQUIPMENT REGION B		
		f_1 Hz	f_2 Hz	Category	f_1 Hz	f_2 Hz	Category
1.	Atmospheric turbulences (severe) (see Note 1)	10	60	4	10	60	3
2.	Atmospheric turbulences (normal) (see Note 2)	10	60	3	10	60	2
3.	Unprepared runway operation (see Note 3)	10	60	4	10	60	4
4.	Normal runway operation	10	60	3	10	60	2
5.	High external noise levels > 140 dB (see Note 4)	60	1000	3	60	1000	2
6.	High external noise levels > 150 dB (see Note 4)	60	1000	4	60	1000	3
7.	High external noise levels > 160 dB (see Note 4)	60	1000	5	60	1000	4
8.	Aerodynamic buffeting or transonic flight	10	1000	3	10	1000	2
9.	Low level high speed flight	10	1000	3	10	1000	2
10.	Cruise (supersonic)	10	1000	2	10	1000	1
11.	Cruise (subsonic)	10	1000	1	-	-	-

Note : 1 Flight condition 1 is intended to cover turbulent atmospheric conditions such as severe thunderstorms which would normally be avoided, but in some circumstances may have to be encountered.

2 Flight condition 2 is intended to cover conditions in which action may be taken to avoid severe atmospheric disturbance.

3 Flight condition 3 is intended to apply to operations from rough fields, stony or potholed ground, or any other surface not normally considered suitable for aircraft operation.

4 Flight conditions 5,6 and 7 are intended to apply to equipment which is mounted in a reverberant enclosure. If the enclosure is absorptive the category of vibration may be numerically decreased by 1 (that is, category 4 for equipment in a reverberant enclosure becomes category 3 for equipment in an absorptive enclosure, etc.). The test covers only vibration which is transmitted to the equipment throughout its mountings, and an additional acoustic test may be required. When ground engine running produces high noise levels equivalent to those in Table 4.28-5 the appropriate time shall be included in the assessment.

5 Flight condition 11 for equipment in Region B is considered to result i in negligible vibration.

d) When the equipment is designed for general application in different aircraft and the Service environments cannot be specified, the relevant equipment specification may specify an endurance test in any of the categories 2,3,4 or 5 using wide and random vibration for the duration specified in clause 4.2.3.2 (a).

Note : In general, for equipment fitted in aircraft zones not subject to high external noise levels, category 3 should prove to be generally acceptable test level; although for rack mounted equipment, category 2 may prove suitable .

4.2.3. Duration

4.2.3.1 Equipment installed in vehicles - The total duration shall be calculated based upon the estimated vehicle movement. This shall be subject to a maximum of 50 hours vibration conditioning for Equipment used in tracked vehicles and a maximum of 10 hours vibration conditioning for Equipment used in wheeled vehicles and trailers. Subject to these maximum limits the duration shall be calculated as follows :

a) Equipment used in tracked vehicles: 2 hours duration per 1 600 km estimated movement.

b) Equipment used in wheeled and trailers: 2 hours duration per 8 000 km estimated movement.

4.2.3.2 **Airborne Equipment** - Of the total test duration calculated as given below, 0.4 shall be in a direction appropriate to vertical, 0.4 in a direction appropriate to lateral and 0.2 in a direction appropriate to fore-and-aft. If it is clear that vibration in one or more directions will have an insignificant effect on the life of equipment, tests shall not be made in these directions and the total test time shall then be divided between the remaining directions in the proportion given above.

a) The relevant equipment specification shall state the expected life (in hours) which the equipment is estimated to spend in each of the flight conditions listed in Table 4.28-5. This shall be taken as endurance duration in the particular vibration category and frequency range which are determined from Table 4.28-5.

b) The duration in each category and frequency range shall be converted to equivalent duration in the most severe category for that frequency range as given in (c) below. The sum of the duration specified in the most severe category and the equivalent duration, calculated as above, shall be the total duration for which the equipment shall be subjected to the endurance conditioning at the ASD level corresponding to the most severe category. However, the total duration shall be limited to a maximum of 50 hours.

Note : Care should be taken to ensure that the correct duration are obtained when different frequency ranges apply to the flight conditions in the most severe category. The overriding aim of the 50 hour endurance test is that every resonance frequency of the equipment in the range of frequencies which will be encountered in Service shall be subjected to a 50 hour endurance test at the highest level of vibration appropriate to that frequency range.

c) If t_1 is the test duration at an ASD level of S_1 then the duration of an equivalent test at an ASD level of S_2 is given by:

$$t_2 = t_1 (S_1/S_2)^{2.5}$$

The ASD values corresponding to each category given in Table 4.28-4 may be used directly in the formula for calculating the duration in one category which will be equivalent to a specified duration in any other category. Table 4.28-6 shows the equivalent duration for the five categories listed in Table 4.28-4.

TABLE 4.28-6 EQUIVALENT DURATION
(Clause 4.2.3.2 [c])

HOUR IN CATEGORY	EQUIVALENT HOURS IN CATEGORY			
	5	4	3	2
4	0.101	-	-	-
3	0.018	0.17	-	-
2	0.0032	0.031	0.177	-
1	0.000056	0.00056	0.0032	0.018

d) If it is agreed by the Design Authority that the equipment is so constructed that a full endurance test is unnecessary on the grounds that equipment of similar construction has been shown to be insensitive to the duration effects of vibration, the relevant equipment specification may specify a shortened form of endurance test in which the total duration shall be 4.5 hours. When this test is made, the vibration input shall be either wide band random motion or sinusoidal frequency sweep. The frequency range of the test shall include the frequency ranges of all the relevant flight condition. The vibration level at any frequency in the test range shall be that appropriate to the most severe category with which the frequency is associated in the relevant flight condition.

e) For equipment designed for general application in different aircraft and for which Service environment cannot be specified, the relevant equipment specification may specify endurance conditioning for a duration of 50 hours.

5. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

5.1 Whether driving force limitation is required and if applicable, method or force limitation (see clause 2.1.2.3).

5.2 **Mounting** (see clause 3.1)

5.2.1 Whether equipment is to be tested with isolators. If it is impracticable to test the equipment isolators, the applicable severity, determined as stated in clause 3.1.4. Whether additional test without isolators is required and applicable severity (see Note below clause 3.1.4).

5.2.2 Whether gravitational effects are significant (see clause 3.1.5).

5.2.3 Whether influence of stray magnetic field is important and if applicable, the acceptable limit of magnetic interference (see clause 3.1.6).

5.3 **Control** (see clause 3.2.)

5.3.1 The control points to be used (see clause 3.2.2)

5.3.2 The reference point to be used (see clause 3.2.3)

5.4 Initial Measurements (see clause 3.3)

5.5 Applicable Test Sequence (see clause 3.4.2 and 3.4.4).

5.6 The Axes along which the Equipment is to be Vibrated (see clause 3.4.3).

5.7 Whether Initial Resonance Search to be carried out to determine only the Frequencies at which Equipment Malfunctioning and/or Deterioration of Performance are Exhibited (see clause 3.4.5.2).

5.8 The Sweep Rate if other than 1 Octave per minute (see clause 3.4.6.1)

5.9 Details of Equipment Operation and Performance Check if Required (see Clauses 3.4.5.3, 3.4.6.5 and 3.4.8.4).

5.10 If Endurance at Fixed Frequencies is required, the Frequencies at which Endurance Tests are to be carried out (see clause 3.4.7.1. and 3.4.7.2)

5.11 Test Schedule and Severities for Narrow Band Random Vibration, if applicable (see clause 3.4.9)

5.12 Whether Final Resonance Search is Required (see clause 3.4.10)
5.13 Final Measurements (see clause 3.5)

5.14 **Severity**

5.14.1 **Sinusoidal Vibration**

5.14.1.1 **Ground and Shipborne Equipment**- The frequency range, amplitude (see Table 4.28-2) and duration (see clause 4.1.4.1 and 4.1.4.2).

5.14.1.2 **Airborne Equipment** - The frequency range, amplitude (see clause 4.1.3.2) and duration (see clause 4.1.4.4).

5.14.1.3 **Equipment Transported** - The frequency range, amplitude see Table 4.28-2) and duration (see clause 4.1.4.3).

5.14.2 **Random Vibration**

5.14.2.1 **Equipment Installed in Vehicles** - The frequency range, ASD level (see Table 4.28-3) and duration (see clause 4.2.3.1)

5.14.2.2 **Airborne Equipment** - The flight condition, equipment region (see Table 4.28-5 and clause 4.2.2.2 [a]) and estimated duration in each flight condition (see clause 4.2.3.2).

5.15 Any deviation from the normal test procedure.

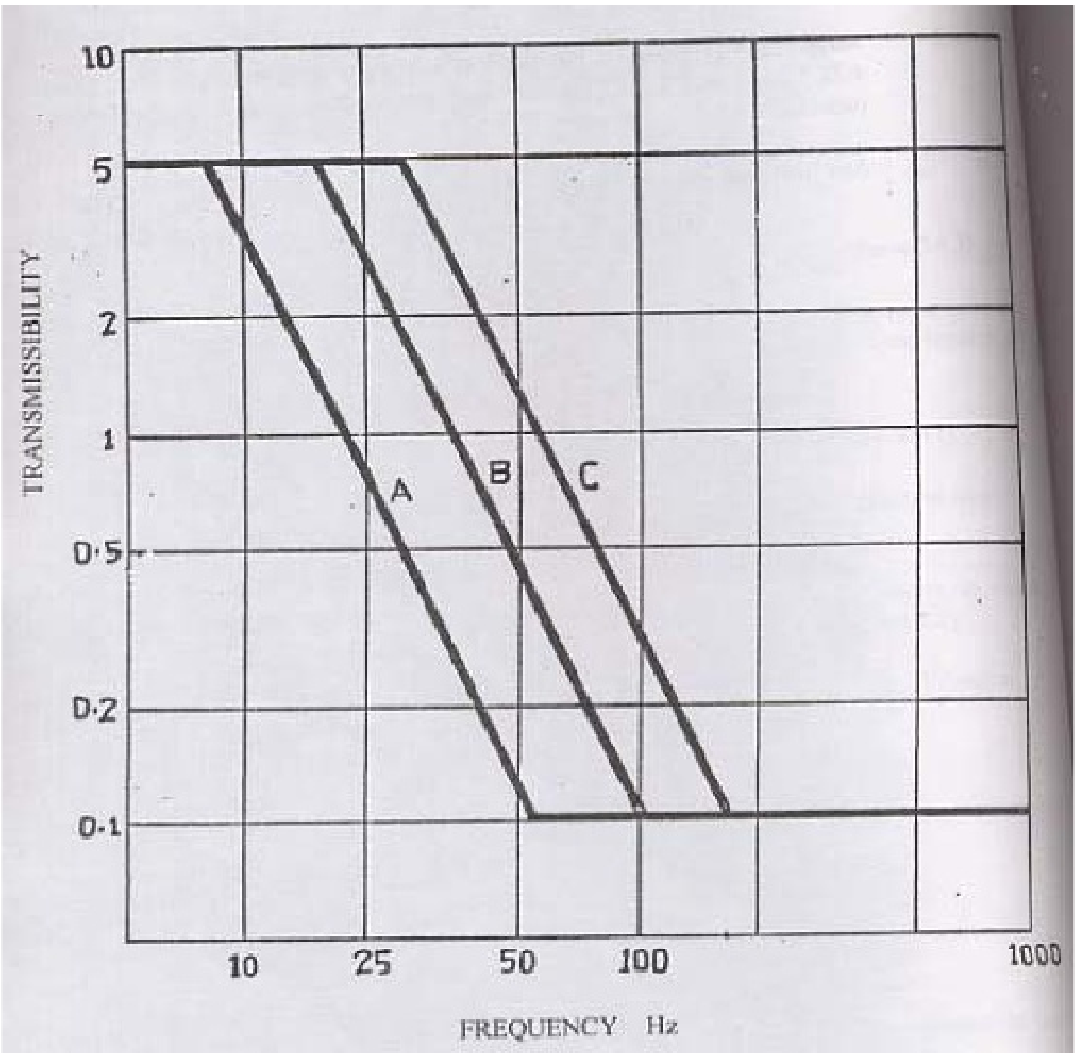


FIGURE 4.28-1GENERALISED TRANSMISSIBILITY FACTOR FOR ISOLATORS

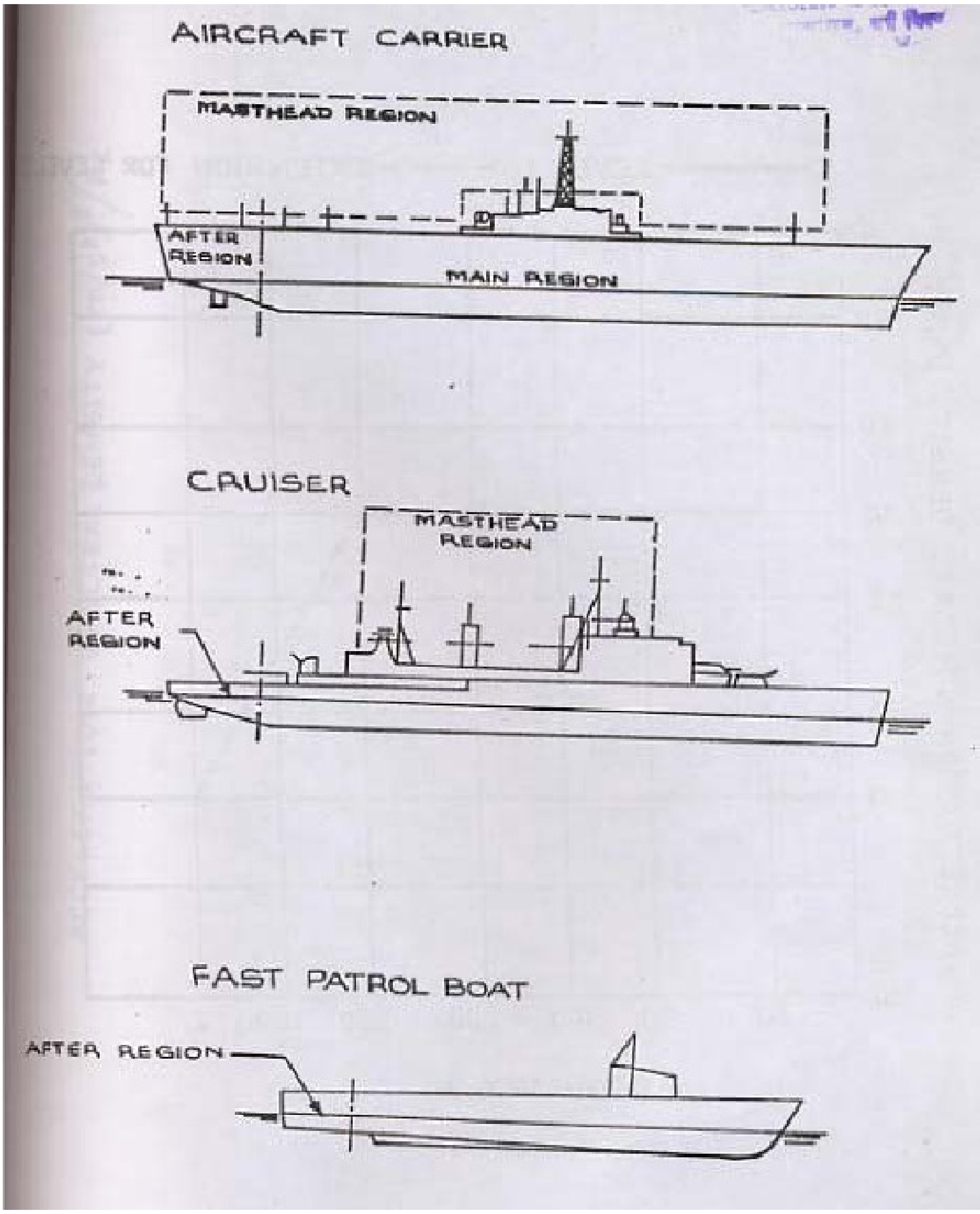


FIGURE 4.28-2 SUB DIVISION OF SHIPS FOR VIBRATION TESTS (PROCEDURES)

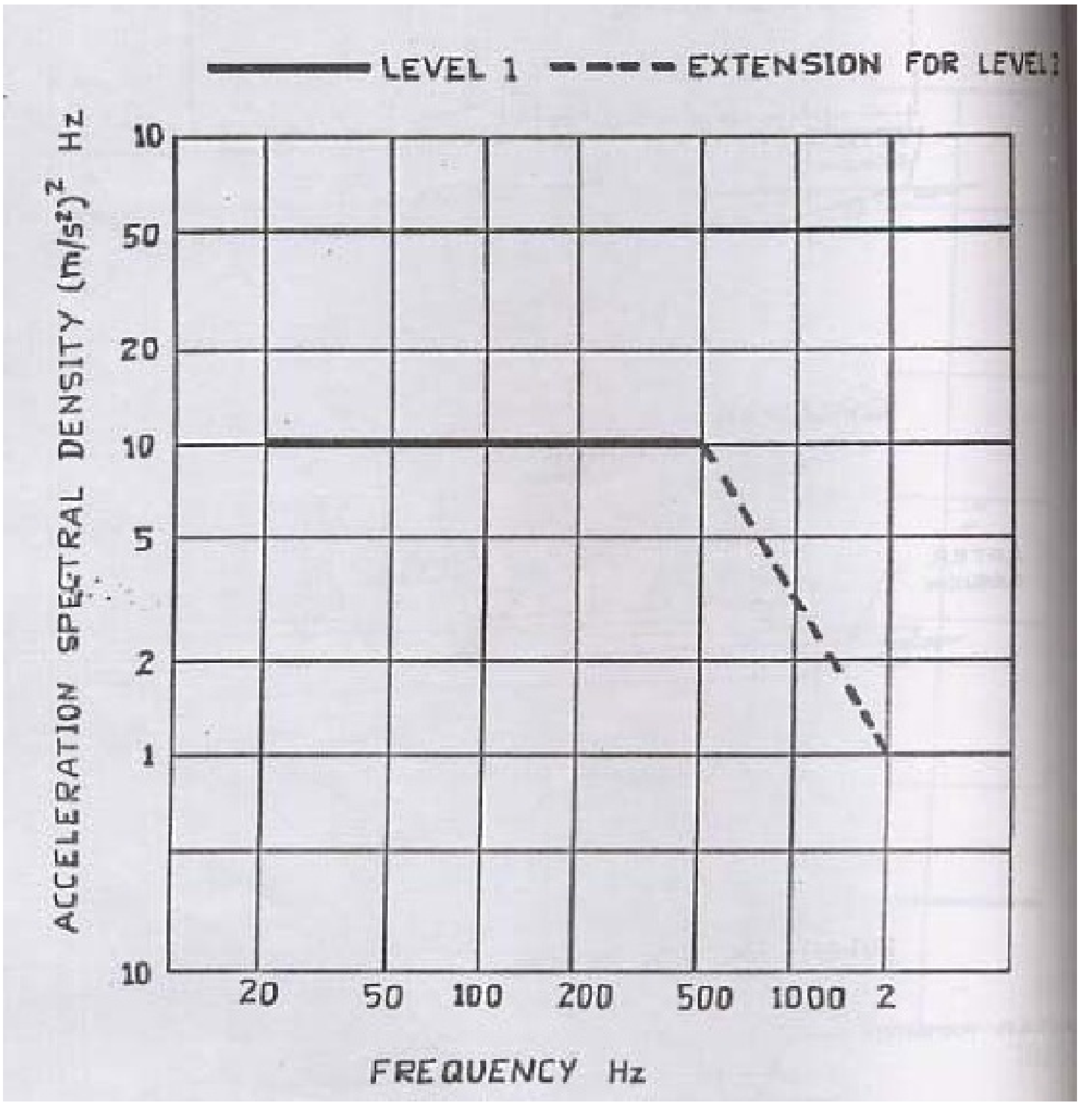


FIG. 4.28-3 RANDOM VIBRATION LEVELS FOR TRACKED VEHICLES

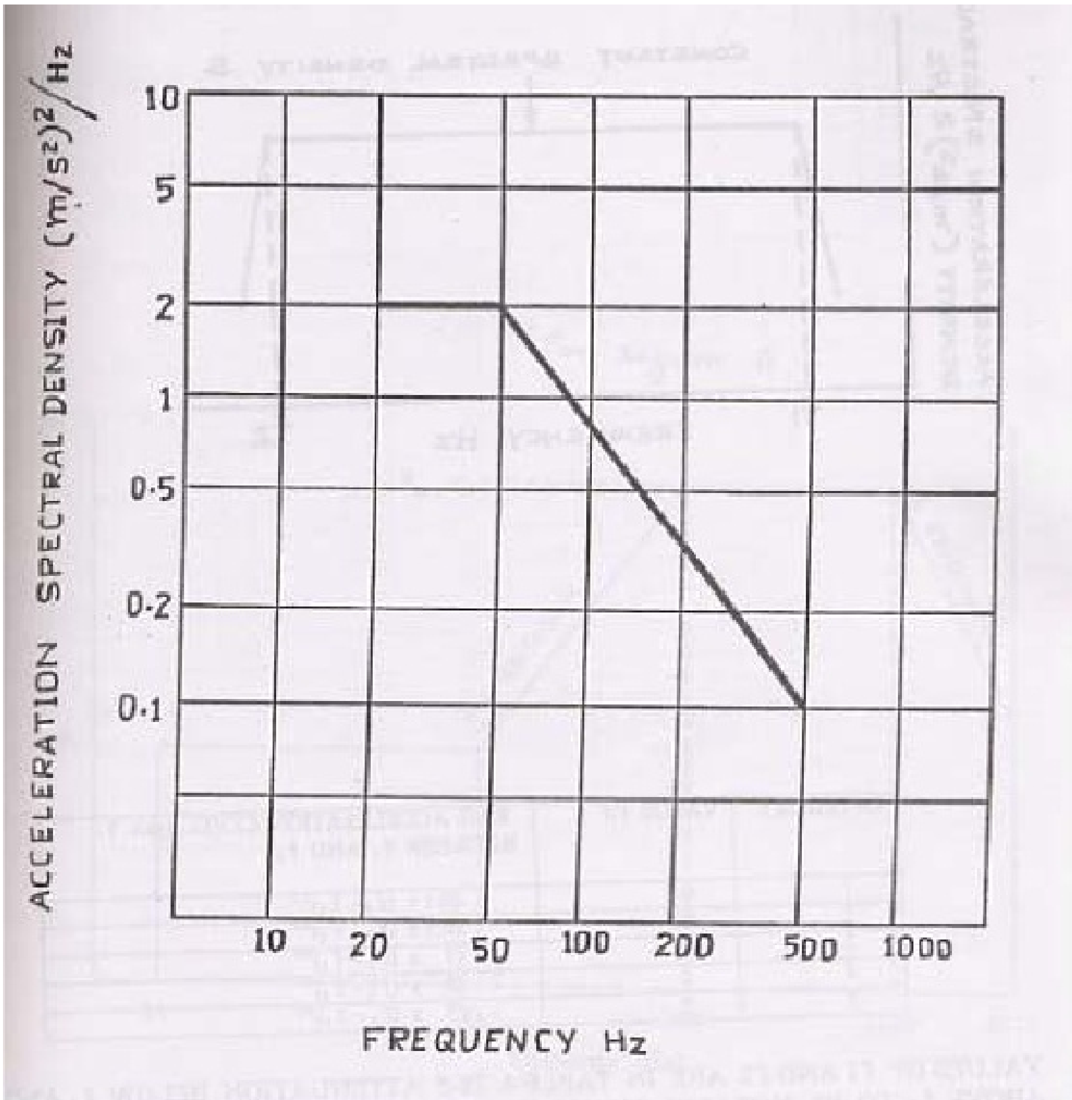
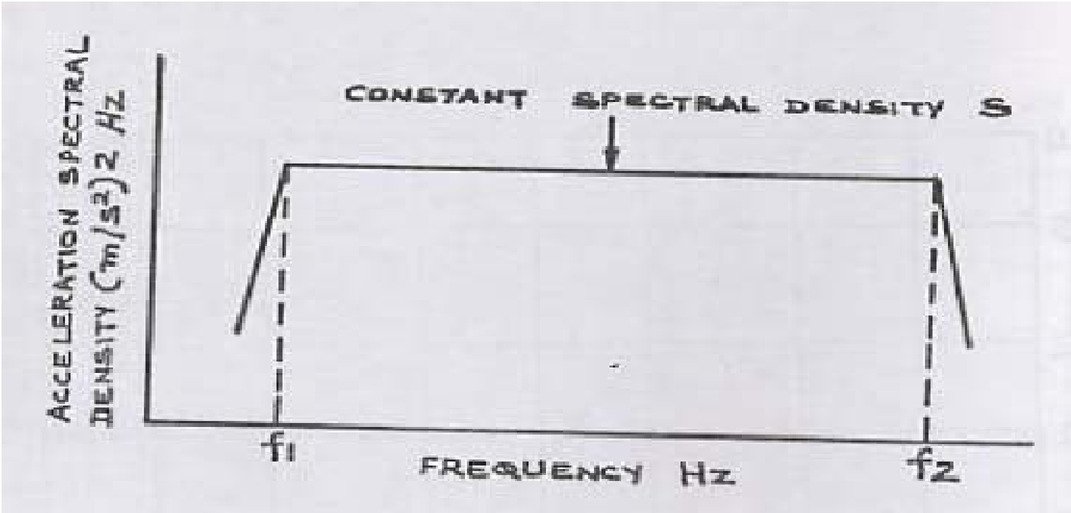


FIG. 4.28-4 RANDOM VIBRATION LEVELS FOR WHEELED VECHICLES AND TRAILERS



CATEGORY	VALUE OF S	R MS ACCELERATION LEVEL (m/s^2) BETWEEN f_1 AND f_2
1	0.1	$(0.1 \times (f_2 – f_1)^{1/2}$
2	0.5	$(0.5 \times (f_2 - f_1)^{1/2}$
3	1	$(1 \times (f_2 – f_1)^{1/2}$
4	2	$(2 \times (f_2 – f_1)^{1/2}$
5	5	$(5 \times (f_2 – f_1)^{1/2}$

FIG. 4.28-5 TEST SPECTRA FOR EQUIPMENT REGIONS A AND B

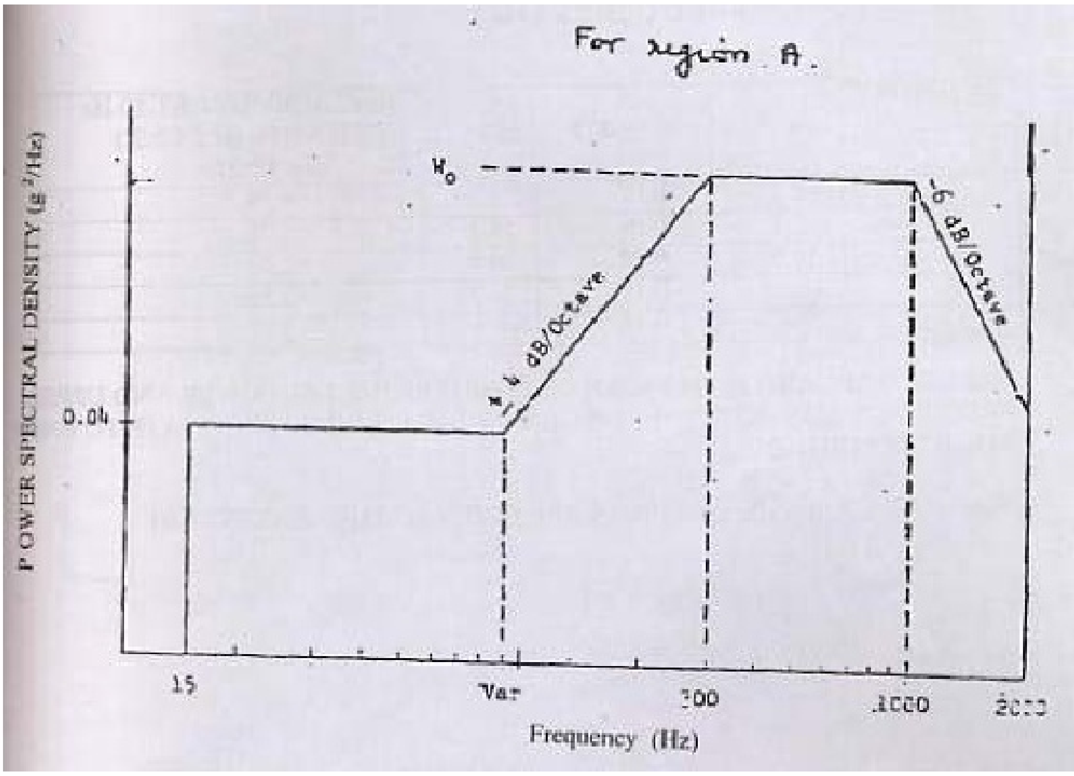
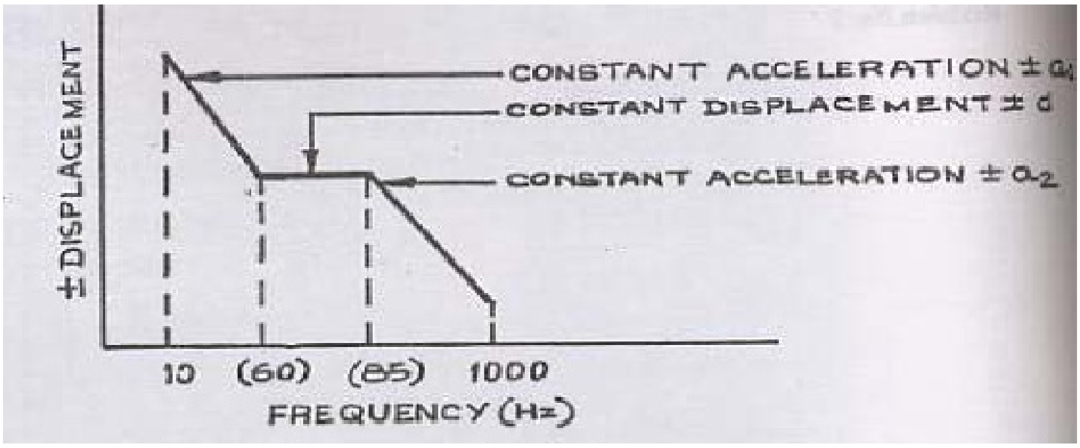


FIGURE 4.28-6 SUGGESTED VIBRATION SPECTRUM FOR JET AIRCRAFT EQUIPMENT



CATEGORY	a_1 m/s^2	d mm UNITS	a_2 m/s^2	DISPLACEMENT AT 10 Hz (SEE NOTE IN 3.4.5.2.) mm UNITS
1	3.2	0.02	6.3	0.79
2	7.1	0.05	14.1	1.76
3	10.0	0.07	20.0	2.49
4	14.1	0.10	28.3	3.52
5	22.4	0.15	44.7	5.57

Note: - UNDER d THE mm UNITS ARE GIVEN TO THE NEAREST 0.01

FIGURE 4.28-7 MINIMUM SINUSOIDAL TEST LEVELS FOR EQUIPMENT REGIONS

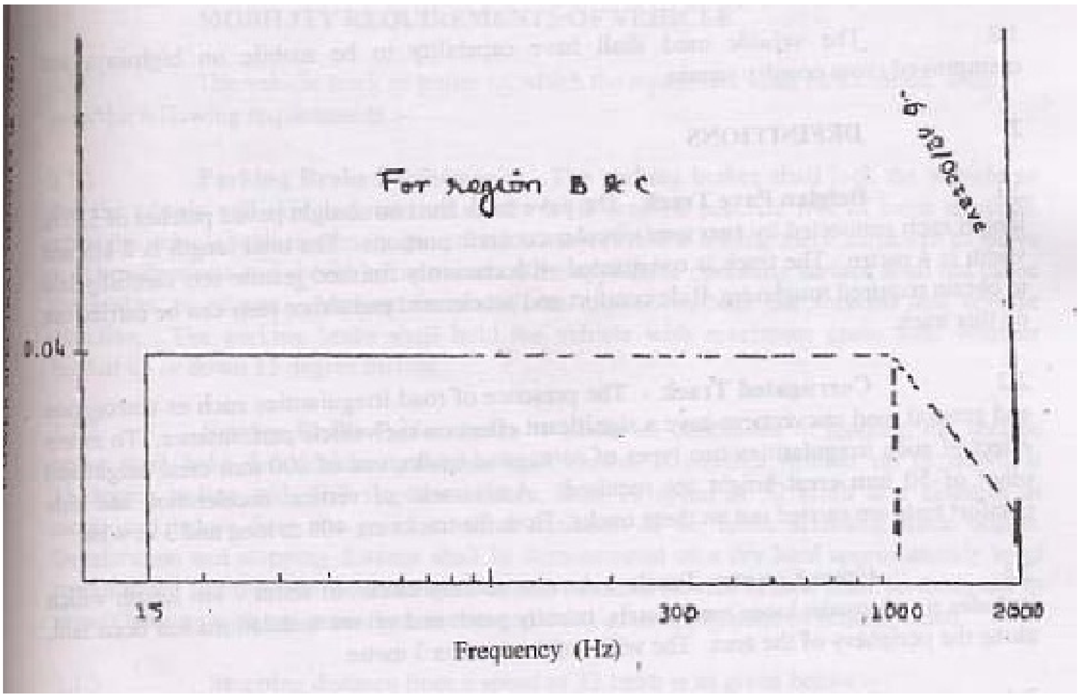


FIGURE 4.28-8 SUGGESTED VIBRATION SPECTRUM FOR JET AIRCRAFT EQUIPMENT

TEST NUMBER 29
ROADABILITY

1. OBJECT

1.1 The objective of this test is to ensure that the system shelter assemblage shall be capable of withstanding the vibrations and other dynamic duresses normally induced during transportation. Test track trials formulated to include movement over the types of terrain representative of more severe condition of deployment are more realistic than laboratory test since they reproduce the combination of various environmental/dynamic duresses that occur in the field. The system shelter assemblage may consist of equipment mounted on platform of the wheeled vehicle or equipment mounted in a shelter which is then mounted on a platform of wheeled vehicle.

1.2 The vehicle used shall have capability to be mobile on highways and unimproved cross country terrain.

2. DEFINITIONS

2.1 **Belgian Pave Track** - The pave track has two straight paved patches of 530 m length each connected by two semi-circular concrete portions. The total length is 2 km and width is 4 metre. The track is constructed with unevenly finished granite sets carefully laid to obtain required roughness. Ride comfort and accelerated endurance tests can be carried out on this track.

2.2 **Corrugated Track** - The presence of road irregularities such as corrugation and general road unevenness have a significant effect on the vehicle performance. To assess effect of such irregularities two types of corrugated tracks, one of 100 mm crest height and other of 50 mm crest height are required. Assessment of vertical acceleration and ride comfort tests are carried out on these tracks. Both the tracks are 400 m long and 3 m wide.

2.3 **Cross Country Track** - A cross country circuit of about 7 km length which includes rough roads, loose road metals, marshy patch and severe undulations has been laid, along the periphery of the area. The width of the track is 3 metre.

2.4 **Steering Pad** - A concrete level circular platform of 76 m diameter is provided to investigate the steering and handling characteristics of the vehicle. Dynamic stability of vehicles can also be assessed.

2.5 **High Speed Track** - This track is a 4.226 km long and 10 m wide closed circuit with necessary super elevations for a speed of 150 km/h. The track can be used for sustained high speed testing as well as maximum speed, fuel consumption. acceleration capabilities, brake performance, calibration of speedo/odometer, coast down, vibration level and lane changing tests.

2.6 **Pot Hole Track** - Response of vehicle systems, especially the suspension and the vehicle structure to the pot holes on unpaved roads formed under natural conditions is of great importance during the vehicle testing. This track is used to assess this effect. The depth and diameters of holes are as given below :-

Dia (mm)	450	550	650	750
Depth (mm)	75	100	125	125

Length and width of the track are 300 m and 6 m respectively

3. MOBILITY REQUIREMENTS OF VEHICLE

3.1 The vehicle truck or trailer on which the equipment shall be mounted, shall meet the following requirements :-

3.1.1 **Parking Brake Performance** - The parking brakes shall lock the vehicle so that the wheels will skid and not troll on dry level brushed concrete free of loose material, when the vehicle with maximum gross load is subjected to a towing force sufficient to move it. The vibrations and shocks encountered on the applicable operating surface shall not cause the brakes to engage. Moving force shall be applied in both the forward and reverse direction. The parking brake shall hold the vehicle with maximum gross load whether headed up or down 15 degree incline.

3.1.2 **Service Brake Performance** - Under all conditions of loading, the service brake shall hold the vehicle motionless and control it whether headed up or down at 15 degree incline and shall stop the vehicle, from a speed of 32 km/h at a distance as mentioned below from the point at which initiation of the brake actuating force begins. Deceleration and stopping distance shall be demonstrated on a dry hard approximately level road surface free from loose materials. Inertia actuated service brakes shall be designed to permit braking with not more than one second delay after application of braking force.

3.1.3 Stopping distance from a speed of 32 km/h is as given below :-

a) Vehicle with Gross Vehicle Mass (GVM) 2700-4500 kg — 7.6 metres

b)	Over 4500 kg GVM	10.7 metres
c)	Combination of Vehicles	13.7 metres.

4. TEST PROCEDURE

4.1 **Initial Measurements** - The equipment shall be visually examined, and checked electrically and mechanically as specified.

4.2 **Conditioning** - The tyre pressure of the van or shelter transport vehicle shall be adjusted for tactical (off road) cross country service. The vehicle shall be checked for mobility Requirements as given in clause 3, before subjecting the equipment for roadability test.

4.3 **Procedure 1.**

4.3.1 The system shelter assemblage shall be driven for the following distances, over a section of track in following order at specified speed, to assess reliability of equipment mounted and mounting arrangements. This constitutes one cycle.

	Track	Distance	Speed
(a)	Belgian Pave	50 Km	16 km/h
(b)	Corrugated	4 passes each on 5 cm & 10 cm crest height of 400 meters length	16 km/h
(c)	Steering pad	20 rounds (4.8 km)	Maximum safe speed
(d)	High Speed	100 km	60 km/h
(e)	Pot holes	4 Passes (1.2 km)	8 km/h

4.4 **Procedure 2.**

4.4.1 In the absence of suitable test as per clause 4.3 the equipment shall be hauled for a total distance of 40 kms on a cross country drive as per details given below:

4.4.1.1 Natural/Virgin Terrains other than metalled roads, comprising of bullock cart or animal tracks, slushy or sandy terrain such as river bed crossing, levelled or undulated boulder sections or hilly terrain for a distance of 20 km at a speed of 5 to 10 kmph.

4.4.1.2 Cross Country fields with bunds of 20 to 25 cm high for a distance of 20 km at a speed of 3 to 5 kmph.

4.5 **Test Severities**

4.5.1 Test Condition 'A' One Cycle

4.5.2 Test Condition 'B' Three cycles

Note : When this test is specified in the relevant equipment specification, the facilities regarding the test tracks to be used as per procedure 1 or the alternative test tracks suggested in procedure 2 shall be mutually agreed to between the contracting parties.

4.6 **Final Measurements** - The vehicle and system shelter assemblage shall be visually examined. The equipment shall be electrically and mechanically checked as specified.

5. INFORMATION TO BE GIVEN IN THE RELEVANT EQUIPMENT SPECIFICATION

5.1 Initial Measurement (see clause 4.1)

5.2 **Test Severity** - Number of cycle the vehicle shall be driven on test track (see clause 4.3) and (4.4)

5.3 Final Measurements (clause see 4.6).

5.4 The Applicable Test Procedure & Test.

TEST NUMBER 30

TEMPERATURE, HUMIDITY, VIBRATION, ALTITUDE

SECTION -1

1. OBJECTIVE

1.1 The purpose of this test is to identify failures that temperature humidity, vibration, and altitude can induce in aircraft electronic Equipment either individually or in any combination, during ground and flight operations. It may used for other similar purposes.

1.2 **Environmental Effects** - Studies have shown that thermal effects, vibrations, moisture, humidity, and in certain cases, altitude have the greatest effect on life of aviation electronic equipment in the operational environment. These forcing functions collectively account for all, but 12% of the environmentally induced failures in the field (of course other stresses, such as sand and dust, salt, fog etc. are also significant and must be considered in a fully integrated test program). Temperature, humidity, vibration and altitude can interact to produce failures such as the following:-

a) Shattering of glass vials and optical equipment,

b) Binding or slackening of moving parts,

c) Separation of constituents,

d) Changes in electronic components,

e) Electronic or mechanical failures due to rapid water or frost formation,

f) Cracking of solid pellets or grains in explosives,

g) Differential contraction or expansion of dissimilar materials,

h) Deformation or fracture of components,

j) Cracking of surface coatings and,

k) Leakage of sealed compartments,

1.3 **Guidelines for determining Tests Procedures and Test Conditions.**

Note : The tailoring process as described in Section 4 of this document should be used to determine the appropriate tests and test variables.

a) Applications - This method is primarily intended for electronic equipment mounted inside an aircraft. The procedures of this method can be used for engineering development, for support of flight testing and for qualification.

b) Restrictions - This method does not apply to electronic equipment, transported as cargo in an aircraft.

c) Sequence - Procedure 1 is intended to be used before final equipment designs are fixed.

d) Test Variations - The test variables are temperature, humidity, vibration, altitude, cooling airflow, electrical stresses, rates of change and test duration.

1.3.1 **Choice of Test Procedures**

1.3.1.1 **Procedure 1** - Engineering Development Tests - The engineering development tests is used to find defects in a new design while it is still in the development stage. The test is failure oriented meaning that the tester should hope to uncover as many defects as possible. A combined environment test is good for this purpose, since it does not require the tester first to predict which stress states are most critical and then to tailor the test to emphasize these states. This test is generally accelerated by eliminating benign conditions or by using higher stresses than the item is likely to encounter in the field.

1.3.1.2 **Procedure 2** - Flight or operation support test - This test is performed in preparation for, or during, flight or operational testing. Its purpose is to minimise delays in the flight testing program due to environmental factors. This test is not accelerated, the damage accumulation in the test is no faster than in operational or in-flight testing. Therefore, development hardware can be interchanged between laboratory and flight or operational testing. This means that when unusual problems develop in flight or operational testing, the equipment system can be brought into the laboratory to help identify any environmental contribution to the observed problem.

1.3.1.3 **Procedure 3** - Qualification Test.- The qualification test is a formal test intended to demonstrate compliance with contract requirements. Generally, qualification testing is an accelerated test that emphasizes the most significant environmental stress conditions. The use of Procedure I of this test method for qualification is not recommended. The qualification test shall include the maximum amplitude of each stress and any unique combinations of stress types that were found to be important in the engineering development testing of the test item.

1.3.2 **Choice of related test conditions**.

1.3.2.1 **Procedure 1**– Engineering Development Test.

1.3.2.1.1 Use the analysis outlined in 1.3.2.2, flight or operational support test, to determine realistic environmental stress levels, durations and rates of change. The more benign portion of the test profile can be eliminated for engineering development test. Likewise the amplitude of environmental stress can be increased to accelerate the occurrence of failures.

1.3.2.1.2 It is recommended that a Procedure 2 test of short duration be done when the test item is fairly mature and its design stable. This would test the accuracy of the pre-judgment made as to which environmental stresses are benign.

1.3.2.2 **Procedure 2** – Flight Operational Support Test. The combined environment test combines the environmental stresses of temperature, vibration, humidity and if required, altitude and cooling airflow in a manner occurring in actual deployment. Mission profiles are used as the basis for formulating the environmental stresses. The failure data obtained from this test will help determine the corrective actions to be performed on the item to prevent failure in the operational environment. Generally, the combined environment test simulates those environmental effects that occur for the majority of the deployment life. Depending upon available facilities, environmental stresses may be tested in combination or singly.

1.3.2.2.1 **Environmental Conditions for Test -** This section describes the step-by-step approach in the measurement, prediction and choice of forcing functions for a combined environment test. Fig 4.30-1 is a flow diagram for generating a test profile, as described throughout this section.

1.3.2.2.2 **Test Cycle Formulation -** A test cycle is defined as a unit of time where several mission profiles are simulated under different atmospheric conditions. A test cycle shall consist of at least three atmospheric segments on the sequence, composed as follows : cold and dry, warm and moist, and hot and dry. Within each atmospheric segment of the test cycle, several different mission profiles may be simulated. A mission profile is defined as a Mach number – altitude-time history than an aircraft can fly. For example, a fighter aircraft may predominantly fly three different mission, air superiority, ground support and interdiction; therefore, this aircraft has three mission profiles. Each mission profile is divided into flight phases, such as takeoff, cruise, combat, low level penetration etc. (Fig 4.30-2). During a test cycle, temperature, vibration, humidity and cooling airflow shall be varied. Altitude simulation may be considered for a test item that is varied. Altitude simulation may be considered for a test item that is hermetically sealed, uses pressurized cooling path to transfer heat, has components that contain a vacuum, has voltages of sufficient potential to arc in the presence of rarefield air, long range missions, or for other appropriate cases. Cooling airflow is required for all test items that use supplementary airflow in the aircraft.

1.3.2.2.3 **Mission Profile Selection** - The first step in constructing a combined environment test is to select the mission profiles to be used. An individual aircraft is designed to operate within a specified flight envelope (Mach number/altitude regime) and to fly specific mission profiles. Generally, an aircraft can fly many different missions, such as training, air superiority, interdiction, ground support etc. In addition, aircraft are flown under specialized conditions that simulate a high threat combat environment. These wartime skill exercises, such as red flag, are designed to train operational squadrons under realistic wartime conditions. Usually, not all the missions flown by the aircraft need to be included in the test cycle. It is possible to identify two or three of the most highly utilized mission profiles that, as a group, reasonably approximate the aggregate affect of all the missions flown by the aircraft. This will adequately simulate the routine deployment life. In addition, the utilization of wartime skill exercises as part of the mission profile will stress the equipment under simulated combat conditions. To select the mission profiles to be used, the following approach is recommended:-

a) Identify all aircraft missions and the utilization rate of each mission of the aircraft in which the equipment is to be installed. This information may be obtained from the operational commands or the flight manual used by aircraft crews. For aircraft under development, the design flight envelopes, design mission profiles, and the design utilization rate of each mission shall be used when actual flight data are not available.

b) Determine the missions that comprise a majority (if possible, 80 of percent total flown) of the total routine, daily mission utilization. To do this, examine the utilization rates for all mission profiles of the aircraft and rank them in order from highest to lowest. Then, take the mission profiles that comprise the majority utilization rate and use these as mission profiles for combined environment testing. Missions with similar functions and flight characteristics can be lumped together to minimise the number of profiles to be generated. Table 4.30-1 shows an example distribution of missions.

c) In order to simulate the high threat environment, missions flown under the wartime skill exercises shall be separately identified. These data may be obtained from the operational command or provided by the procuring agency. Once these data have been obtained, two separate test cycles can be constructed according to clause 1.3.2.2.2. One test cycle using the mission profiles in clause 1.3.2.2.3 (b) will be developed to simulate routine usage and another test cycle using the mission profiles in clause 1.3.2.2.3 (c) will be developed to simulate usage under combat or combat-training conditions.

TABLE 4.30-1 EXAMPLE UTILIZATION RATES OF MISSION PROFILES

Mission	Percent Utilization Rate
Ground Attack, Training	40
Ground Attack, Combat	20
Defensive Maneuvers	20
Search and Rescue	10
Functional Check	5
Training Cycle	5
Total	100

Obtain the altitudes and Mach number versus time values for each mission profile selected, as shown schematically in Fig 4.30-3. These parameters of the mission profile are used to calculate the environmental stresses.

1.3.2.2.4 **Environmental Stresses** - The second step is to determine environmental stresses including vibration, temperature, supplemental cooling, humidity, altitude and electrical stresses. Test levels for each stresses are determined from mission profile information in the manner described in clause 1.3.2.2.5 through 1.3.2.2.9. Other information, such as engine rpm or data on the aircraft's Environmental Control System (ECS) may also be needed.

Since the first three missions, as a group, total 80 percent of the utilization rate, then these three mission profiles would be selected for combined environment testing. If any of the other missions are determined to include extreme or sustained environmental conditions not encountered in the first three missions, then those missions containing these extreme or sustained conditions and adding the most diversity to the test cycle also should be selected. If the first mission selected is utilized twice as much as the other two missions, then Mission 1 should be run twice as much per cycle.

1.3.2.2.5 **Vibration Stress -** Random vibration shall be applied to all equipment items designated for jet aircraft installation. Random vibration or sine superimposed on random vibration should be used for all Equipment designated for propeller aircraft. Vibration of an appropriate level and spectrum shape shall be applied continuously during mission profile simulation in the test cycle. Unless measured data exist, it is recommended that the appropriate tables and Figs of Test Number 28 be used to determine vibration conditions except as modified in Table 4.30-2.

Short duration vibration events and those that occur infrequently need not be included in the test cycle. These events include firing of onboard guns, general aircraft notion and shock of hard landings. These events may be tested separately using the appropriate test method.

TABLE 4.30-2 SUGGESTED RANDOM VIBRATION TEST CRITERIA FOR AIRCRAFT EQUIPMENT

Jet AIRCRAFT Use Table 4.28-3 with these modifications $K = 6.8 \times 10^{-9}$ for cockpit panel equipment and equipment attached to structure in compartments adjacent to external surfaces that are smooth, free from discontinuities. $k = 3.5 \times 10^{-8}$ for equipment attached to structure in compartments adjacent to or immediately after external surfaces having discontinuities (cavities chines, blade antennas, speed brakes etc) and equipment in wings, pylons, stabilizers and fuselage of trailing edge wing root. If Mach number is not in the range of 0.85 to 0.95 the calculated levels can be reduced by 5 dB. For propeller aircraft and helicopters, use appropriate tables in method 28.4.

For those segments with the same vibration spectrum shape, the following analysis can be used to reduce the number of vibration test levels. The discussion is in terms of the suggested spectrum shapes for jet, rotary wing or propellar aircraft of Test Number 28.

For test purposes a W_o vibration level for each mission segment can be determined, using the altitude and Mach number plots for each mission. (Note: For test purposes the larger of W_o due to aerodynamic or W_o due to jet engine noise is utilized at any point in time in the mission). The maximum W_o value that occurs in each mission shall be identified. All segments of the mission that have W_o values within three dB of the maximum shall be considered for test purposes, as having a constant W_o value determined using the value of W_{oMax}-3 db. All segments of the mission that have dynamic pressure values between W_{oMax}-3 dB and W_{oMax}-6 dB shall be considered for test purposes as W_{oMax}-3 dB having a constant W_o value determined using the value of W_{oMax}-4.5 dB. This process of identifying three dB bands of dynamic pressure values over which W_o is considered to be a constant and whose value is determined by using the dynamic pressure values of the band's midpoint is continued until the calculated W_o value is less than 0.001. For test purposes, segments of the mission with calculated values of W_o less than 0.001 can be set equal to 0.001 unless the test facility can control below this test level.

The value of W1 reflects the changes in aerodynamic flow field around the aircraft. A cruise W1 value reflects normal angle of attack flight, while a maneuver W1 value reflects highly separated flow conditions which induce intense low-frequency aircraft vibration.

TABLE 4.30-3 AMBIENT OUTSIDE AIR TEMPERAUTES

HOT ATMOSPHERE MODEL

Altitude		Word Wide Air	Operations	Relative Humidity (%)	Dew Temperature	
(km)	(kft)	(°C)	(°F)		(°C)	(°F)
0	0.00	43	109	<10	4	40
1	3.28	34	93	<10	-2	29
2	6.56	27	81	<10	-6	21
4	13.10	12	54	<10	-17	2
6	19.70	0	32	<100	0	32
8	26.20	-11	12	<100	-11	12
10	32.80	-20	-4	<100	-20	-4
12	39.40	-31	-24	<100	-31	-24
14	45.90	-40	-40	<100	-40	-40
16	52.50	-40	-40	<100	-40	-40
18	59.10	-40	-40	<100	-40	-40
20	65.60	-40	-40	<100	-40	-40
22	72.70	-39	-38	<100	-39	-38
24	78.70	-39	-38	<100	-39	-38
26	85.30	-38	-36	<100	-38	-36
28	91.90	-36	-33	<100	-36	-33
30	98.40	-33	-27	<100	-33	-27
Hot Ground Soak 2/		71	160		26	78

TABLE 4.30-3 AMBIENT OUTSIDE AIR TEMPERAUTES (Contd.)

GOLD ATMOSPHERE MODEL

Altitude		World Wide Air Operations		Relative Humidity	Dew Temperature	
(km)	(kft)	(^oC)	(^oF)	(%)	(^oC)	(^oF)
0	0.00	-51	-60	<100	-51	-60
1	3.28	-49	-56	<100	-49	-56
2	6.56	-31	-24	<100	-31	-24
4	13.10	-40	-40	<100	-40	-40
6	19.70	-51	-60	<100	-51	-60
8	26.20	-61	-78	<100	-61	-78
10	32.80	-65	-85	<100	-65	-85
12	39.40	-67	-89	<100	-67	-89
14	45.90	-70	-94	<100	-70	-94
16	52.50	-82	-116	<100	-82	-116
18	59.10	-80	-114	<100	-80	-114
20	65.60	-79	-112	<100	-79	-112
22	72.70	-80	-114	<100	-80	-114
24	78.70	-80	-114	<100	-80	-114
26	85.30	-79	-112	<100	-79	-112
28	91.90	-77	-108	<100	-77	-108
30	98.40	-76	-105	<100	-76	-105
Cold Ground Soak 2/		-54	-65	<100	-54	-65

TABLE 520.1-III AMBIENT OUTSIDE AIR TEMPERATURE (Contd...)

WARM MOIST ATMOSPHERE MODEL

Altitude (km)	Altitude (kft)	World Wide Air Operations (°C)	World Wide Air Operations (°F)	Relative Humidity (%)	Dew Temperature (°C)	Dew Temperature (°F)
0	0.00	32.1	90	>85	29	85
1	3.28	25.0	77	>85	22	72
2	6.56	19.0	66	>85	17	62
4	13.10	4.0	39	>85	2	38
6	19.70	-11.0	13	>85	-13	9
8	26.20	-23.0	-10	>85	-25	-13
10	32.80	-38.0	-36	<100 1/	-38	-36
12	39.40	-52.0	-62	<100	-52	-52
14	43.90	-67.0	-88	<100	-67	-88
16	52.50	-78.0	-108	<100	-78	-108
18	59.10	-73.0	-100	<100	-73	-100
20	65.60	-65.0	-85	<100	-65	-85
22	72.70	-58.0	-72	<100	-58	-72
24	78.70	-53.0	-63	<100	-53	-63
26	85.30	-48.0	-54	<100	-48	-54
28	91.90	-43.0	-45	<100	-43	-45
30	98.40	-38.0	-36	<100	-38	-36
Ground Soak 2/		-43.0	109	>75	37	98

1/ Uncontrolled humidity (dry as possible)
2/ Ground soak temperatures are not necessarily related to measured data but are extreme levels to reduce ground soak time.

The vibration stresses to be considered for the test cycle are those due to both attached and separated aerodynamic airflow along the vehicle's external surfaces, jet engine noise, or pressure pulses from propeller or helicopter blades on the aircraft structure. The vibration spectrum and level can be determined for each mission segment by careful use of measured data. Guidance written below shall be applied in those cases.

In many instances, measured flight data are not available for the specific aircraft equipment location in the aircraft or flight phases. In such cases, there are several analytical techniques for vibration spectrum and level prediction that can be used to determine vibration test conditions (ref a)

The scaling of vibration less conditions from data measured on another aircraft, at a different equipment location, or for a different flight condition has to be done with extreme care because of the numerous nonlinear relationships involved and the limited amount of data being utilized. For example, maneuver induced vibration conditions generally cannot be predicted from cruise vibration data. A more prudent approach is to utilize the linear dynamic pressure models in Test Number 28.

In all cases, measured flight vibration should be in acceleration power spectral density (PSD) format based on one third octave analysis or 20 Hz or narrower constant bandwidth analysis. Experience has shown that the use of standardised vibration spectrum shape and the modified levels of Test Number 28 yield as good results in terms of equipment deficiencies as the use of the highly shaped vibration spectra (ref b).

Because of the nature of vibration control equipment, it is difficult to change vibration level and spectrum shape in a continuous smooth manner. Therefore, the mission profile has to be divided into segments over which it will be assumed that the vibration level and spectrum shape is constant for test purposes.

1.3.2.2.6 **Bay Thermal Stress** - The thermal stresses that internally carried avionics equipment experiences during a mission are dependent upon the ambient conditions, flight conditions and the performances of the ECS. For the purposes of this test, the ambient outside air conditions shall be as shown in Table 4.30-3 for the hot, warm moist and cold day environment. Hot and cold ambient environments of Table 4.30-3 are based on the 20 percent Worldwide climatic extreme envelops from MIL-STD-210. The warm moist environment is based on the tropical environment shown in MIL-STD-210. These temperature values are to be used as the ambient conditions for thermodynamic analyses for the development of the mission profile test conditions. The ground scale temperatures in each mission are not necessarily related to measured data. The values shown in Table 4.30-3 are extreme conditions that have been used in previous programs to accelerate time and reduce time between transitions from one mission to another.

The specific environmental test conditions for any test item are dependent on the type of cooling for the compartment in which the equipment is to be located (air conditioned or ram-air cooled). Avionics equipment systems that consist of more than one black box may require different environmental test conditions for each black box. (For example, when boxes are in different aircraft compartments). For the common case of two black box system where one box is cooled by supplemental air or fluid and the other box is ambiently cooled, both boxes can be tested in one chamber as long as appropriate vibration and altitude simulation for each box can be achieved. The thermal stimulation would be realistic since the ambient cooled box would respond to the ambient temperature simulation while the box that required supplemental cooling would be primarily responsive to the supplemental cooling air or fluid.

For the purposes of this test, the following types of thermodynamic analysis is adequate. A more detailed analysis can be utilized, if desired.

The mission profile time history of altitude and Mach number from clause 1.3.2.2.3 is analyzed to identify each break point at which the slope of either the altitude or Mach number plots change. A thermodynamic analysis is done at each break point using steady-state thermodynamic relationships. Between each break point, linear interpolation is done on each stress to construct a continuous profile for each environmental stress. At each such break point, the thermal stress conditions for a test shall be determined in accordance with clauses 1.3.2.2.6.1 and 1.3.2.2.6.2.

1.3.2.2.6.1 **Ram-Cooled Compartments** - This section is to be used to determine the bay temperature for an avionics system in a compartment that is ram-cooled. The thermal stress in a ram-air-cooled compartment can be determined from the following relationship:-

$$\text{Thermal Stress} = T\,[1 + 0.18\,M^2]$$

Where T = ambient air temperature at altitude being flown in degrees Kelvin from Table 520.1-III.

M = Mach number being flown.

1.3.2.2.6.2 **Supplemental Air-Cooled Bay -** This section is to determine the bay temperature for an avionics system located in a bay that receives its cooling from the aircraft's ECS. The mass flow rate and temperature level of supplemental air needs to be determined at each break point in the mission profile. The onboard ECS is modeled in terms of its primary components such as pressure regulators, heat exchanges, turbo machinery, water separator, etc. Also, calculate the mass flow rate being injected into the bay and the location of other systems in order to determine if the heat load from these systems should be considered (refs. c and d). The calculation of the bay temperature stress can be done using the following simplified thermodynamic analysis:

a) Assume that steady-state thermodynamic relationships are valid.

b) Assume constant but nominal or typical efficiency constants that can be achieved from good design practices for turbo machinery and heat exchangers.

c) Neglect secondary affects in components of ECS (i.e. pressure losses in heat exchanger, temperature losses in ducts).

1.3.2.2.6.3 **Equipment Supplemental Thermal Stress -** This section is used to determine the thermal and mass flow for an avionics system that requires forced or supplemental cooling from the aircraft. Clause 1.3.2.2.6.2 recommends an approach to determine the bay thermal stress for an avionics located in a supplementally cooled compartment. This same approach is recommended here with one addition: continue the thermodynamic analysis to determine the temperature and mass flow being injected directly into the avionics system. The same sources used to obtain the information for 1.3.2.2.6.2 are also applicable here.

1.3.2.2.7 **Humidity Stress -** The humidity stress that an internally carried avionics system experiences is dependent upon the ambient humidity conditions and the performance of the water separator of the environmental control. (Some aircraft do not cool equipment with ECS air, thus the equipment sees only ambient humidity conditions). For the purposes of this test, whenever the cold day environment is being simulated, humidity will be uncontrolled, but less than or equal to the dew temperature shown in Table 4.30-3. For the hot environment dew temperatures will less than or equal to values shown in Table 4.30-3. In the case if the warm moist day, dew temperatures will be greater than or equal to the values found in Table 4.30-3 up to 10 km. Above 10 km, the dew temperature shall be less than or equal to the values found in Table 4.30-3. If the platform has an ECS, the design specifications for the water separator shall be used to define humidity conditions for the warm moist day. When the efficiency of the ECS is unknown, the approximate technique put forth above should be used.

> Note : The formation of free water on the test items during combined environment testing can be a normal condition. It will occur whenever the temperature of the test item is cooler than the dewpoint temperature of the air being delivered by the ECS or from ram airflow. This is normal and a realistic condition.

1.3.2.2.8 **Altitude Stress -** Altitude simulation should be employed when there is reason to believe that system performance may be affected by variations in air pressure. Examples of such situations are : hermetically sealed units that use pressurized cooling parts to maintain sufficient heat transfer, vaccum components where the seal is maintained by air pressure, and units where change in air pressure may cause arcing or change of component values. When altitude effect is to be tested, the altitude stress or reduced atmospheric pressure variations, shall be applied according to the mission profiles selected for test. The altitude or reduced pressure, is initially applied at the simulated aircraft takeoff and continues at the pressure changes corresponding to the various flight phases from climb-out to landing. The rate of change of pressure should reflect the climb or descent rate of the aircraft while performing the various flight mission phases. Maximum pressure (minimum altitude) used for the test shall be that of ground elevation at the test site.

1.3.2.2.9 **Electrical Stress -** Electrical stresses are deviations of the equipment's electric supply parameters at the equipment terminals from their nominal values. The test procedure must assure that all electrical stresses occurring during normal operation in service (mission profile) are simulated to the required extent.

It is not the purpose of this test method to simulate extremes specified for special situations or to take the place of special electrical stress tests. Special conditions, like emergency operation of certain aircraft equipment within the electrical/electronic system, shall be simulated only on request.

Depending upon the requirements and the availability of data, the simulation may cover the range from the exact reproduction of the specific electric supply conditions within a specific aircraft for a specific mission profile, down to a standardized simplified profile for generalized applications. The following conditions and effects must be taken into consideration to determine whether they affect the operation and reliability of the equipment to be tested:

a) AC system normal operation stresses.

b) Normal ON/OFF cycling of equipment operation.

c) DC system normal operation stresses.

d) Electrical stresses induced by mission related transients within the electrical system.

1.3.2.2.9.1 **AC System Normal Operation Stresses -** Voltage variations are quasi-steady changes in voltage from test cycle to test cycle. Input voltages shall be maintained at 110 percent of nominal for the first test cycle, at the nominal for the second test cycle, and at 90 percent for the third test cycle. This cycling procedure is to be repeated continuously throughout the test. However, if a failure is suspected, this sequence may be interrupted for repetition of input voltage conditions.

1.3.2.2.9.2 **Normal ON/OFF cycling of equipment operation -** The equipment shall be turned on and off, in accordance with equipment operating procedures outlined in appropriate technical manuals, to simulate normal use.

1.3.2.2.9.3 **DC System normal operation stresses**

a) **Voltage variations**. see clause 1.3.2.2.9.1.

b) **Ripple voltage.** - Ripple is the cycling variation about the mean level of the DC voltage during steady-state DC electric system operation. Values shall be taken from actual flight data or from the applicable system specification if flight data are not available. Ripple voltage shall be applied continuously during the mission simulation portion of each test cycle.

1.3.2.2.9.4 **Electrical stresses induced by mission related transients within the electrical system -** Unless the equipment has its own power supply which is not affected by the transients mentioned, or the equipment is not influenced by these electrical stresses at all, these stresses must be reproduced during test. The reproduction has to cover all transients – like power surges, voltage peaks, electrical current changes, phase unbalance etc – which may influence the equipment on test and are induced by the mission related operation of the aircraft's electrical/electronic equipment taken as a whole (switching equipment on or off, operating with changing power output, short time system overload, differing generator rpm, operation of regulating devices, etc).

The test should reproduce measured transient exactly. If this is not possible tolerances should be calculated individually for each transient type. Tolerances should be narrow for stresses the equipment is more sensitive to and vice versa. The basis for calculations shall be the requirements document – stress values that the equipment must be able to withstand during normal operation – provided the actual measured stresses of the electrical system do not exceed these limits.

In the absence of any other means of simulating power line transients, the equipment shall be cycled on while performance measurements are made and then backed off for five minutes prior to the turn-on at the end of each ground part phase.

1.3.2.3 **Procedure 3.** - Qualification Test - Qualification can be accomplished either with a single test which combines all the appropriate environmental stresses or with a series of separate tests. It is not recommended to run all environmental stresses in separate tests. When the use of separate environmental tests is selected, the following single and combined environment stress tests are recommended: vibration, a combined temperature, altitude, and humidity test, and a combined supplemental cooling airflow with humidity, temperature and mass flow rate as test parameters. The following guidance is recommended for each separate test.

1.3.2.3.1 **Vibration Stress -** Use the test conditions and durations recommended in Test Number 28 for qualification testing.

1.3.2.3.2 **Temperature-Altitude-Humidity Test -** This test is for the conditions inside an equipment bay or cockpit. Identify the maximum and minimum temperatures to be experienced in anticipated deployment by the item to be tested. Identify the maximum

minimum temperature under which the test item is expected to operate. These temperatures can be obtained from the analysis outlined in clause 1.3.2.2. of procedure 2. If such an analysis was not accomplished, Tables 4.30-5 and 4.30-6 and Fig 4.30-5 can be used.

The values in Tables 4.30-5 and 4.30-6 are based on measured data and are representative of extreme temperature conditions (air temperature, not equipment temperature). Therefore, there is reasonable confidence that these test levels will sufficiently stress the test item.

The maximum altitude to be experienced by the item to be tested should come from the analysis outlined in clause 1.3.2.2. Often the altitude lair pressure inside a cockpit or equipment bay is different from that outside the aircraft because of cabin pressurisation. If an analysis has not been done, use maximum flight altitude or, if unknown, use 16 km (52,500 ft).

The recommended durations of stress exposure in Table 4.30-6 are based upon anticipated extreme case exposure durations. It is not recommended to force the test item to reach thermal stability. As would happen in actual usage, the mass of the test item will determine how close the test item will get to the imposed temperatute.

The humidity stress is based upon reasonable levels that can be experienced in actual usage. Unless analysis much as outlined in clause 1.3.2.2 shows that the equipment bay or cockpit environment are significantly more or less humid, the level shown in Table 4.30-5 is recommended.

1.3.2.3.3 **Supplemental Cooling Air Humidity, Mass Flow Rate and Temperature Test -** This test is for supplemental cooling airflow the flows directly through an equipment system. The temperature, humidity and mass flow rate can be determined from an analysis as outlined in clause 1.3.2.2 of procedure 2. If such an analysis is not available, the levels in Table 4.30-5 and combined as shown in Table 4.30-6 and Fig 4.30-5 are recommended.

1.3.2.3.4 **Electrical Stress -** Unless otherwise defined, use the electrical conditions outlined in clauses 1.3.2.2.9.1 and 1.3.2.2.9.2 as applicable.

1.3.2.3.5 **Test Item Operation** - The item shall be operated throughout each test except when being exposed to maximum and minimum temperatures that occur in equipment bays or the cockpit. If separate tests are conducted, the test item shall be turned on and off using the same schedule as if the test environments were all combined.

1.3.3 **Test Duration**

a) **Procedure 1** - The test should be conducted so that the test item experiences 300 to 600 mission hours of stress exposure. The rate of occurrence of defects in conjunction with schedule and cost generally determine the duration of an engineering development test. If few or no failures are occurring, little new information is being generated as to how or where to improve the test item and the test should be terminated.

b) **Procedure 2 -** Test duration shall be sufficient either (i) to give the tester confidence that environmental factors will not cause significant problems during the flight test program or (ii) to resolve a problem that arised during flight or operational testing.

c) **Procedure 3 -** Procedure 3 shall be conducted for ten test cycles as per Fig 4.30-5 or its equivalent (40 environmental stress hours with 30 hours of equipment turned on). This is somewhat arbitrary, but reflects the duration of previous temperature altitude humidity tests.

1.4 Special Considerations

1.4.1 **Test Interruption -** In the event of an unplanned test stoppage due to an event such as facility failure, the following is recommended. If the item has not failed and there is no apparent damage to the test item, the test continues. If the test item is damaged when the unplanned event occurred, testing should not be resumed until it can be determined whether the stress combinations during the unplanned event are likely to occur in the deployment environment. Testing should be resumed at the point of interruption and failed test article(s) removed before beginning the next phase, unless the nature of the failure precludes any useful equipment operation.

1.4.2 **Failure Criteria -** All incidents where the test item does not meet equipment operating requirements shall be analyzed to determine the cause and impact of such occurrences. Corrective actions shall be proposed or implemented as required to meet equipment performance requirements.

1.4.3 **Chamber/Sensor Tolerances** – The accuracy required in general requirements applies for each stress measurement system. The ability of a given test chamber to control to the specified stress conditions is a function of the chamber’s design and appropriate placement of transducers. Thus, in evaluating the test tolerances for any given combined environment test, the test plan should clearly identify the placement of the stress measurement transducer relative to the test item.

Test Phase Definition	Temp. (ºC)	Relative Humidity	Vib-r	Supp Cooling Air (ºC)	Attitude	Test Item-Operating/ nonop	Duratio-n
Ground Cold Day	-54	<100%	Off	-54	Ambient	Nonoperating	60
Mission 1	*	*	On*	*	*	*	*
Ground Cold Day	-54	<100%	Off	-54	Ambient	Nonoperating	60
Mission 2	*	*	On*	*	*	*	*
Ground Cold Day	-54	<100%	Off	-54	Ambient	Nonoperating	60
Mission 3	*	*	On*	*	*	*	*
**							
Transition to Hot							>20
Ground Hot Day	71	<10%	Off	71	Ambient	Nonoperating	60
Mission 1	*	*	On*	*	*	*	*
Ground Hot Day	71	<10%	Off	71	Ambient	Nonoperating	60
Mission 2	*	*	On*	*	*	*	*
Ground Hot Day	71	<10%	Off	71	Ambient	Nonoperating	60
Mission 3	*	*	On*	*			*
**							
Transition to Moist							
Ground Warm Moist Day	43	75%	Off	43	Ambient	Nonoperating	>20
Mission 1	*	*	*	*	*	*	60
Ground Warm Moist Day	43	75%	Off	43	Ambient	Nonoperating	*
Mission 2	*	*	*	*	*	*	60
Ground Warm Moist Day	43	75%	Off	43	Ambient	Nonoperating	*
Mission 3	*	*	*	*	*	*	60
**							*
Transition to Cold							>20

* Determine from aircraft mission profile.
** The number of different missions in each segment is determined in accordance with I-3.2.2.2
*** These values are based upon historical experience, reference f.

Table 4.30-4 Combined Environment Test Cycle Structure

EQUIPMENT BAYS	MIN TEMP. (ºC)	MIN OPER TEMP (ºC)	MAX. TEMP. (ºC)	MAX. OPER TEMP (ºC)	MAX. HUMIDITY (RH)	MASS FLOW RATE (KG/MIN)
Supplmentally Cooled	-54	-40	60	54		--
Ram Air Cooled	-54	-40	60	54	75% at 43ºC	--
Unconditioned	-54	-40	60	54		--
CREW STATION						
Open Areas	-54	-40	60	25		--
Behind Instrument Panels	-54	-40	100	75	75% at 43ºC	--
Supplement Cooling Airflow Equipment	-51	-51	54	54	75% at 43ºC	+0% of design -80% point

Table 4.30-5 Suggested Extreme Qualification Test Levels when no other data exists

TIME	TEMP.	ALTITUDE	HUMIDITY	SUPPLEMENTAL COOLING AIR			EQUIPMENT ON/OFF
				TEMP.	MASS FLOW RATE	HUMIDITY	
0	T_{min}			T_{min}	M_{max}		Off
60	T_{min}			T_{min}	M_{max}		On
*							
60	$T_{oper\ min}$			T_{min}	M_{min}		On
90	$T_{oper\ min}$			T_{min}	M_{min}		On
*							
90	$Thum_{soak}$				M_{max}	max RH	On
150	$Thum_{soak}$				M_{max}	max RH	On
*							
150	T_{max}				M_{max}		Off
210	T_{max}				M_{max}		Off
*							
210	$T_{oper\ max}$			T_{min}	M_{min}		On
240	$T_{oper\ max}$			T_{min}	M_{min}		On
*							
Return to time zero							

* the amount of time to ramp temperature is dependent upon the tyest facility change rate and is not counted in the four hours of the test cycle.

Table 4.30-6 Qualification Test Cycle

1.4.4 **Test Profile Tolerances -** The tolerances for each stress in each phase of procedure II can be derived from design specifications. For example, the design specification may call for a phase of cruise between 6080 and 9120 metres. For the test mission, this can be translated into an altitude of 7600 metres with a tolerance of ±1520 metres.

1.5 **References**

a) Savy, R.W. Computer program for Vibration Prediction of Fighter Aircraft Equipment, AFFDL-TR-77-101, November 1977.

b) Hall, P.S. Vibration Test Level Criteria For Aircraft Equipment, AFWAL -TR–80-3119, December 1980.

c) Lloyd, A.J.P., G.S, Duleba and J.P. Zeebenm, Environmental Control System (ECS) Transient Analysis, AFFDL-TR-77-102, October 1977.

d) Dieckmann, A.C., et al. Development of Integrated Environmental Control System Design for Aircraft. AFFDL-TR-72-9. May 1972.

e) Quartz, I., A.H, samuels, and A.J. Curtis, A Study of the Cost Benefits of Mission Profile Testing. AFWAL-TR-81-3028. 1981

f) Burkhard, A.H. et al CERT Evaluation Program Final Report . AFWAL-TR-82-3085.

g) F-15 AFDT&E High Temperature Desert Test and Climatic Laboratory Evaluation. AFFTC-TR-75-19, October 1975 DTIC Number AD BO11345L.

SECTION - 2

1.1 **APPARATUS -** The combined environment test chamber(s) shall be capable of producing the required combinations of temperature, altitude, humidity random vibration and cooling air mass flow. All instrumentation shall be able to meet the accuracy specified in section 4 of general requirements.

1.2 **PREPARATION FOR TEST -** Select which test procedures shall be implemented. Identify if the test shall be a combined environment test or a series of single and appropriate environmental combinations tests. Select which of the following steps are appropriate for the environmental stresses being included in the test of interest.

Step 1 - For vibration testing in Procedure 1 or 2, the individual equipment test item (s) should be subjected to random vibration in either the aircraft vertical or lateral axis, whichever seems to offer the greatest potential from direct disclosure. If either axis seems to offer a distant benefit, the test axis may be selected to suit facility convenience. When practical diagonal vector vibration (vibration applied diagonally at a test item corner through its centre of mass, rather than along a single orthogonal axis may be applied to provide multi axis excitation using a single test setup. For Procedure 2 conduct vibration test in accordance with Test Number 28.

Step 2 - For tests that do not include vibration, mount test items in their normal orientation with the ground plane when the carrying aircraft is parked on the ground.

Step 3 - For Procedures 1 and 2, mount at least two vibration pickups to measure the vibration environment for each test item. Follow practices for the accelerometer mounting output averaging and data analysis techniques outlined in Test Number 28 of this standard.

Step 4 - For test items that require supplemental cooling air, measure mass flow rate, humidity and temperature. Mount instrumentation so that these values are known as close as possible to where the air enters the test item(s).

Step 5 - Bay air conditions around the equipment shall be measured as specified in general requirements clause 5.3.2. The air temperature around the equipment under test shall be used to control this environmental stress.

Step 6 - Mount humidity sensor to measure bay air humidity. A single point measurement is adequate as long as the measurement point is not shielded from the bulk conditions around the test item.

1.3 **PROCEDURES**

1.3.1. **Procedure 1 - Engineering development**

Step 1. Mount test item in accordance with 1.2.

Step 2. Confirm that the test item is operational.

Step 3. Start test and test to conditions specified in test plan developed as outlined in 1.3.2.1.

Step 4. Conduct test and monitor performance of test item against failure criteria.

Step 5. Continue test until malfunction occurs (see 1.4.2)

Step 6. Analyze failures and take corrective actions.

Step 7. Document malfunctions as per clause 1.4 and 1.4.3.

Step 8. Continue test until a suitable number of hours of environmental exposure have been achieved (see clause 1.3.3 a of Section - 1)

Step 9. Repeat steps 1 through 8 for each single stress or combination of stresses until all the stresses have been combined.

Step 10. Document entire test as per clause 1.4.

1.3.2. **Procedure 2 – Flight/Operational Support Test**

Step 1. Mount test item in accordance with clause 1.2.

Step 2. Confirm that test item is operational.

Step 3 Start test cycle with a cold-day park simulation and continue the sequence as shown in Table 4.30-5.

Step 4. Monitor test item performances throughout environmental exposure.

Step 5. Continue test until a test item malfunction occurs.

Step 6. Analyze and document malfunctions as per clause 1.4 and 1.4.3.

Step 7. Continue test until a multiple number of hours of environmental exposures have occurred on at least one specimen (see clause 1.3.3b of Section -1)

Step 8. Document entire test as per clause 1.4 of Section –1.

1.3.3 **Procedure 3 - Qualification Test**

Step 1. Mount the test item and instrumentation as per clause 1.2 of Section -2.

Step 2. Start the test cycle developed from clause 1.3.2.3 of Section -1.

Step 3. Function the test item while being exposed to environmental stresses in step 4.

Step 4. Expose the test item to the number of test cycles decided as per clause 1.3.3 of Section -1.

Step 5. Check the test item for functioning in accordance with general requirements clause 4.5.

Step 6. Repeat steps 1 through 5 for each of the single or combined environment tests specified in clause 1.3.2.3 of Section - 1 unless they were conducted as one test that combines all the environments.

Step 7. Document test results as given in clause 1.4.

1.4 **INFORMATION TO BE RECORDED**

a) Test item identification (manufacturer, serial number etc.)

b) Pre-test, during test and post-test performance data according to general requirements and the individual test specification and/or test plan.

c) Test cycle including environmental conditions applied.

d) Test time history of each failure occurrence.

e) Nature of failure including environmental effects.

f) DC ripple voltage, as applied during the mission simulation portion of each test cycle.

g) AC voltage variation, as conducted during the mission simulation portion of each test cycle.

h) Type, location and orientation of stress measuring sensors.

j) Description and calibrations status of data recording and analysis equipment.

k) Voltage modulation, as applied during the mission-simulation portion of each test cycle.

l) Frequency modulation as applied during the mission-simulation portion of each test cycle.

m) Electrical stress induced by mission-related transients within the electrical system.

n) Prior test history of test item.

o) Corrective action proposed.

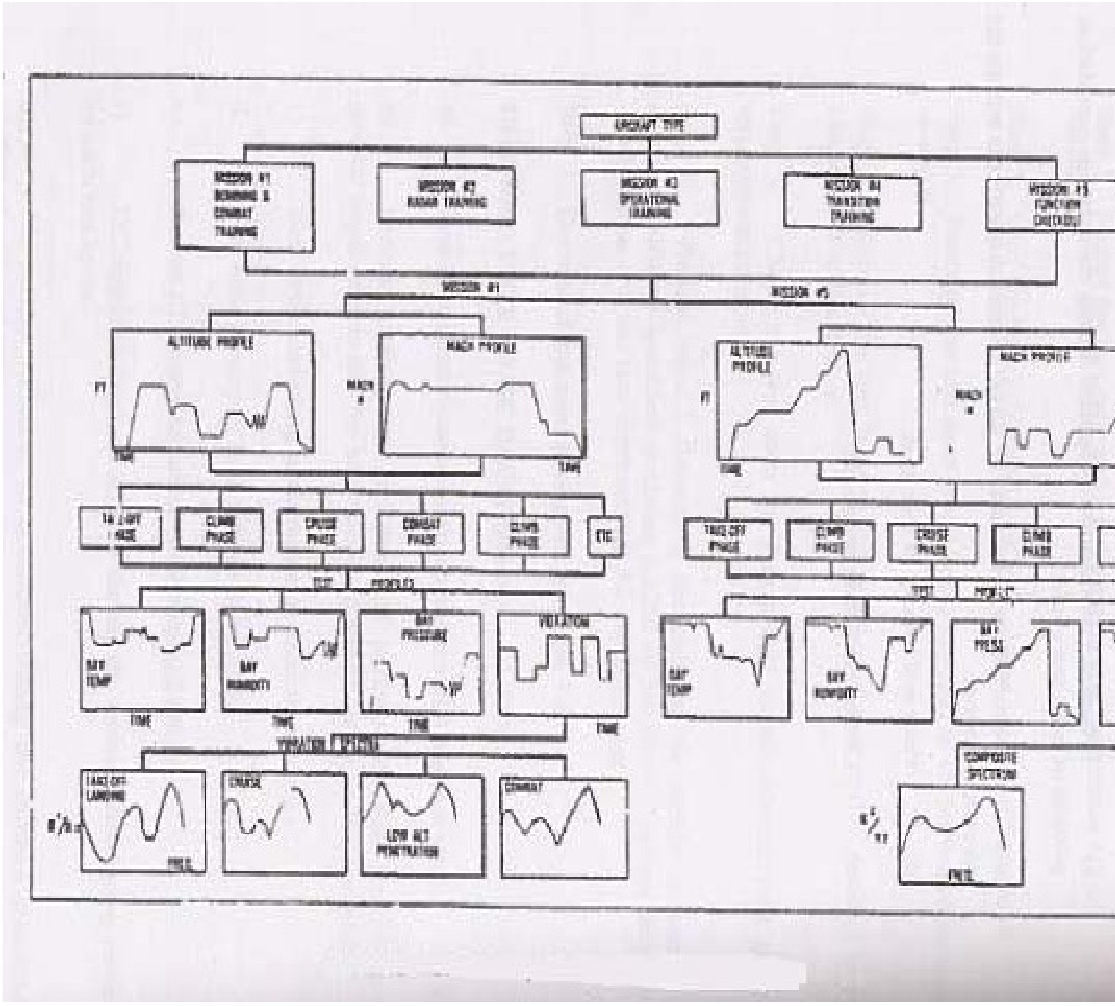


FIG. 4.30-1 Test profile generation flow diagram

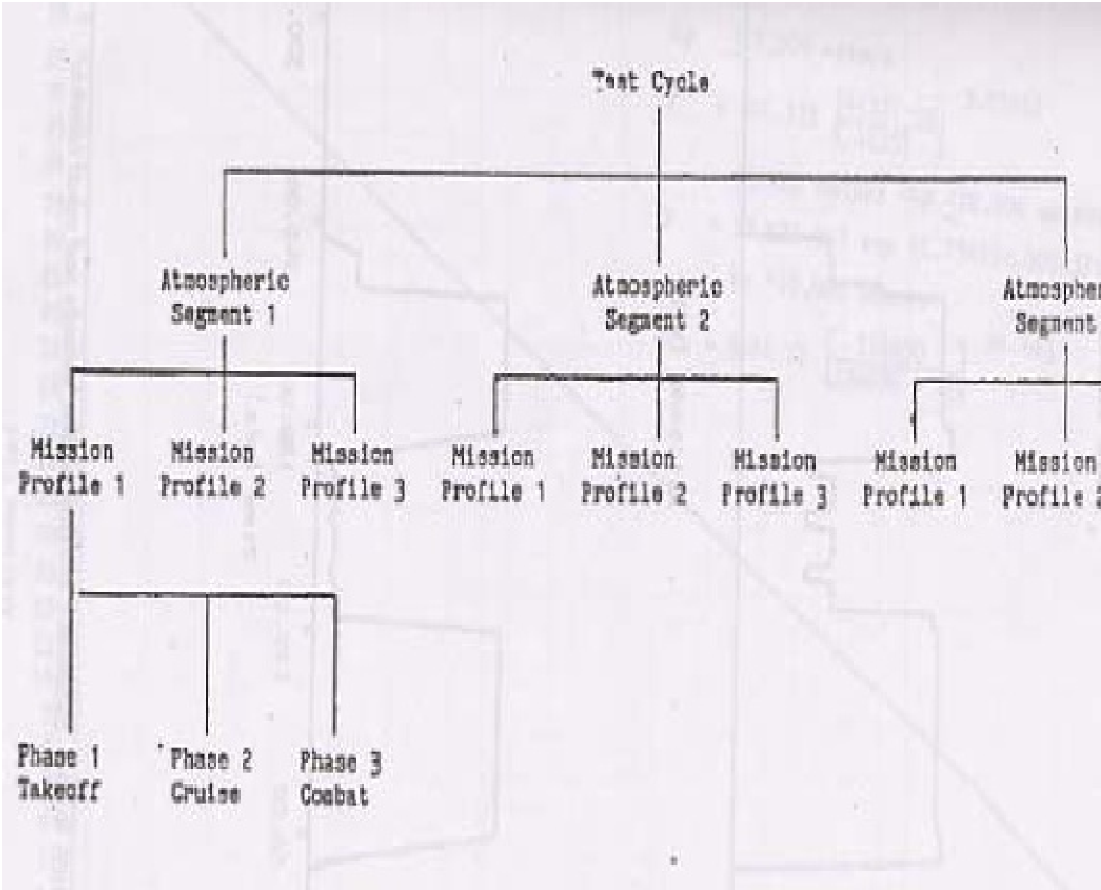


FIGURE 4.30-2 Bottom up view of a test cycle

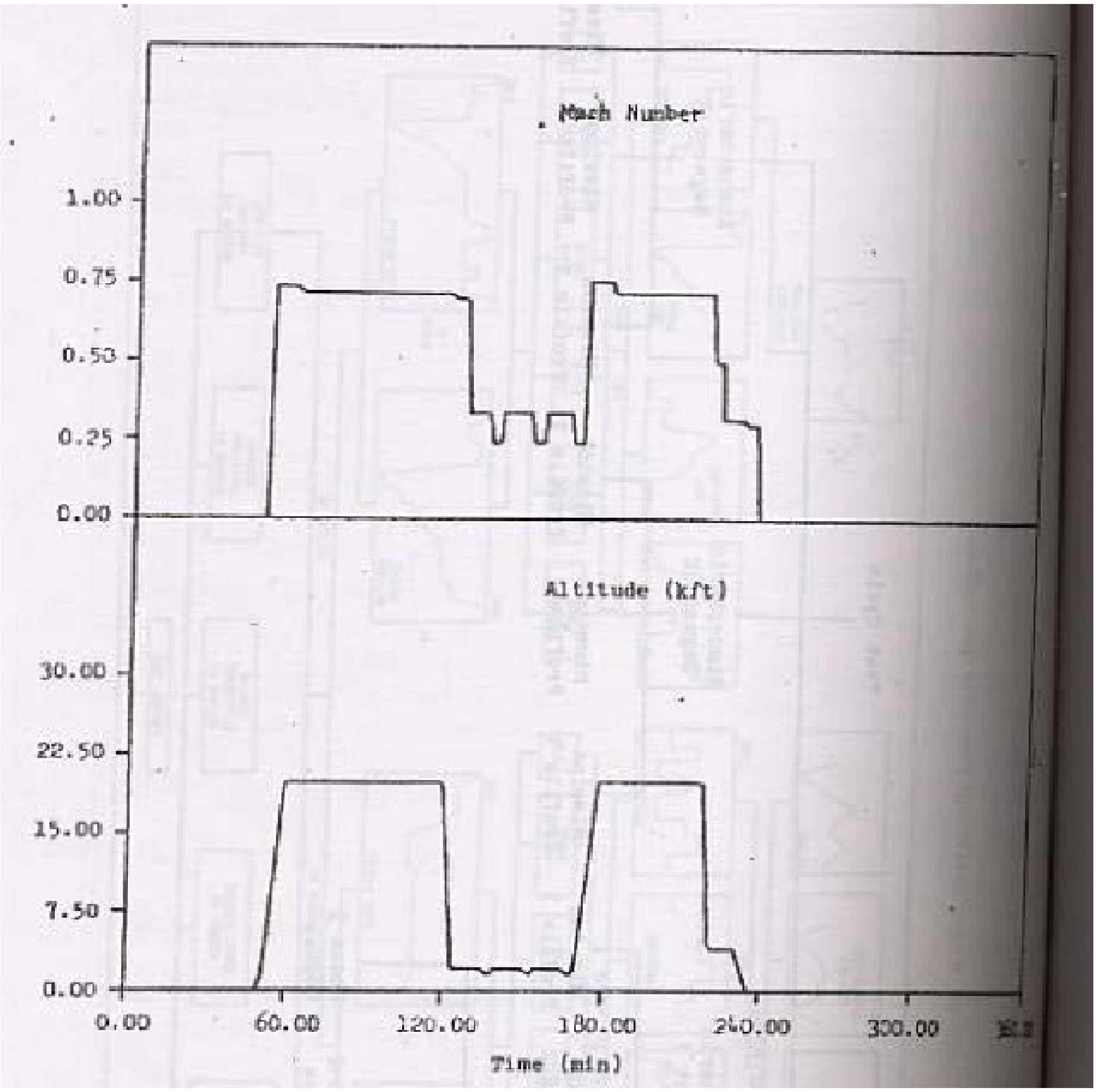


FIGURE 4.30-3 Schematic mission profile, altitude and mach number

FIGURE 4.30-4 Altitude vs pressure

FIGURE 4.30-5 Qualification test cycle example

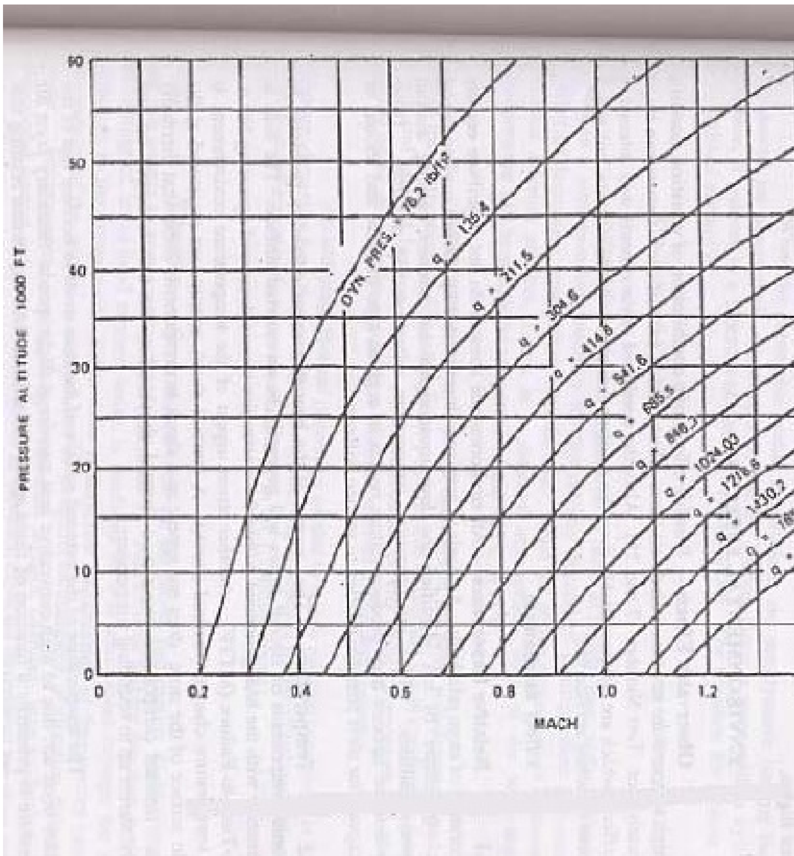


FIGURE 4.30-6 Dynamic pressure (q) as function of mat

TEST NUMBER 31

VIBRO ACOUSTIC, TEMPERATURE
SECTION - 1

1. OBJECTIVE

1.1 This method seeks to reproduce the combined temperature, vibration and other operating stresses as needed, that an externally carried aircraft store experience during in-service flights.

1.2 ENVIRONMENTAL EFFECTS

1.2.1 **Observable Effects -** Possible effects of a combination of vibration, acoustic and high temperature stresses include all those effects which each of these factors can cause separately (see Test Number 17 and 28). Also, the combined environments may interact to give effects which are not predictable from the results of single environment tests, but which do occur in actual service use.

1.2.2 **Effect mechanism**

1.2.2.1 **Relative Importance -** All environmental stresses do not contribute equally deterioration of store reliability. Analysis of service failures caused by aircraft environmental stress (reference b) has identified the four most significant stresses causing aircraft equipment failures. These are operation, temperature, vibration and moisture. Other environmental stresses may produce failure modes in a given type of store and should be investigated for their possible relation to service failures.

1.2.2.2 **Temperature -** The source of the heat that cause reliability problems in electronic components of aircraft stores will generally be an external surface. The heat in combination with the heat generated within the electronics causes decreased operating life or Mean-Time-to-Failure (MTTF). Another stress aspect of the temperature environment is rapid temperature change (thermal shock). A thermal shock or transient registered at the outside surface of the store does not appear as a shock to components somewhat thermally within. Internal components experience thermal shock when the unit is turned on and quickly warms up to operating temperature.

The temperature of the external surface of the store tends to become that of the boundary layer air, due to high convective heat transfer at flight speeds. Boundary layer air temperature is primarily a function of flight speed and altitude. An expression relating this temperature to flight conditions is:

$$T_r = T_h \left(1 + \frac{r(k-1)M^2}{2}\right)$$

Where:

T_r	=	adabatic recovery temperature (Kelvin)
T_h	=	ambient air temperature (Kelvin) as a function of altitude
r	=	recovery factor
k	=	ratio of specific heat (1.4 for air)
M	=	Mach number

When the expression within the brackets, the aerodynamic heating factor, is evaluated for atmospheric air brought to rest by friction along a store with a cylindrical surface, it reduces to a function of aircraft velocity alone. The equation for a store with a cylindrical surface is:

$$T_r = T_h (1 + 0.174\ M^2)$$

Higher Mach number flights tend to occur at higher, thus colder, altitudes and there is a corresponding tendency for the velocity dependent heating effect to cancel the effect of decreasing temperature with altitude. When the above expression is evaluated for normal mission profiles, flown in a standard atmosphere, 90% of the time the skin temperature will be within the temperature band $-15^{o}C$ to $35^{o}C$.

Temperature patterns at points deep within the store will depart considerably from the corresponding skin temperature patterns, due to thermal lag in conduction from the skin and internal heating sources such as electrical or electronic components. A thermal model of the store can be generated to calculate internal temperature patterns.

An additional thermal parameter needed to satisfy mission conditions is that of climatic departure from the standard atmosphere, which depends on the global and seasonal variations of atmospheric temperatures (the T_h in the T_r formula above).

1.2.2.3 **Vibration** - Experimental evidence has shown that captive flight vibrations are due largely to aero-acoustic loads (reference 3). This acoustic forcing function, typically consisting of broad-band random noise, is modified as it is transmitted through the store structure to the component. When there is sufficient transmission of frequencies causing resonances of the unit or its components or structural mechanisms, a vibration failure can occur. Environmental testing, using reverberant acoustic chamber, tries to duplicate the directional, spatial and spectal distributions of vibration expected throughout the store during captive flight.

The turbulent boundary layer is the most significant source of aero-acoustic loads because it is always present during flight and acts on the total surface frequencies of electronic components and structural parts. The intensity of the turbulent boundary layer pressure fluctuation and resulting store vibration primarily depends on flight dynamic pressure, q, a function of flight speed and altitude:

$$q = \frac{kP_h M^2}{2}$$

Where:

q	=	dynamic pressure (pounds per sq.ft)
k	=	ratio of specific heats (1.4 for air)
P_h	=	ambient pressure as a function of altitude (pounds per sq.ft)
M	=	Mach number

Store vibration also includes lower frequencies (usually less than 100 Hz) mechanically transmitted from the aircraft through the stores's support mechanism frequency vibration is discussed in 1.3.4.2.

1.2.2.4 **Operating Stress -** Operating stresses are usually estimated because the service conditions (e.g. on-time/off-time, aircraft power fluctuations) are seldom measured and recorded. This stress cannot be omitted unless the store has no operating mode while carried on aircraft.

1.2.2.5 **Moisture -** In combined environments testing, moisture often condenses on to test item during transitions from low to high temperatures. Its presence, although uncontrolled, is useful as a test condition to indicate leakage or sensitivity to moisture. Where humidity or corrosion problems are expected, separate tests are advised.

1.3. GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

Note : The tailoring process as described in Section 2 of this document would be used to determine the appropriate tests and test variables.

a) **Application -** This method applies to reliability-related testing of externally carried aircraft stores (Table 4.31-1).

TABLE 4.31-1 TYPICAL APPLICATIONS

TEST TYPE	PURPOSE	APPLICATION	TYPE OF INFORMATION FAILURE MODE	REQUIRED TIME-TO FAILURE
Test, Analyze and Fix (TAAF)	Reveal and correct design weaknesses	Development of a more reliable design prior to production	Essential to induce potential service failures	Not important
Debugging or Screening	Show whether or not a design meets the specified relia-bility	Start of product-ion is usually based on a successful relia-bility demonstration	Important only if the demonstration is unsuccessful	Essential
Acceptance	Estimate the MTTF of the lot units from the time-to-failure of a small sample	Determination as to whether the lot is of accepta-ble quality	Important only if the lot is rejected	Essential that successive lot measures be consistent and comparable. Baseline similarity to service MTTF is desirable
Source Comparison	Determine the relative reliability of units from the time-to-failure of a small sample	Determination as to which of two sources should get the larger share of a production buy	Important for improvements at the poorer source	Only consistency comparability is essential

b) **Restrictions -** This method is intended primarily for the electronics and electro-mechanical assemblies within the store.

c) **Sequence -** This method applies to the environmental stresses occurring in final phases of the store's logistic cycle, and when used in combination with other test methods, should follow these methods.

d) **Test Variations** - Unlike the other methods in this standard, this method contains no step-by-step procedure for generating valid test data. The vibro/acoustic/temperature environment is too complex, and the variety of equipment applications too great, for such detailed instructions to be given here. Instead this method provides guidance for writing a test procedure which will be more or less unique for the item under consideration.

1.3.1 **Background -** Experiments have shown (ref a) that the only way to reproduce service failure distribution is to reproduce the service stress distribution. Stress distribution is a range of stresses, in proper proportion of level and durations determined by mission profiles. The proportioning is applied to vibration, temperature, thermal shock and electrical stress. Procedure I uses combinations of temperature, acoustic vibration, mechanical vibration and store operating pattern to simulate in service missions.

1.3.2 **General -** Military aircraft service use may be characterised by a set of specialized missions, with a duration and relative frequency assigned to each mission type. Each mission type is described by its `mission profile' and idealized mission history which specifies altitude, velocity and operating state as a function of time and which locates the occurrence of stressful events such as special maneuvers, gunfire and landings. From such mission profiles, corresponding mission environmental histories (e.g. vibration levels, skin temperatures) can be constructed. Data from instrumented flights may be used in this construction. By treating the mission environment profiles probabilistically, summing the durations of each stress level in each mission and weighing by the relative frequency of each mission, a service distribution function for each stress may be obtained. A composite environment profile may then be constructed for each stress of interest. This composite environmental profile may then be constructed for each stress of interest. This composite environmental profile is a sequence of stress levels constructed to simulate the service environment profiles for the different mission

taken together. Its total duration should be no longer than a few missions, it must represent realistic flight conditions, and it must reflect the calculated combined service distribution function for the stress. A composite mission profile consists of the combination of composite environmental profiles for each environment, so coordinated that the mixture of stress levels at any point in time represents the typical service condition being simulated. Simulation of typical (5^{th} to 95^{th} percentile) values is emphasized. If extreme values were used similar to qualification test levels, the results would not correlate with field experience.

1.3.3 **Mission analysis -** The first step in developing the composite mission profile is to determine the types of aircraft and the types of missions with which the store is to be employed. For each aircraft type, each mission will have its own typical mission operational profile, usually charted as altitude and velocity versus time and indicating critical points or periods. A typical aircraft mission operational profile is shown in Fig 4.31-1.

The relative frequency for each type of store-carrying mission must be established for each aircraft type along with the proportion of total store use expected for each aircraft type. Tables, such as 4.31-2 are usually prepared to handle this information.

Since both vibration causing acoustic fields and skin temperatures of a store can be related to altitude and aircraft speed, the pattern of expected altitude/ velocity combinations will be needed for each relevant mission. Table 4.31-3 shows one method of organizing such data, by dividing each mission into segments or phases. Similar charts for each mission of each aircraft type are suggested. Additionally, a frequency weighed means of mission durations should be calculated.

1.3.4 **Environment Analysis**

3.4.1 **Temperature Profile** - With a standard atmosphere Table the corresponding ambient temperature for each altitude used in the mission analysis may be found. Corresponding store skin temperatures may then be calculated from the ambient temperature when the aircraft velocity is known (see clause 1.2.2.2.). Sometimes skin temperature data from instrumented flights is available to provide a check for the calculated temperatures. For each pertinent mission, a chart of expected skin temperature versus time is proposed. Fig 4.31-2 is an example of a temperature profile for a single mission.

The next step is to prepare a frequency distribution of store skin temperatures for a standard day. One method of accomplishing this is to divide each mission into a group of representative stabilized temperature levels (temperatures stabilized for a period of three minutes or more) and then determine the total mission duration for each level.

These mission temperature level durations are then weighed for the relative frequency of each mission (i.e. multiplied by the fraction of total mission operations time for the store that the individual mission type is used). A composite distribution can now be generated by performing a run of the weighed mission durations for each temperature level used.

With a composite frequency distribution of temperature levels at hand, a composite mission temperature profile may be constructed by arranging the composite temperature level durations in segments ordered to simulate a typical mission or a few missions. Such a standard composite mission temperature profile is shown in Fig 4.31-3. When the temperature profile of the various missions are dissimilar, segments may separated into groups of similar characteristics and the composite profile constructed to include a mission or mission phase requirements for each of the group. Total duration at each temperature level must still reflect the distribution function calculated.

The standard composite mission temperature profile must now be adjusted for climatic temperature variations since the standard atmosphere, based on the `standard day' represents only an abstract climatic condition. Temperatures both higher and lower than 'standard day' values are commonly met due to seasonal or geographical changes in mission operations. Preparation of temperature - altitude information to cover all likely climatic mission situations would become too involved for practical consideration. Therefore, judgement of the relative frequency of expected occurrence of temperatures within this range is normally resorted to. Temperature extremes frequency of occurrence 5% or less) may be omitted. A climatic atlas is helpful at this step.

Climatic temperature estimates may be incorporated into the test by selecting a representative group of fixed temperature offsets which add to or substract from the standard composite mission temperature profile. By having these offsets represent equiprobable temperature intervals, a full climatic set of these temperature profile can simulate the whole temperature system which the store could experience. A sample composite mission temperature profile climatic set is shown in Fig 4.31-4. Note that the profiles are clustered around the standard value to reflect the higher frequency of operations in more temperature climates. For practical test operation, each test cycle (one composite mission) will trace a composite temperature profile, starting and ending at a resting temperature. The resting period between consecutive test cycles should be sufficient to allow internal store temperature to stabilize, thus simulating the ground time occurring between service missions. A climatic set of test cycles will consist of a sequence of test cycles (usually 6 to 15) in which the composite mission temperature pattern is offset stepwise upward and downward from zero offset. Fig 4.31-5 illustrates a typical offset sequence for an 8-cycle climatic set. To provide uniformity and consistency from one test to the next, it is important that several full climatic sets be completed before the expected Mean-Time-to- Failure of the store is reached. A test minimum of five sets is recommended.

1.3.4.2 **Vibration Profile** - A composite mission vibration may be generated by determining the dynamic pressures during each stable segment of aircraft flight (see clause 1.2.5). A rough profile can now be constructed. The periods of changing temperature will usually also be periods of changing 'q' since both are dependent on aircraft altitude and velocity. However, since vibration in the laboratory may be changed almost instantaneously (notwith lag, like temperature) and is more easily controlled at fixed levels, the 'q' profile is usually laid out as a series of steps. Fig 4.31-6 shows a typical composite mission dynamic pressure profile matching the corresponding Fig 4.31-7 temperature profile. Data from instrumented flight are used to determine the spectral envelope for various mission phases and the translation from ‘q’ to vibration level.

The simplified vibration profile shows intensity only. The spectrum envelope and the spatial distribution (including directivity) of the vibration are additional variables that, when uncontrolled, can cause error in the simulation process. Experimental adjustment should be done in the test chamber so as to achieve a reasonable correlation between accelerometer vibration records from captive flights and from the store under test.

1.4 **SPECIAL CONSIDERATIONS**. None

1.5 **REFERENCES.**

a) Meeker, D.B. and A.G Piersol, Accelerated Reliability, Testing Under Vibroacoustic Environments, Reliablity Design for Vibroacoustic Environments, ASME AMD – Vol 9, New York, NY 1974.

b) Dantowitz, A., G. Hirschhberger, and D, Pravidlo, analysis of Aeronautical Equipment Environmental Failures . Air Force Flight Dynamics Laboratory, TR-71-32, May 1971

c) Meeker, D.B. and W.D. Everett, U.S. Navy Experience on the Effects of Carrier-Aircraft Environment on Guided Missiles. AGARD Conference peroceedings No. CP271, May 1979.

SECTION - 2

1. APPARATUS

1.1 **General -** The facility must include a large acoustical noise test chamber capable of approximately a 155 dB intensity level and associated air-conditioning equipment to provide controlled fixed air temperatures and rapid temperature changes (4^oC per minute) in the range of 40^oC to $+85^oC$. Mechanical or hydraulic shakers capable of stressing the store (s) under test may also be required. Adequate instrumentation for controlling, monitoring, calibrating and recording the environment variables will be needed.

1.1.2 **Test Chamber** - Chamber shape and dimensions shall provide for diffusion and uniform distribution of the acoustic field, and support reverberation of acoustic frequencies of 150 Hz and above. Ports must be provided for introduction of the acoustic energy, for pressure stabilization (exit of modulator air) for entry and exit of temperature conditioned air and for access by multiple electrical cables and wave-guides, light beams, anechoic ducting, etc. as applicable. Some stores may require specialized test apparatus such as artificial targets, r-f anechoic shrouds, or visible gages which must be incorporated without compromising the combined environments.

1.1.3 **Vibration equipment -** A suitable acoustic energy field shall be provided by an acoustic power source controlled to reproduce the acoustic mission profile. Typical apparatus consists of a constant pressure compressed air source such as a reciprocating compressor with pressure regulator feeding an air modulator that is acoustically coupled to the chamber through an exponential horn. The air modulator is excited electrically by an amplified audio signal. Considerable acoustic power is needed to reach required levels, often 10 to 30 kW, multiple modulator-horn units may be necessary to reach desired intensities.

To provide low-frequency vibration below about 100 Hz electro-dynamic or hydraulic shaker may be used to augment the acoustic field. Such shakers may be used to provide limited mechanical shock impulses. To maintain access to the stores by the conditioned air and acoustic energy suspended stores can be vibrated at low levels using a rod and coller arrangement to conduct the vibration from the shaker (s). Procedure 6 of Test Number 28 will furnish some guide-lines for this procedure. A possible arrangement is diagrammed in Fig 4.31-7.

1.1.4 **Temperature Equipment -** Temperature conditioning of the store (s) under test must be accomplished without adversely affecting the acoustic environment. One process for accomplishing this is to duct high velocity conditioned air across the stores by means of thin flexible shrouds that are acoustically transparent. They can be supported by light metal framework.

Thin silicone rubber and rip-stop nylon sheetings have been found to be suitable shroud materials. To provide the rapid temperature changes required, one method uses insulated tanks or hot and cold fluids which are pumped through heat exchangers as required to temperature-condition the blower driven air. By increasing the blower speed or by narrowing the circumferential gap between the surfaces of the test item and the shroud usually between 2 and 4 cm) the boundary air velocity can be raised to provide the needed rapid heat transfer to or from the store to stimulate the captive flight conditions. A possible arrangement is diagrammed in Fig 4.31-7.

1.1.5 **Electrical Stress Equipment -** Basic electrical stresses always present in electrical or electronic circuits are produced by power ON/OFF transients and resulting localized thermal shocks, and also by hot spots accompanying the full power condition. A switching system is normally used to form typical patterns of store operation during the composite mission test cycle. The use of equipment to modify the power source to the store(s) to simulate likely variations (voltage, frequency, transients, ripple, noise etc) met during mission operations, is optional.

1.1.6 **Instrumentation and Control**

1.1.6.1 **Functional Monitoring of the Store -** The operating stress should be adequately monitored to indicate failures when they occur. Some form of manual or automatic test performed at intervals (at least once for each composite mission cycle) can be used. Failure criteria, based on equipment specifications and functional requirements, must be clearly defined. Functional monitoring must be accomplished without adversely affecting the environmental simulation. Functions which can only measured outside the environmental chamber should be checked at intervals which are short compared to the equipment's Mean-time-to Failure.

1.1.6.2 **Vibration Monitoring**

1.1.6.2.1 **Acoustic Stimulus -** The acoustic signal source is normally a pre-recorded tape or the shaped output of a noise generator. Filters are used as required to control spectral distribution. Intensity level is monitored by calibrated microphone. Microphone placement should conform with clause 1.2, step 6, Test Number 2, unless other placement can be justified by measurement and analysis.

1.1.6.2.2 **Mechanical Stimulus -** The shaker input signal is normally a pre-recorded tape or the shaped output of a noise generator. Filters are used as required to control spectral distribution. Intensity level is monitored by calibrated accelerometer mounted on or in the store(s) which measure the vibration response (see II-1.6.2.3). The shaker frequency range is limited (typically (200 Hz) so that feedback control is unnecessary.

1.1.6.2.3 **Vibration Response** - Calibrated accelerometers mounted in an on the store(s) when used with appropriate analysis equipment, provide the needed response monitoring for both acoustic and mechanical stimuli. Accelerometer positions in and on the store, at least during setup, should be as close as possible to those used to obtain captive flight data.

Accelerometer placement should aim to provide coverage for possible directional vibration (e.g. longitudinal, lateral and vertical axes) and for possible extension or radial variation (e.g. fore, mid, aft, external, internal). Power Spectral Density (PSD) measurement or display g^2/Hz units) plus intensity readings (grms units) furnish the needed information for comparing test chamber and captive flight vibration parameters (see 1.2.4).

1.1.6.3 **Temperature Monitoring** - Temperature sensors on the surface of the store(s) provide the best location for monitoring and feedback control.(Fig 4.31-7).

1.1.6.4 **Humidity Monitoring** - Although humidity is not a controlled variable for procedure I, the ducted airstream may be continuously monitored for moisture content, either by dewpoint or relative humidity sensing. It should be noted that moisture can collect on a store's surface when it has reached and holds a cold temperature that is below the dewpoint of warmer air following in the mission cycle. This is a normal and expected condition.

1.1.6.5 **Electrical input monitoring** - All electrical inputs to the store (s) should be monitored whether or not they are modified to represent expected mision irregularities.

1.2 PREPARATION FOR TEST

1.2.1 **Test Plan** - A test plan shall be prepared to document tests using this method. The following areas should be addressed in the test plan:

a) **Scope and purpose -** Test procedures differ with different test goals. A design qualification test might require demonstration of a specific Mean-Time-to-Failure (MTTF), a quantitative value. A test, analyze and Fix (TAAF) during development would be qualitative in nature since its primary purpose is the identification of failure areas to be expected in service.

b) **Test Time** - The items to be tested must be clearly identified. Their service designation, source and exact configuration should be recorded. Drawing number or other specific documentation should be referenced.

c) **Performance Parameters -** List those to be used in the test.

d) **Failure Criteria -** These must be clearly stated and be based on the performance monitoring system to be used.

e) **Failure Analysis -** Indicate how failures are to be analyzed, classified and reported. For example, failures can be classified by cause (suspected stress), subsystem or unit involved, affect on store operation, or responsibility (i.e. bad component or material, poor workmanship, inadequate inspection, deficient design, etc).

f) **Mission Profile -** Information must be supplied that will allow the mission profile to be properly charted for the particular test item. The needed information may be provided through the referencing of relevant documents or by inclusion in the test plan. The information should include:

i) The particular environments that are to be controlled. Temperature acoustic energy environments are always used. Shaker vibration and/or chock stress are optional additions.

ii) Data on all operational missions using the test item in the aircraft captive-carry mode. Needed information includes types of aircraft used, length of missions, aircraft flight paths and patterns, aircraft velocities in different operational modes, theatre of expected use and percent of time estimates for the various categories.

iii) Climatic and atmospheric data. World-wide seasonal altitude-versus-temperature tables or charts are needed.

g) Measured store responses to environments used in determining test stresses.

h) **Test Data -** List specific performance and environmental parameters to be recorded before, during or after a test cycle and whether recordings should be continuous or made at stated intervals. Explain how data are to be handled and specify recording methods. If analysis is required, methods should be referenced. All raw test data should be sorted, labeled and stored for possible later use in analyses or for graphic illustration (see clause 1.4).

j) **Test Reporting -** State how results are to be reported and whether conclusion and recommendations are to be included.

k) **Test Procedures -** Critical operations should be pointed and requirements for step-by-step procedures stated (see clause 1.3).

1.2.2. **Safety Program Plan -** A safety program plan shall be prepared which shall incorporate all safety policies, practices and regulations applicable to the preparation and conduct of the test. Safety policies and directions of the facilities conducting the test, contractual safety requirements where applicable, safety precautions applying to the stores under test and special hazards involved with the test apparatus shall be treated. The plan shall require that operating procedures prepared for this test method shall be even-sequenced and contain suitable warnings and precautions to be taken by operators wherever and whenever potential hazards exist. MIL-STD-882 Requirements for System Safety Program for Systems and Associated Subsystems and Equipment shall be used as a guide for preparation of the Safety Program Plan. After approval by proper authority, the Safety Program Plan shall be strictly followed during preparation and conduct of this test method.

1.2.3. **Composite Mission Test Cycle**

1.2.3.1 **Test Cycle -** A test cycle consists of a single simulated composite mission. A climatic set is a fixed number of test cycles (usually 6 to 15, as called out in the test plan) in which the temperature profile is offset by a fixed temperature difference predetermined for each test cycle of the set. A complete Composite Mission Combined Environments Test consisted of a number (usually five or more) of repeated climatic sets of test cycles.

1.2.3.2 **Environment Profile Charts** - For each of the controlled environments, prepare a chart plotting stimulus level versus time that best represents the composite mission. Each chart should be based on a standard atmosphere and the time period for the composite mission. These plots define the basic environment profiles that constitute a single test cycle and provide the patterns for controlling the environmental test apparatus. Methods for generating composite mission environmental profiles are discussed in clause 1.2.3 of section -1.

1.2.3.3 **Climatic Offset Table -** Prepare a table or chart indicating the temperature offset applying to consecutive test cycles in a climatic set of about 6 to 15 cycles (refer to Fig 4.31-5). The offsets are chosen so that one climatic set will represent the predicted mixture of climates expected in operational missions. This process is discussed in clause 1.3.4.1 of section - 1.

1.2.3.4 **Combined Environments Control Directions** - Provide directions for adjusting each of the controlled environments throughout each complete climatic set of test cycles. Levels are obtained from the composite mission environment profile with the temperature pattern for each cycle of the climatic set offset according to plan. These directions should not be finalized until test setup is completed (see clause 1.2.4).

1.2.4 TEST SETUP

1.2.4.1 **General -** Using instrumented (but not necessarily operable) stores, assemble test items and environmental apparatus, with accompanying instrumentation and controls, into the planned configuration. After sensor calibrations, test each environment separately to check ability to reach test levels and rate of change requirements. With individual environments checked out, run combined environments through a test cycle. Correct problems as necessary. The general accuracy and tolerance requirements of Section 4 of this standard shall be followed where applicable.

1.2.4.2 **Vibration checkout -** Adjustment of the vibration sources to provide the best simulation of in-flight vibration response is an essential part of test setup. Vibration response simulation can involve the following types of error: spatial (relative distribution of levels among various location and in different directions in or on the store), spectral (frequency/spectrum shape at any location and direction in or on the store), and intensity (peak and rms values). An interactive process of adjusting vibration stimulus variables (intensity, spectral envelope, limited directivity/store positioning) and observing responses is conducted to minimize these errors. The goal is to find the stimulus adjustments for each test level, which will optimize the correlation of test setup with corresponding captive-flight total vibration responses. Optimum values are noted and made part of the Combined Environments Control Directions (clause 1.2.3.4).

1.2.5 **Operational checkout -** Replace instrumented stores with one or more operable `practice' stores. Provide input power as required and use performance monitoring system at room environment and then, if required, during one or more mission test cycles of combined environments. Debug as necessary.

1.3. PROCEDURES

1.3.1 **General -** Written step-by-step procedures shall be prepared as called on the test plan.

1.3.2 **Specific Procedures -** The following operations should be considered as candidates for written procedures:

a) Pre-test visual inspection and checkout.
b) Mounting and connection of test units in the chamber
c) Calibration of instruments and apparatus
d) functional testing of the store(s)
e) Controlling the test cycle environments
f) Post-test operations.

1.4 INFORMATION TO BE RECORDED

1.4.1 **General -** The test information to be recorded shall be included in the test plan.

1.4.2 Examples of Information to be Recorded

1.4.2.1 **Test Operation Information -** For each test cycle, starting with number 1:

a) Starting and ending time.
b) Any deviations from specified time limits or environment patterns, or alternately, preservation of all continuous environment response records.
c) Operators on duty.
d) Pertinent comments.

1.4.2.2 **Test Item Information** - For each item under test:

a) Test item identification (manufacturer, serial number etc).
b) Specific identification.
c) Results of pre-test, inspection and checkout.
d) Position occupied in test chamber, if more than one used.
e) Time when item installed in chamber and number of the test cycle first encountered.
f) Reason for removal.
g) Results of post-test inspection and checkout.
h) Disposition of item.

1.4.2.3 **Special Information for Non-Conforming Item**

a) Time non-conformance was noted and number of test cycle in or after which it was discovered.
b) Evidence indicating non-conformance.
c) Confirmation of failure if failure suspected and explanation of how it was confirmed.
d) Failure analysis and diagnosis.
e) Disposition of item.
f) Failure report number.
g) Name of operators providing the above information.

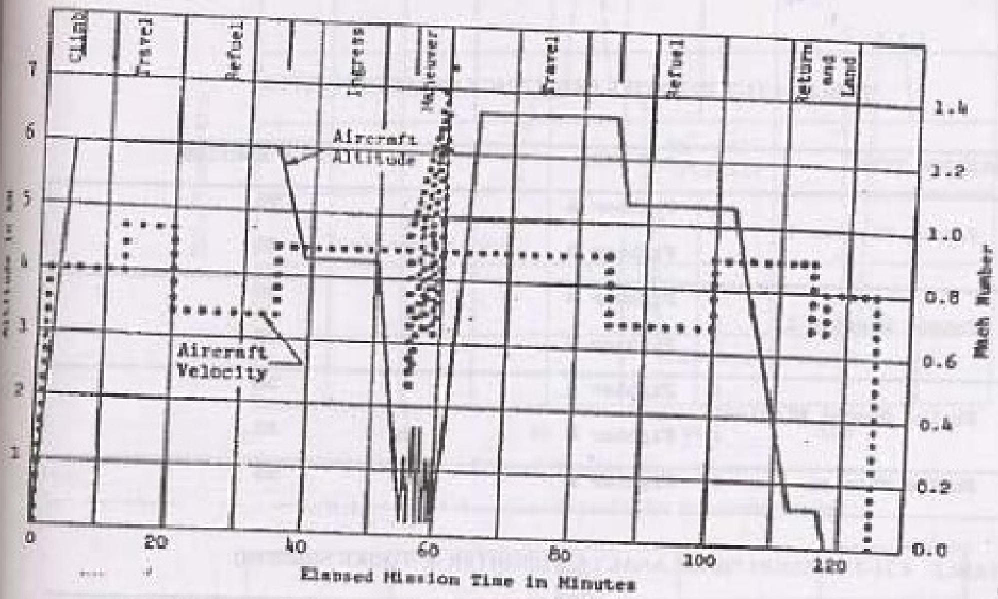


FIGURE 4.31-1 Typical aircraft operational mission profile.

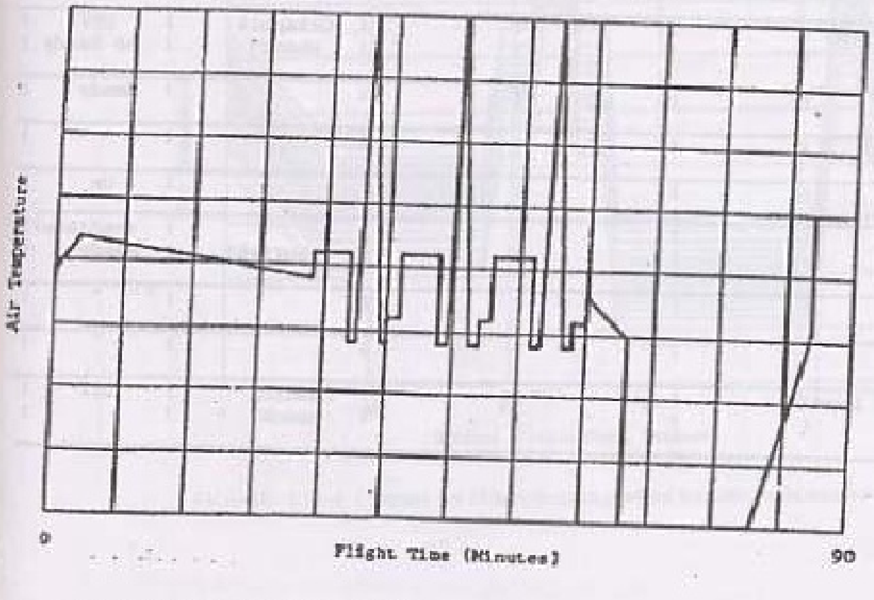


FIGURE 4.31-2 Temperature profile for a single mission type.

TABLE 4.31-2 RELATIVE FREQUENCY OF MISSION TYPES

MISSION TYPE		A/C TYPE	% OF SORTIES
1.	Patrol Mission I	Fighter A	50
		Fighter B	30
2.	Patrol Mission II	Fighter A	20
		Fighter B	20
3.	Strike Escort Mission	Fighter A	30
		Fighter B	30
4.	Strike mission	Fighter B	20

TABLE 4.31-3 MISSION PHASE ANALYSIS (FIGHTER B, STRIKE MISSION)

MISSION PHASE	MACH NUMBER	ALTITUDE (Km)	DURATION (Min.)	ADDITIONAL FACTORS	DUTY CYCLE OF STORE
Takeoff & Climb				Catapult shock?	Off to Ready
Travel					Ready
Refuel					-
Ingress					On
Maneuvar				Buffet	(radiate) Ready
Return					-
Refuel					-
Descent and Land				Landing shock	Off

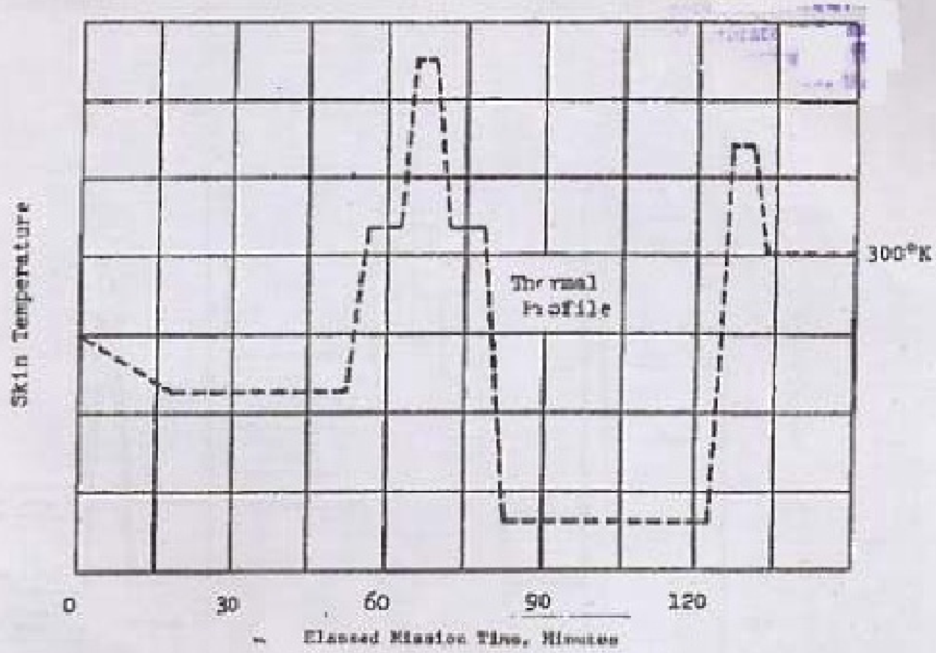


FIGURE 4.31-3 Temperature profile for composite mission

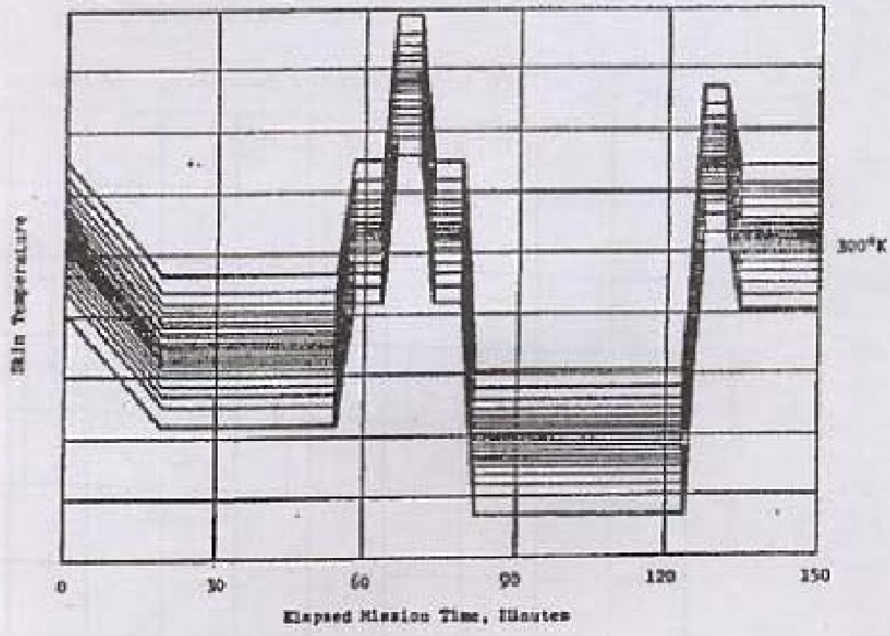


FIGURE 4.31-4 Climatic set of temperature profiles for composite mission

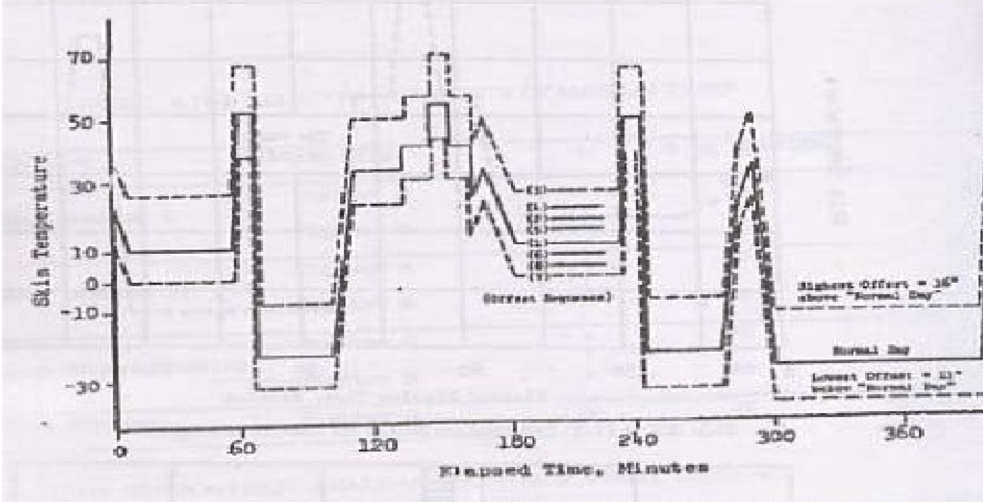


FIGURE 4.31-5 Climatic set plan showing offset sequence

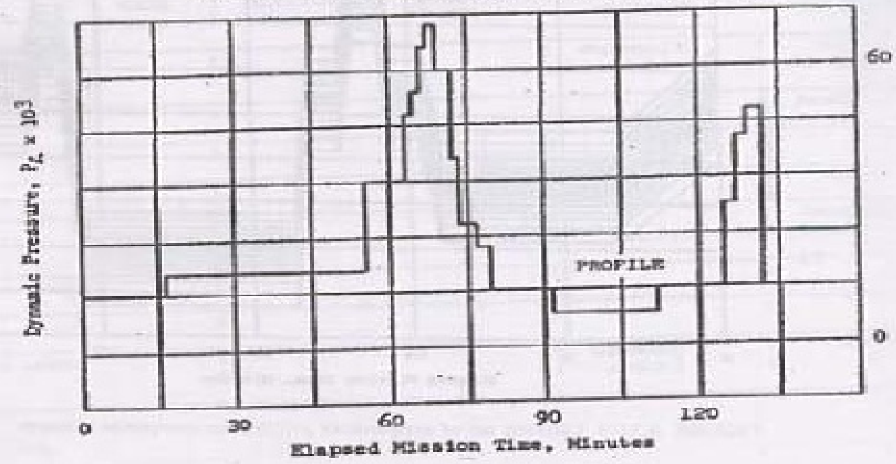


FIGURE 4.31-6 Dynamic pressure, Q, profile for composite mission

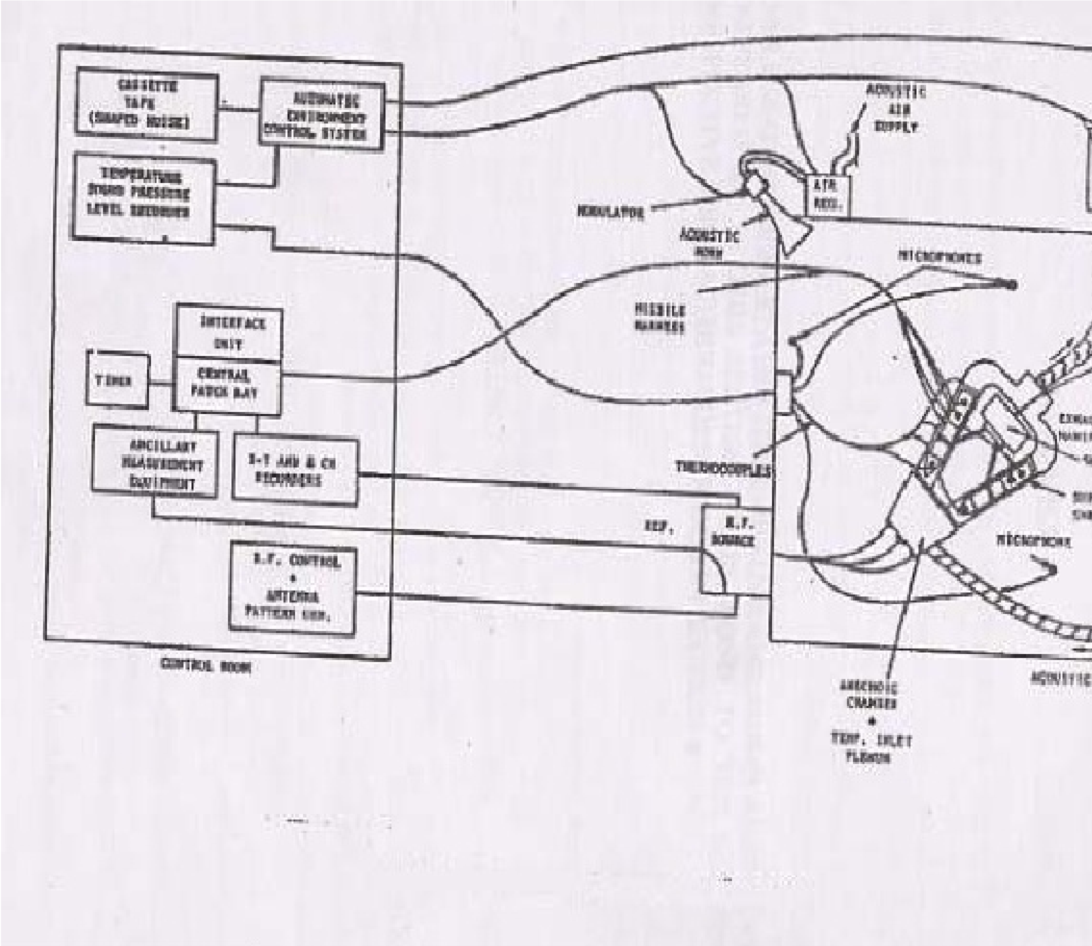


FIGURE 4.31-7 Typical arrangement of apparatus

SECTION 5

GUIDANCE

UNLESS OTHERWISE STATED ITEM, CLAUSE AND SUB CLAUSE NUMBER REFERRED TO IN THIS SECTION CORRESPOND TO THE NUMBER IN RESPECTIVE TEST METHODS DESCRIBED IN SECTION 4.

SUB SECTION 5.1

ACCELERATION

1. GENERAL

1.1 This sub section together with Test Number 1 specify design and test requirements for equipment in aircraft, some of which are required to operate during and after normal and crash acceleration phases. They relate these requirements to various grades of equipment and classes of acceleration.

1.2 The accelerations, normal and crash have been further classified in various acceleration classes as follows:

a) Normal Acceleration: Acceleration classes A to S (see Table 4.1-1)

b) Crash Acceleration: Acceleration classes T, U, V and W (see Table 4.1-2)

2. NORMAL ACCELERATION

2.1 **Design Requirements**

2.1.1 Equipment shall be designed with an ultimate strength at least 1.3 times the proof load due to acceleration appropriate to relevant acceleration class given in Table 4.1-1.

2.1.2 Acceleration greater than stated in Table 4.1-1 may be experienced by equipment in particular region of an aircraft (for example, under carriage legs, tips of flexible wings). Aircraft designers should, therefore, be approached to ascertain any increased loading requirements to which the equipment will be subjected.

2.1.3 When equipment contains rotating parts that have an appreciable polar moment of inertia, account should be taken of gyroscopic couple effect that will arise during certain aircraft maneuvers. The rate of precession shall be assumed to be as follows:

a) Acceleration classes A to G : 5 rad/s

b) Acceleration classes H to T : 3 rad/s

2.2 **Grades of Normal Acceleration** - Equipment shall be graded as follows:

2.2.1 Grade C - Equipment that will continue to function correctly during and after being subjected to proof load due to acceleration appropriate to its class (see clause 3.3.1.5 [a]).

2.2.2 Grade D - Equipment that regains its ability to function correctly immediately after the removal of the proof load due to acceleration appropriate to its class, and will also continue to function correctly during and after being subjected to a smaller load due to acceleration, the value of which shall, if applicable, be as specified (see clause 3.3.1.5[b]).

3. CRASH ACCELERATION

3.1 Design Requirements

3.1.1 Under crash conditions, acceleration greater than those specified in Table 4.1-1 may be encountered. The limiting requirements under these conditions consistent with safety during an emergency landing are stated in Table 4.1-2.

3.1.2 Equipment shall be designed with an ultimate factor (greater than 1.0) on the maximum proof load due to acceleration appropriate to the acceleration class stated in Table 4.1-2. It shall also be designed and constructed not to break loose from its mountings under applications of limiting loads due to acceleration.

3.1.3 Certain items of equipment may be required to withstand or to continue to function during local accelerations that are considerably greater than those stated in Table 4.1-2. These limiting acceleration shall be as specified.

3.2 **Grades of Crash Acceleration** - Equipment shall be graded as follows:

3.2.1 Grade E - Equipment that is capable of functioning correctly during and after being subjected to limiting loads due to acceleration (see clause 3.3.2.5 [a])

3.2.2 Grade F - Equipment that regains its ability to function correctly immediately after the removal of limiting loads due to acceleration (see clause 3.3.2.5 [b])

3.2.3 Grade G - Equipment that may cease to function during and after being subjected to limiting loads due to acceleration (see clause 3.3.2.5 [c]).

4. EQUIPMENT ORIENTATION FOR TEST

4.1 In aircraft applications the forces on the moving body giving rise to accelerations are invariably complex but can be considered at any instant, to be a single force which can be described in direction by its angular position relative to the three main axes of the moving body.

4.2 For design purposes, the maximum acceleration levels for a particular maneuver of the moving body are resolved and specified with respect to each major axis of the moving body.

4.3 If an equipment has a known fixed attitude with respect to a given moving body and in cases where it is necessary to apply the three components of acceleration simultaneously, these can be combined and the equipment may be subjected to a single acceleration equal in magnitude and direction to the resultant of the three components.

4.4 Such an action, however, would necessitate rather complicated rigs in order to orient an equipment relative to the test machine in such a manner that the acceleration is directed along the line of the resultant.

4.5 Unless it is important to preserve the angular relationship between the resultant acceleration and the equipment, it is simpler and usually adequate to apply the resultant acceleration along the major axis of the equipment having the highest of the three components. In the remaining axes, the appropriate component levels could be applied.

4.6 When the attitude of the equipment with respect to the vehicle is not known, the maximum resultant level for the particular moving body should be applied in each direction in turn along each of the major axes of the equipment.

4.7 Equipment that will always be mounted in one fixed attitude shall be subjected to the appropriate resultant proof loads due to acceleration applied in each of the resultant directions calculated from the component proof accelerations relative to the three aircraft body axes X, Y and Z as shown in Tables. 4.1-1 and 4.1-2.

Note - The inertia loads would be in the opposing direction to the accelerations.

4.8 If the tests are made on a centrifuge, the radius of gyration should be such as to ensure that the load due to acceleration is sensibly constant over the whole of the equipment under test.

5. TEST PROCEDURE

5.1 Two procedures are specified in this test. Procedure 1 specifies maximum proof loads due to normal acceleration (see Table 4.1-1) and procedure 2 specifies maximum proof loads due to crash acceleration (see Table 4.1-2).

5.2 The relevant equipment specification should grade the equipment (see clause 2.2 and 3.2) and specify the acceleration class for each application based on typical maneuvers for normal acceleration (see Table 4.1-7) and based on equipment location for crash acceleration (see Table 4.1-2).

SUB SECTION 5.2

ACOUSTIC NOISE

5.2 GUIDANCE ON ACOUSTIC NOISE TEST

1. CHOICE OF TEST SPECTRA

1.1 The test spectrum given in Fig.4.2-2 was derived from consideration of the following factors.

1.2 The external exhaust overall noise level can range from 130 dB to 165 dB when both jet and rocket noise are considered. Below this range acoustic problems are unlikely, whilst above this range special attention is necessary.

1.3 The maximum band level occurs in the frequency range 200 Hz to 1000 Hz with a 6 dB per octave roll off at higher and lower frequencies.

1.4 The attenuation by the skin etc. below 1000 Hz is of the order of 10dB. Above 1000 Hz the attenuation can increase at a rate of 6 dB per octave, giving up to 30 dB attenuation at high frequencies. However, these figures are only generalizations since many factors may be involved.

1.5 Depending on the type of vehicle, maximum boundary layer noise will normally be in the region of 145 dB, with a spectrum closer to white than that for jet noise.

1.6 When exhaust and boundary layer spectra are combined, and skin attenuation is taken into account, the result is similar to the external spectrum for jet noise only.

1.7 Although the preferred signal should be random, reverberation conditions may modify the amplitude distribution giving misleading distribution measurements in the reverberation chamber.

1.8 These consideration give rise to a general purpose test, but should one particular type of noise predominate, a special test may be required.

2. SOME CONSIDERATIONS IN THE SELECTION OF A TEST FACILITY

2.1 **Choice of Test Chamber** - The test is based on conditions arising primarily with aircraft equipment which operate in an enclosed compartment. Hence the first characteristic of the normal environment is that of an enclosed space.

2.1.1 The greater part of the acoustic field in such enclosed compartments is usually due to secondary radiation of sound from vibration of the surrounding structure. Thus the sound radiating source can comprise a large area of the compartment.

2.1.2 A combination of enclosed space, reflective surfaces and a relatively large radiating area, will result in sound waves being reflected and transmitted in random directions to build up a diffuse field. This is closely simulated in a reverberation chamber. Other types of chamber that may be considered would not give the same correlation of pressures over the specimen, and would therefore not excite specimen resonance in quite the same way.

2.2 **Test Chamber Size** - The class of equipment and components to be dealt with is to be confined to the airborne type, although some conclusions may have more general applications.

2.2.1 Much airborne equipment will be in the form of "Black boxes" which will generally be the largest items to be tested. They will seldom approach 1 m^3 in volume, a more realistic limit being in the order of 0.1 m^3. In general, components will be enclosed inside the black boxes so that, for the component, the environment is enclosed in the box (or whatever equipment the component operates in).

2.2.2 The volume of operating space for equipment cannot be specified, although some generalizations may be permissible. The largest volumes are usually passenger and crew compartments where an overall noise level of less than 120 dB makes noise problems unlikely. Crew compartments of small military aircraft have a relatively small volume (8 m^3 or less), but noise levels up to 135 dB are possible. Generally, airborne equipment subject to intense noise environment will be operating in small compartments in the nose, tail, wings and under floor compartments. Possible exceptions are where aircraft have large under floor cargo spaces, or in the case of military aircraft where electronic equipment may be carried in large bomb bays.

2.2.3 It is unlikely to find equipment operating in volumes of the order of 500 m^3, and even more unlikely that such equipment will require an acoustic test. Components will operate in an environment formed by the casing of the equipment and can therefore be tested in a small test chamber.

2.3 **Standardisation of Test Conditions**- Standardisation of test conditions is needed if different establishments are to obtain similar results with the same type of specimen. In addition, if the cataloguing of equipment as complying with a specification is to have meaning, the conditions need to be related to some standard conditions. These conditions would include frequency spectra, sound pressure levels and type or pattern of acoustic field.

2.4 The test item shall be exposed on every surface to the sound field by centrally locating it in the test chamber. The test volume shall not be more than 10% of the test chamber volume. When the test chamber is rectangular no major surface of the test item shall be installed parallel to the chamber wall.

2.5 **Acoustic Noise Generators** - For the acoustic test, a source should be capable of delivering controllable random noise at high power; controllable in that the shape of the spectrum can be changed without altering the randomness of the output. A high efficiency is also desirable although this tends to take second place to the first mentioned requirement.

2.5.1 At the present time, the most suitable devices are those which are electromagnetic in operation: loud speakers and electromagnetic air modulators. The only other suitable device is the random siren although this is of doubtful value due to control problems.

3. PREFERRED CHAMBER AND GUIDE TO SUITABLE SOURCES

3.1 Test Chambers

3.1.1 The preferred test chamber is an uneven pentagon as shown in Fig. 4.2-1 and in order that a measure of standardisation of the test can be achieved it is recommended that the size of the chamber be chosen from one of three sizes having the following dimensional constants:

$n = 0.5$ m
$n = 1.25$ m
$n = 3$ m

The mean absorption coefficient α should be between 0.03 and 0.04.

3.1.2 Material suitable for the test chamber include painted brickwork, smoothed concrete, or steel or aluminium plate. Vibration damping of the wall and horns coupling the sources to the chamber is of importance if high absorption, due to mechanical resonance, is to be avoided. Absorption coefficients for these materials commonly range from 0.02 to 0.05 with adequate vibration damping the figure is closer to 0.02 than 0.05.

3.1.3 Brick and concrete may also give figures of less than 0.02, although this should normally be avoided. The recommended range for α is a compromise between power requirements, diffusion and smoothness of frequency response. Absorption coefficient, when tending to be high, may sometimes be reduced by coating the appropriate surfaces with an epoxy paint.

3.1.4 The sound source opening and the specimen are also absorbers of acoustic energy. Initially it may be found best to assume the absorption coefficient of the sound source opening to be unit (α =1) Q.

3.1.5 Absorption by the specimen would normally be 10 W, as the specimen would have a similar absorption coefficient range to those materials quoted above. If however, the specimen to be tested has non-metallic or highly resonant surfaces, special consideration should be given to the absorption by the specimen.

3.2 **Acoustic Power Requirements** - The basic power requirement may be initially estimated from:

$$PWL = SPL - 10 \log \left(\frac{4}{R}\right) \text{ dB referred to } 10^{-12} \text{ Pa}.$$

where PWL = 10 log 10 W + 120 dB

and W is the acoustic power in watts:

SPL is the sound pressure level in decibels with reference to 2 x 10^{-5} Pa,

R is the room constant in m^2.

$$R = \frac{S\alpha}{1\alpha}$$

where : S is the total surface area absorbing acoustic energy in m2.
α is the mean absorption coefficient of the surface area.

3.2.1 Most sound sources deliver their power unevenly through the spectrum, so that spectrum shaping may be accomplished by reducing the power output in the most efficient part of the output spectrum of the source. Additional power may therefore be required to allow for the inefficiency of the source in parts of its output spectrum.

3.2.2 For the test chambers recommended in clause 3.1.1 above, the higher absorption coefficient ($\alpha = 0.04$) should be assumed in initial calculations.

3.3 **Source Requirements** - An indication of power requirements and of the type of source which may be associated with the recommended test chamber, is given in Table 5.2.1.

3.3.1 Acoustic powers, as calculated by the method in clause 3.2 above have been increased to allow for spectrum shaping and other uncertainties .

3.3.2 Input power for loudspeakers and pressure drive units is given in electrical watts, all other power being given in acoustic watts. In the table these are shown as watts (E) and watts (A) respectively.

3.3.3 Any individual device may not necessarily cover the whole of the frequency range required.

3.3.4 The air modulators referred to are not necessarily commercially available in the intermediate sizes, but represent types which are feasible and would be suitable. A 2 kW (A) modulator if available could be used in the absence of intermediate sizes.

3.3.5 The use of a large number of sources should be avoided, where possible. Since the source area is absorbent to sound, the addition of extra sources will increase the absorption and a state may be reached where the SPL falls when more sources are added. Thus one high powered source is in general more effective than a number of low powered sources.

3.3.6 A random siren is a possible alternative to the air modulator where very high acoustic powers are required. With this type of device, however, spectrum shaping is very difficult to achieve. In addition, special care should be taken to ensure that the output is random under all conditions of use.

3.3.7 Unless otherwise specified in the relevant equipment specification, the time duration to exposed the equipment in the different types of sound pressure chambers shall be taken as 10 hours.

TABLE 5.2.1 - TYPICAL SOURCE REQUIREMENTS

Spectrum		**Grade A**	**Grade B**	**Grade C**	**Grade D**
~~Dimension~~	~~SPL~~	~~130 dB~~	~~140 dB~~	~~150 dB~~	~~160 dB~~
Test Chamber n= 0.5 m (see fig. 4.2-1)	Acoustic Power Source	0.5W (A) 30W (E) Loud- speakers	5W (A) 100W (E) Pressure Drive Unit	50W (A) 6 off 100W (E) Pressure Drive Unit or 50W (A) Air Modulator	500W (A) 500W (A) Air Modulator
Dimension	SPL	130dB	140dB	150dB	160 dB
Test Chamber n= 1.25 m (see fig. 4.2-1)	Acoustic Power Source	5W (A) 100W (E) Pressure Drive Unit	50W (A) 6 off 100W (E) Pressure Drive Unit or 50W (A) Air Modulator	500W (A) 500W (A) Air Modulator	4kW (A) 2 off 2 kW (A) Air Modulator or random Siren
Test Chamber n= 3 m (see fig. 4.2-1)	Acoustic Power Source	25W (A) 3 off 100W (E) Pressure Drive Unit 25W (A) Air Modulator	250W (A) 250W (A) Air Modulator	2 kW (A) 2 kW (A) Air Modulator	16 kW (A) 8 off 2 kW (A) Air Modulator or random Siren

SUB SECTION 5.3

ALTITUDE

1. GENERAL

1.1 Five procedures have been covered in the altitude test described in Section 4. The guidance on application of procedure No. 5 is given below.

2. AIRBORNE EQUIPMENT

2.1 Procedures 1 to 4 are intended for airborne equipment, the guidance on application of these procedures is given in Sub Section 5.20 (AIRBORNE EQUIPMENT - TEMPERATURE REQUIREMENT).

3. GROUND EQUIPMENT

3.1 **Procedure 5**

3.2 This procedure specifies a combination of low temperature and low air pressure which ground equipment are likely to encounter at high (ground) altitude operation or during transportation in unpressurised aircraft.

3.3 In this procedure, test conditions L1 and L2 specify the low temperature severity and test conditions A1 and A2 specify the low air pressure severity.

3.4 The combination of low temperature low air pressure severities applicable for (ground) altitude operation is L2 A2 and L1 A1 is applicable to equipment to be transported in unpressurised aircraft.

SUB SECTION 5.4

BOUNCE

1. GENERAL

1.1 The bounce test is not intended as a replacement for the vibration test, but it is preferred to the bump test for the equipment in the intended state for transportation. The response of the package to the bounce test is significantly dependent on the dynamic characteristics of the package. A resilient package may be subjected to considerable stress by bouncing and chattering about on the support platform and by colliding with the side walls or other items of cargo, whereas non-resilient item may remain in close contact with the platform and will therefore not be subjected to the same stresses.

1.2 **Equivalent Motion** - The motion experienced by the specimen during this test is almost comparable in severity to the environment during transportation in a lightly laden four wheeled truck traversing potholed road at a speed of 10 to 15 km/h, with the specimen located over the rear axle.

1.3 A basic drive mechanism and a typical barrier arrangement is shown in Fig. 5.4-1 and 5.4-2 respectively.

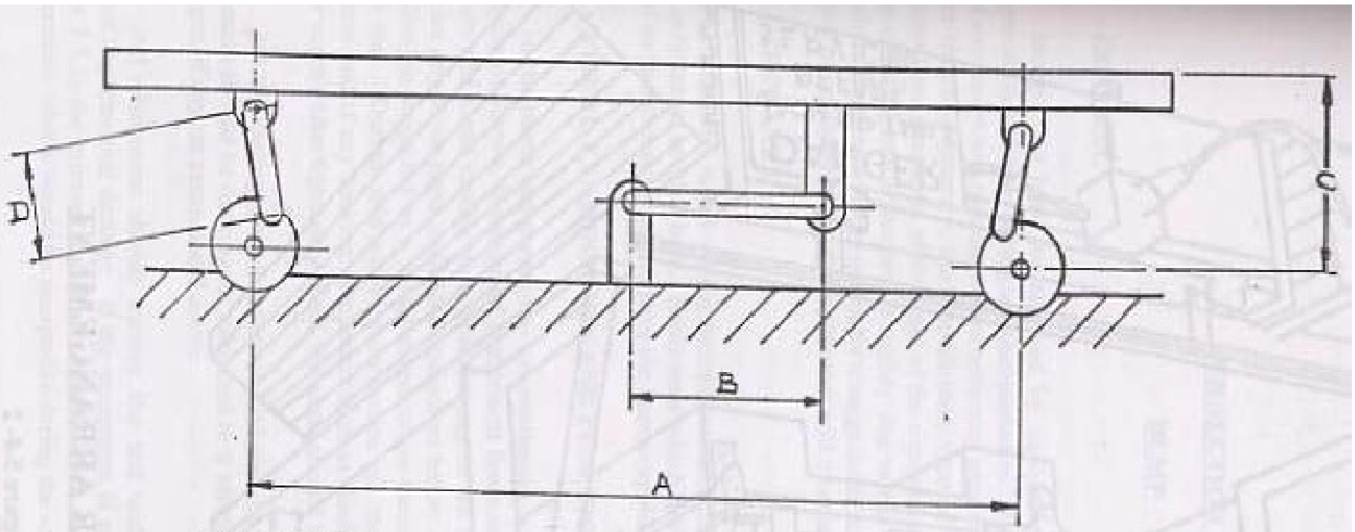
2. TEST PROCEDURES

2.1 **Synchronous Circular Motion - (Procedure 1)**

This is based on a platform motion which in the vertical plane provides a circular motion of amplitude and speed to produce a mean peak acceleration in excess of 1g. Vertical motion induces bounce and the horizontal motion occasional impact with the barrier rails. This procedure is generally meant for equipment, which are normally transported by rail.

2.2 **Non-Synchronous Motion - (Procedure 2)**

This is based on a non-synchronous motion of the platform in which two input points are driven at different speeds. This results in a motion which progressively changes from linear vertical to pitching the vertical motion induces bouncing, the pitching motion impact with the barrier rails. This procedure is generally meant for equipments which are normally transported on vehicles over rough pot holed roads or tracks and cross country.



DIMENSIONS :

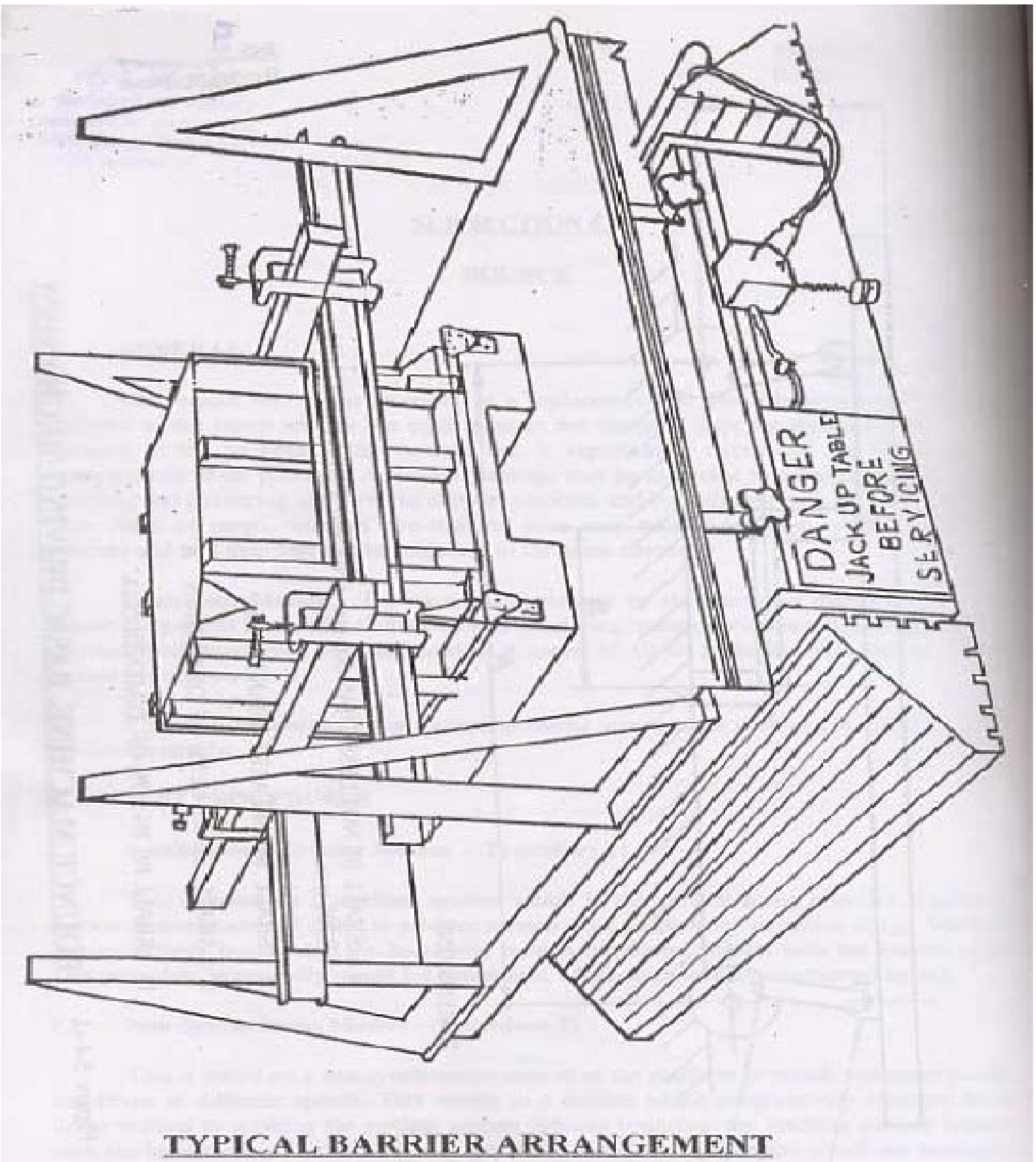
A : SHALL BE NOT LESS THAN 600 mm AND NOT GREATER THAN 1700 mm.

B : SHALL BE GREATER THAN 250 mm.

C : SHALL BE 25% ± 5% OF DIMENSION 'A'

D : SHALL BE 3% ± 7% OF DIMENSION 'A'

Figure 5.4 -1 **BOUNCE MACHINE, BASIC DRIVING MECHANISM**



TYPICAL BARRIER ARRANGEMENT

Figure 5.4-2

SUB SECTION 5.5

BUMP

1. GENERAL

1.1 Bumps and jolts are received by equipment during their movement by overland transportation and also during air transportation. These bumps and jolts can be severe and are of a complex and random nature occurring over various periods of time and are dependent on the length of journey, track conditions, type of vehicle, speed of vehicle, mass of the equipment and condition of stowage of the equipment on the vehicle or its trailer. Repetitive bumping during rail transport is mainly due to rail discontinuities and is of relatively low intensity. The bump test is generally a ruggedness test which is conducted to give the user a measure of confidence that the equipment will meet service conditions.

2. TEST AXES

2.1 Equipment, which during transportation or use, would always be on its normal base need only tested on that base. Equipment which during transit, can be placed on more than one of its faces, may require to have the bumps applied to each relevant face.

3. VISUAL EXAMINATION AND FUNCTIONAL PERFORMANCE

3.1 In the bump test damage to the equipment is usually of a mechanical nature such as loosening of screws, breakage of component leads and development of cracks in supporting brackets and metal casting etc. This damage to the equipment will be further aggravated if there are any loose parts inside the equipment before starting the test. The equipment should therefore be subjected to a visual examination thoroughly before subjecting the same to a bump test. During this visual examination all the screws should be checked for their tightness and if any locking compound such as `look-tight' is recommended for application on the screws after tightening them, the same should be applied properly.

All the castings and brackets should also be examined. On completion of the test, equipment should be once again subjected to a visual examination to reveal the mechanical damages, if any, as enumerated above.

3.2 All equipment should survive the test without degradation in performance and without any physical damage. If the equipment is required to function during the test (see clause 3.3.3) the relevant equipment specification should state the allowable degradation in performance which would be acceptable during the test.

3.3 Certain equipment which are not mobile need not be operated during this test, even then, the relevant equipment specification may specify deterioration in performance, if any, allowable at the conclusion of the test.

3.4 In general, mobile equipments may have to operate during the test. Where such operations considered necessary, the relevant equipment specification should clearly state:

(a) at what stage during the test the equipment should be switched on,

(b) what parameters should be monitored and for how long.

Note : It may not be necessary to monitor all the electrical parameters specified. The testing authority in consultation with the design authority may monitor only the most significant parameters which may be one or two only.

(c) what deterioration in performance is allowed during the Bump phase e.g., for manually operated equipment the phase where the operator would be incapable of carrying out his function because of the environment.

SUB SECTION 5.6

CONTAMINATION

1. GENERAL

1.1 A variety of fluids are used in, or in close proximity to various equipments and contamination of these equipments by accidental spillage or from the normal functioning may frequently occur. Such fluids include fuels, lubricants, hydraulic fluids, antifreeze, deicing salts and fluids, acid and alkalic battery electrolytes, plasticizers and proofing agents. These materials may be directly deleterious to many metals or plastics or may indirectly induce corrosion by removing or degrading the performance of protective coatings. An example is the migration of plasticizers from flexible PVC wraps on to painted surfaces with subsequent softening of paint.

1.2 This test is intended to be applied, where an equipment, which is designed to operate in a particular environment, is or may be subject to contamination by a specific fluid or fluids such as those mentioned in 1.1 either as mixtures or in succession. In specific cases, this test may be applied only to materials, components or sub-assemblies of an equipment which are likely to be exposed to the contaminants in order to avoid unnecessary and expensive testing of complete equipments.

1.3 When an equipment is sealed, it may only be necessary to apply this test to the components and finishes located outside the seal and a dummy unit can be used for the test.

1.4 If it is expected that the equipment is not likely to be exposed to the influence of contaminants during the operational/storage conditions, this test may be omitted from the applicable test sequence.

2. CONTAMINATING FLUIDS

2.1 There are many fluids which can be encountered by equipments under service conditions. The fluids specified in clause 3.2.2 are representative of the different families most likely to have a deleterious effect on equipment.

SUB SECTION 5.9

CORROSION (SALT/SALT FOG)

1. GENERAL

1.1 The Corrosion (Salt) test procedures included in this specification are to be used on equipments fabricated from known and approved materials protected according to design requirements. The test conditions chosen are intended to intensify corrosion attack, i.e. to equate with the more corrosive conditions of service. It should be emphasized that no attempt has been made (or should be made) to accelerate corrosion in such a way as to produce effects that would not occur in a natural environment. The tests needed are usually known to the material experts as a result of experience on previous designs or from a knowledge of the basic properties of the materials themselves. The use of non-specified or otherwise unproven materials or procedures involves a greater degree of risk and uncertainty in proving the final design. Similarly, the use of non-standard components in prototypes, often introduced into early production runs to hasten availability of equipments for proving degrades the value of the final results.

1.2 Corrosion tests are very useful in assessing the quality of materials and coatings and they also reveal the most serious short-comings of designs but a great deal of experience, common sense and scientific interpretation is needed in assessing the results of environmental corrosion tests. These results, at best, can be considered only as qualitative indications.

2. FACTORS AFFECTING ATMOSPHERIC CORROSION

2.1 Humidity

2.1.1 High relative humidity or pure water causes only very slow corrosion of metals. Contaminants on the metal surface are corrosive only in the presence of water or a relative humidity exceeding a critical value which is different for different metal/contaminant systems. Thus, corrosion can be prevented by maintaining a high level of purity on the metal surfaces or by desiccation of the adjacent atmosphere. Corrosion may often be accelerated by injudicious use of processes or materials which introduce contaminants or which readily retain water.

2.1.2 High humidities also occur in the external environment due to diurnal variations or as a result of rain fall. The accompanying wet or high humid conditions will accelerate corrosion. In such cases, the designs of the components and the way in which the water runs off or is trapped will influence corrosion rates. The washing action of rain may also remove corrosive salts on the surface of the metals and thus reduce corrosion. It is often noticed that sheltered surfaces corrode more rapidly than those fully exposed for the above reasons. One more cause for the concentration of water and high humidities within enclosures and other confined surfaces of equipment is the `breathing' associated with temperature changes and the temperature lags of items of high heat capacity.

2.2 Contaminants

2.2.1 One of the most common contaminants, especially in marine conditions, is salt spray. Corrosive microclimates also frequently occur and may radically alter the pattern expected from general classification. Examples of such microclimates are situated near chemical works, power stations, ships' smoke stacks, vehicle exhausts, rocket launchers, gas, oil and solid fuel burning appliances etc. Such microclimates may also occur within enclosures as a result of corrosive vapors emitted by organic materials such as plastics and paints. The most frequently encountered vapors under these conditions are acetic acid and formic acid but ammonia, hydrogen, sulphide, sulphur dioxide, hydrochloric acid, phosphine and phenols have all been identified as corrosive agents in such conditions. Apart from the general corrosivity of contaminants, the pattern of corrosion and the relative effects on various metals vary widely. Thus, in marine atmospheres, cadmium is more resistant than zinc whereas in industrial atmosphere Zinc Corrodes less rapidly than cadmium. Corrosive contaminants may also be present on the surfaces of metals from casting and forming operations.

2.2.2 Other contaminants are residues from machining fluids, degreasing chemicals, treatment solutions and drying materials, though good production practices demand steps to avoid these, especially on creviced parts. Contaminants may also migrate onto metal surfaces from contact with materials containing corrosive ions such as fabrics, paper, vulcanized rubber, rubberised hair, certain types of plastics like halogneted plastics, and occasionally certain materials used as protectives (staining and corrosion of some metals is sometimes associated with chemical or bio-chemical breakdown of oils and greases used as protectives).

3. SPECIAL TYPES OF CORROSION

3.1 Apart from the general type of atmospheric corrosion discussed above, a variety of defects may occur by the reaction of corrosion processes with some other aspects of the design of the equipment. Such as proximity of dissimilar metals (bimetallic effects), conjoint action of corrosion and mechanical forces (corrosion fatigue, stress corrosion and fretting corrosion), break down of passivity (crevice corrosion) and embattlement produced in high strength steels by hydrogen etc. A full discussion of such effects is beyond the scope of this guidance document but many of these factors are of great importance and are tending to assume even greater, importance as design stresses increase and more sophisticated alloys are used. It is essential that such factors should be considered in the design and construction of equipment, in the selection of corrosion test, the state of the equipment during test and in assessing the results of such tests.

3.2 **Bimetallic Corrosion**

3.2.1 Corrosion of a metal may sometimes be stimulated by contact with a less reactive metal in a corrosive environment. This stimulation results from the electro-chemical nature of corrosion and, in general, is controlled by the conductivity and type of the electrolyte which bridges the metals. Bimetallic effects are most frequently encountered in immersed conditions, particularly in solutions of high electrolytic conductivity such as sea water.

3.3 **Breakdown of Passivation**

3.3.1 Certain metals such as titanium, aluminium and stainless steel which resist corrosion due to their ability to form and retain an oxide film on the surface may corrode rapidly under some conditions, particularly if oxygen is lacking. This type of corrosion is most frequently encountered in deaerated or reducing solutions and in atmospheric conditions may occur in areas shielded from the atmosphere, typically at crevices and overlaps.

3.4 **Hydrogen Embrittlment**

3.4.1 High strength steels when stressed at loads well below their tensile strength may fracture if traces of hydrogen are present in the metal. Hydrogen may be introduced as a result of finishing processes or as a bi-product of corrosion while using such materials, care should be taken to remove hydrogen after processing and a high level of protection is necessary during service if such components are under load for more than very brief periods.

4. PRE-CONDITIONING

4.1 The equipment under test shall have to be properly prepared for the test in view of the fact that any contaminants on the surface of the exposed parts will aid in corrosion as discussed earlier. The equipment should, therefore, be given a minimum of handling, particularly on the significant surfaces. Unless otherwise specified, uncoated metallic parts or metallic coated parts shall be thoroughly cleaned of oil, dirt and grease, as necessary. The cleaning methods shall not include the use of corrosive solvent or solvents which deposit either corrosive or protective films or the use of abrasives other than a paste of pure magnesium oxide. Items having an organic coating shall not be solvent cleaned.

5. TEST PROCEDURES

5.1 Two test procedures are specified. Although the spraying period is same for both the procedures, the duration of storage under humid conditions is longer for Procedure 1. This period of storage is stipulated depending upon the likely severity of the service environment. It should be noted here that a careful evaluation and interpretation of minor effects after a short storage period can usually give as much information as the more usual user evaluation after a long exposure. It will normally be appropriate for the designer to specify the short duration test (viz. Procedure 2) unless he has specific reasons for choosing the long duration test (Viz. Procedure 1), is to be stipulated when the equipment is likely to be exposed to severe salt contamination conditions as in equipments used for shipboard applications. In all other cases Test Procedure 2 may be stipulated.

5.2 Whenever this test is included in the test sequence of a relevant equipment specification, the designer of the equipment may consider whether a separate equipment can be made available for this test alone.

5.3 In case of sealed equipment where the changes of penetration of salt laden atmosphere beyond the seals is negligible, this test may be applied only to the components and finishes located outside the seal and dummy unit can be used for this test.

SUB SECTION 5.10

DAMP HEAT

1. GENERAL

1.1 The temperature and relative humidity of air in varying combinations are climatic factors which always act upon an equipment during storage, transport and operation. In many instances, it is possible that certain equipments placed under particular conditions may be subjected to relative humidities of more than 95 percent at higher temperatures. In particular, this may happen when the equipment is placed in enclosures such as vehicles, tents or aircraft cockpits and this can result in intense heating through solar radiations while, because of inadequate ventilation, any humidity which may be developed will be retained permanently within in the interior. This resultant high relative humidities at high ambient temperatures will cause high degree of deterioration in electronic equipments.

1.2 A damp heat test is intended to determine the ability of electronic and electrical equipment to withstand the stresses occurring in a climate of high relative humidity with or without condensation.

2. INFLUENCE OF HIGH HUMIDITY ENVIRONMENT ON ELECTRONIC AND ELECTRICAL EQUIPMENT

2.1 In a humid atmosphere, mechanical and optical characteristics of materials may change. Examples of such changes are dimensional changes by swelling, variation of surface characteristics such as co- efficient of friction, change of strength etc.

2.2 If the surface of an insulating materials is affected by condensation or by a certain amount of absorbed humidity, some of the electrical characteristics may change like decrease of surface resistance, increase of loss angle etc. The leakage currents may also develop. When equipments are switched on and their electrical characteristics are to be measured, changes in some of the electrical characteristic due to surface moisture become evident.

2.3 The moisture absorbed by an insulating material may produce a variation in a number of electrical parameters like decrease of dielectric strength, decrease of insulation resistance, increase of loss angle, increase of capacitance etc.

2.4. Many types of corrosion can occur only when a sufficient amount of humidity is available. With increasing humidity or temperature the corroding effect is accelerated. The most severe deterioration by corrosion will, in general, occur when there is frequent condensation with re-evaporation. However, damp heat tests should not be used for determination of corrosion effects but when foreign substances are deposited on metallic surfaces, for example flux residues. Other residues of manufacturing processes, dirt, finger prints etc., may produce or promote corrosion in the presence of humidity.

2.5 Joints between different metals or between a metal and a non-metallic material may be a source of corrosion when condensation or a high relative humidity is present without pollutants. Although damp heat tests should not be used for determination of corrosion effects, occurrence of corrosion during/after these tests may have to be analyzed and suitable remedial action taken.

3. APPLICABILITY

3.1 The test can be applied in all cases where condensation is important or when the penetration of vapour will be accelerated by the breathing effect. Breathing effect in this context is the exchange of air between a hollow space and its surroundings produced by changes of temperature.

3.2 Condensation occurs on an equipment when introduced into a test chamber if its surface temperature is lower than the dew point temperature of the chamber air. It is, therefore, preferable to preheat the equipment if condensation is to be avoided. When condensation is wanted on an equipment during the conditioning period, the temperature and the relative humidity of air should rise so fast that a difference between dew point temperature and surface temperature is achieved.

3.3 If the equipment has low thermal time constant, condensation occurs only if the temperature of the air increases very rapidly or if the relative humidity is very close to 100 percent. With the rate of rise of temperature prescribed for this test, condensation may not occur on very small equipment.

3.4 A proven method to determine the tightness of joints or to detect hairline cracks is to apply one or more temperature cycles. The desired effect may be made more stringent when the rapid temperature cycling test is applied immediately after the damp heat test or when a damp heat test is conducted immediately after a cold test.

4. TEST PROCEDURE

4.1 This is only the test procedure which shall be applied whenever the test is included in the test sequence.

4.2 The test duration of 16 hours at the elevated temperature of 40 ^{o} C is intended as a test for the short term effect of high humidity on equipments.

4.3 The equipment shall be kept in `Switched Off' condition throughout the test except in the last 30 minutes of the 16 hours period. Generally a `Switch ON' or `Start up' procedure would be applicable during the last 30 minutes. Excessive operation of the equipment should be avoided as it generates heat and this could mitigate the effects of this test. If this is required to demonstrate survival only, the equipment should be operated and a performance check carried out when the temperature and relative humidity has been reduced to standard recovery conditions.

SUB SECTION 5.12

DRIVING RAIN

1. GENERAL

1.1 This test is intended to demonstrate the effectiveness of protective covers or cases to enable equipments to remain operational during or subsequent to exposure to driving rain.

2. TEST PROCEDURE

2.1 Three test conditions have been specified for this test. The relevant equipment specification may choose one of these conditions for the test. The spraying intensity specified in clause 2.3 of the test is representative of the heaviest rainfall which may persist for more than a very brief period, possibly up to one hour.

2.2 Heavy rain falls at about 45 Deg to the vertical in winds of 25 to 30km/hr. If an equipment is liable to experience heavy rain fall in strong winds or it is moved at high speeds against heavy rain fall in strong winds, then, it is also likely to receive rain horizontally against its sides. Therefore, unless otherwise specified in the relevant equipment specification, Test Conditions `C' is recommended.

2.3 Prior to the starting of test, sockets, terminal boxes, pipe entries etc. in the equipment are to be protected by fitting either the normal connectors, cables, pipes etc. or equivalent sealing blanks. Where applicable, doors and covers shall be opened and closed or removed and replaced a few times immediately before testing.

SUB SECTION 5.13

DROP

1. GENERAL

1.1 This test is applied to equipments to demonstrate their ability to withstand impacts resulting from dropping, handling and use.

1.2 It is neither realistic nor economical to expect all equipments to survive the most severe mishandling which can be encountered in service, e.g. dropping from a vehicle loading platform or from a crane suspension. For tests on equipment where the criteria is one of serviceability, the drop height should be selected taking into account the risk of occurrence, the tolerable level of damage and the conditions of use, transportation and storage.

1.3 An unpacked equipment is at risk to handling hazards depending upon the type of equipment and its deployment. Man packed and portable field equipments are particularly vulnerable and are at risk to drops from heights up to that of the carrying positions or of their tail board of a supply vehicle. In general, the drop hazard associated with unpackaged equipment described above is likely to be in the range of 25mm to 1000 mm. Field unit stores and first line test gear have a lower probability of severe manhandling and the test level should be selected from the lower end of the range. When considering the test severity and attitudes of drop, due regard should be paid to the risk of occurrence in relation to the cost and weight implications on equipment design.

SUB SECTION 5.14

DUST

1. GENERAL

1.1 Dust is generally defined as a particulate matter of particle size up to 150/um. The particle size is the apparent maximum linear dimension (or diameter) of the particle.

1.2 Dust is air-borne in the wind. The amount of dust suspended in the air depends on the strength of the wind and on the size, shape and weight of the particles. Dust can precipitate on the surfaces of electronic and electrical equipments and further penetrate into them.

1.3 The precipitation of dust can occur in a number of ways as follows :

a) by sedimentation in stagnant air.

b) by impact of winds on a facing surface - If some of the wind borne particles are liquid or sticky or if the surface is sticky, the dust will be deposited on the surface.

c) By attraction by electrostatic forces - when dust is generated by wear from electrically insulating materials, the particles become strongly electrically charged and precipitate on the surfaces.

d) by trapping in narrow openings such as grills.

1.4 The penetration of dust into equipments can occur in a number of ways as follows:

a) by forced circulation of air used for cooling.

b) by air that is activated by wind.

c) by the thermal motion of the air.

d) by air entering the equipment because of thermal expansion or variation in the atmospheric pressure.

2. EFFECT OF DUST

2.1 The presence of dust between moving parts can cause friction, clogging and misalignment. It can also cause abrasion of moving parts. It can change the electrical insulation of insulating materials thereby changing their dielectric properties. It can cause electrical short circuits. Due to its disposition on heat generating components, it can cause thermal insulation and consequent overheating. It can also cause electrical interference, corrosion etc.

3. TEST PROCEDURE

3.1 Only one test procedure is specified and the duration of test is one hour.

4. PERFORMANCE EVALUATION

4.1 The effect of dust on equipment is not often readily demonstrated. Dust is not self cleaning (unlike moisture which may evaporate) and tends to cling to surfaces and accumulate. It may absorb moisture resulting in the formation of corrosive electrolytes and also promote biological action, both of which are long term effects. A thin layer of dry dust may not immediately affect equipment operation. Switching problems can be experienced under these conditions which are difficult to visually check for and remove as electrical insulation may not be affected. Damp dust, however, may seriously lower insulating properties but less seriously interfere with switching. When visual examination is carried out, it should be very thorough with particular attention to noting any accumulated dust or entry into enclosures protecting sensitive equipment, which subsequently could be hazardous.

4.2 When survival only is to be demonstrated, the equipment should be allowed to return to standard atmospheric conditions and then cleaned and examined visually. A performance check shall then be made.

4.3 If performance is to be demonstrated, the equipment should be non-functioning during the early part of the conditioning and functioning during the remainder. Assessment of the lengths of the period of operation will depend on whether operation assists accumulation/entry of dust or inhibits it. The equipment in the non-operating state shall be returned to the standard atmospheric conditions and then subjected to a visual examination and performance check.

4.4 When the equipment has a ventilation or cooling system, especially air ducting or fan, the functional period should be extended until the equipment temperature stabilizes.

4.5 SUB SECTION 5.16

FINE MIST

1. GENERAL

1.1 This test is intended to determine satisfactory protection of equipments against ingress of mist or satisfactory operation in the presence of mist.

1.2 This test applies to equipments which have to operate in the open or in partially protected enclosures which will be liable to expose to mist which may collect on exposed surface or enter such enclosures.

2. TEST EQUIPMENT

2.1 A suitable enclosure for conducting this test can be a salt spray chamber described in Test No.9 (Corrosion, Salt) except that tap water is used to produce the mist. This chamber may be adequate for testing small equipments.

2.2 When an equipment is too large to be accommodated in salt spray chamber, the enclosure in which the equipment is tested should be equipped with sufficient number or atomisers to maintain a dense mist. The atomisers should be located with due regard to the geometry of the equipment and directed into the surrounding air. Where necessary, shielding should be interposed to avoid direct spraying on the equipment. Water droplets should not be allowed to fall on to the equipment under test.

2.3 The chamber/enclosure may need to be vented to prevent pressure increase inside the same. The vent may be fitted with a filter to prevent the mist from escaping from the chamber.

3. CONDITIONING

3.1 While preparing the equipment for subjecting to this test, any entries not used in the normal usage of the equipment are to be protected by suitable scaling blanks.

3.2 If it is only required to demonstrate the survival of the equipment, a performance check and visual inspection may be required either immediately after the test or after a specified recovery period. Visual inspection should normally be carried out after the performance check to avoid disturbing any moisture or water which may have collected on or in the equipment.

SUB SECTION 5.17

HIGH TEMPERATURE

1. GENERAL

1.1 High temperature test covers six procedures. Guidance on application of these procedures is given below.

2. AIRBORNE EQUIPMENT

2.1 Procedures 1 to 4 are intended for airborne equipment. Guidance on application of these procedures is given in Sub Section 5.20. (AIRBORNE EQUIPMENT - TEMPERATURE PRESSURE REQUIREMENTS).

3. GROUND AND SHIPBORNE EQUIPMENT

3.1 Procedure 5 and 6 are intended for ground and shipborne equipment.

3.2 **Procedure 5**

3.2.1 This procedure covers the maximum temperature conditions under which the ground and ship borne equipments are likely to operate. Three levels of temperature are specified in this procedure. Test condition G specifies 55^{o} C, test condition H specifies $70\ ^{o}$ C and test condition J specifies $85\ ^{o}$ C.

3.2.2 Generally, test condition G is applicable to ground and naval equipment which are not heated by direct solar radiation.

3.2.3 The conditions H and J are applicable to ground and naval equipments which operate under confined enclosures which have no ventilation and which are close to heat sources like engines etc. These are also applicable to equipments which operate in exposed conditions receiving direct solar radiation, when the temperature rise on the equipment is known.

> Note - If the temperature rise is not known under such condition, the equipment may be subjected to the solar radiation test (Test Number 25) separately.

3.3 **Procedure 6**

3.3.1 This procedure which is an alternative to procedure 5 covers the maximum temperature conditions for both operation and storage in hot confined enclosures. Two test condition are specified as follows.

a) Test conditions K : Operation at 55° C followed by storage at 70° C.

b) Test condition M : Operation at 55° C followed by storage at 85° C

3.3.2 Test condition M is applicable to ground and naval equipments which are stored under conditions where they are exposed to surface heating by direct solar radiation raising the temperature of the equipment to approximately 85° C. In all other test condition K shall be applicable.

3.4 **Duration**

3.4.1 A duration of 16 hours has been specified. This duration intended for applications where temperature is sustained for sufficient period to permit thermal stabilisation within the equipment. It also ensures that the performance or survival capability of equipment is demonstrated only after internal temperatures have stabilised at the test level.

3.4.2 However, for application where the duration of the high temperature conditions is of limited period, such that the equipment will not achieve the thermal stabilisation, the Design Authority may state in the relevant equipment specification a different duration (which is related to the known or anticipated use condition).

3.5 **Performance Evaluation**

3.5.1 Equipment should be operated at the appropriate phase of the test to produce the highest internal temperature level representative of operational and use environment conditions.

3.5.2 For non-heat dissipating equipment a demonstration of performance can generally be acceptable, if carried out immediately following the specified duration at the required test level (here operation of equipment during the test condition may not be significant).

3.5.3 In case of heat dissipating equipment, operation should be representative of the most adverse duty cycle or where there is no defined duty cycle, should continue for a period to allow internal temperature (s) to restabilise at their highest level. In general, one or more of the following procedures may apply:

a) Continuous operation throughout the test with performance evaluation made at significant phases of the test (for example, immediately after the operation commences and towards the end of the operating phase).

b) Operation commencing only when the equipment has stabilised at the test temperature and performance evaluation made immediately following the start of the operating phase and/or after internal temperatures have restabilised.

c) Operating as in (a) and (b) above, but with operation interrupted for a short period (several minutes) after internal temperatures have attained their maximum level to simulate a "hot switch on".

d) For demonstrating survival only, the equipment should be operated and a performance evaluation should be made when the temperature has returned to standard/laboratory atmospheric conditions.

3.6 **Surface Temperatures** - Unless the relevant equipment specification states that it is not required, and assessment is to be made of maximum temperatures obtained during the test on the surfaces of all components and materials within the equipment. Maximum permissible surface temperatures should normally be quoted in the relevant equipment specification. Two methods of assessment of surface temperature are given here. These methods are in general use but do not exclude temperature measurements made by other reliable means; it is important only to know that surface or body temperatures of components and materials do not exceed their safe limits.

3.6.1 The two methods commonly used for measuring, or assessing the surface temperatures of components (or materials) employ:

a) Temperature indicating lacquers and crayons, and

b) Thermocouples.

3.6.2 Each method has its advantages and disadvantages and the choice of a particular method is dependent upon the type of information required and is at the discretion of the responsible authority.

3.6.3 It is recommended that every component in an equipment should be assessed at least in the initial tests.

3.6.4 Temperature Indicating Lacquers and Crayons

3.6.4.1 Temperature indicating lacquers and crayons are of two kinds, those which change colour at a specified temperature and those which melt at a specified temperature. The former at present are not entirely satisfactory as the indication is dependent upon time as well as temperature. The latter can be obtained for temperatures within the range 45° C to 800° C with claimed indicating accuracy of about $\pm$ 1 percent.

3.6.4.2 The appropriate lacquers or crayons are applied to each component to indicate at the component's limit temperature. Each lacquer or crayon should be applied as a spot which should be as small as possible consistent with obtaining a positive indication. Large component should be marked at a number of points as surface temperature gradients may readily occur. Adjacent heat sources must be considered for each component as these may cause local increase of surface temperature. Components whose limit temperatures may vary at different points of their surface must be treated by a number of lacquers or crayons to give appropriate indications.

3.6.4.3 It will be seen that the test as applied above, is in the nature of a GO/NO-GO test. Additional information about the actual temperatures realized at the surfaces of components may be obtained by the application of additional lacquers or crayons indicating above and below component limit surface temperature.

3.6.5 Thermocouples

3.6.5.1 The thermocouple wire should be as small as practicable (wires of diameter 0.193 to 0.376 mm are in fairly common use) and it is important that good quality wires are used. They can usually be supplied in bulk with a temperature coefficient to suit the recorder in use.

3.6.5.2 It is essential that the thermocouple be held, or bonded, in intimate contact with the surface to be measured. It may also be necessary to insulate the couple from metallic surfaces to avoid instrument error due to stray pick up currents.

3.6.5.3 Care should be exercised in positioning the thermocouples and wires so that they neither materially effect the temperature gradients within the equipment or create instability in their proximity to RF circuits .

3.6.5.4 It will be seen that this method enables the actual surface temperatures to be continuously monitored or recorded.

SUB SECTION 5.18

ICING

1. GENERAL

1.1 Various icing conditions which may affect performance of the equipment are :

a) Ice or Frost adhesing to the equipment.

b) The effect of refrozen water from molten ice or from condensation.

1.2 Three procedures have been covered in the Icing test described in Section 4. The guidance on application of these procedures is given below:

2. Procedure 1

2.1 The test is applicable to equipment in which there is movement of parts, for example electrical contacts contained within a non-sealed enclosure into which moist air may penetrate and where the equipment is so located and its duty cycle is such that the temperature of the equipment could vary during flight and on the ground within limits that would produce conditions of both condensation and freezing.

3. Procedure 2

3.1 This test is applicable to all equipment in which there is movement of parts and where such movement could be prevented or impeded by Ice forming as a result of progressive accumulation of water inside non-sealed enclosures where positive drainage is not provided.

4. Procedure 3.

4.1 This test is applicable to items mounted externally or in non-temperature controlled bays where there is a real risk of accretion of free water which would subsequently freeze on the cold surface of the items. The test is intended to examine the effects of a representative thickness of ice on the performance of the items or to determine the maximum thickness that can be permitted before de-icing action is necessary.

SUB SECTION 5.19

IMMERSION

1. GENERAL

1.1 This test is intended to determine the capability of equipment to survive immersion in water.

2. TEST PROCEDURE

2.1 Any entries in the equipment not used shall be protected by suitable sealing blanks .

2.2. During immersion, the equipment is to be kept in the specified attitude. If it floats, or tends to float, it is to be fixed down firmly.

2.3 The test severity is defined by the depth of immersion (or corresponding excess pressure) and the duration of immersion. There are 9 test conditions with different depths of immersion (or the corresponding excess pressures). The duration of test for all the test conditions is 2 hours. The choice of severity must depend upon the technical aspects of user requirements and careful consideration of the operational role of the equipment in order to avoid either undertesting or overtesting.

2.4 The depths (or excess pressures) specified in the 9 test conditions represent a wide range of operational hazards varying from deep puddles to submarine operating depths. Immersion in fresh water is normally sufficient to prove the sealing qualities of equipment. Immersion in sea water need only be specified if this is both a service requirement and a particular functional hazard.

2.5 Equipment should be immersed in the most adverse attitude or position which might occur in service. It should not be operated during immersion unless designed for such an operational role. For equipment which is specified to be operational under water, the most severe procedure is for the equipment to be non- functioning during the first hour's immersion and to be functioning during the second hour.

2.6 The equivalent depth of sea water is 0.975 times the depth of fresh water for the same excess pressure.

SUB SECTION 5.20

LOW TEMPERATURE AND PRESSURE REQUIREMENTS

1. AIRBORNE EQUIPMENT

1.1 Guidance on Procedures 1 to 3 of low temperature test (Test Number 20), procedures 1 to 4 of altitude test (Test Number 3) and procedures 1 to 4 of high temperature test (Test Number 17) is given in this sub section.

1.2 Although low temperature, high temperature and altitude tests have been described separately in Section 4, the guidance on these have been combined for Airborne equipment under "temperature- pressure requirements" to present a more realistic picture. Various procedures have also been related to the different conditions encountered by the aircrafts, for example, procedure 1 of low temperature test has been referred here as low temperature `ground survival test'

2. FIELD OF APPLICATION

2.1 The tests described (see clause 1.1 above) are intended to apply to equipment for general aircraft use, these may also be useful for application to equipment designed for use in specific aircraft. In such cases the relevant equipment specification should state what additional tests or amendments to these standard tests are necessary to meet precise requirements, for example in case of transonic or high performance aircraft having a short- term high performance speed capability, the conditions and duration of high temperature test (procedure 4) and/or altitude test (procedure 3 and/or 4) may not be adequate and may need to be supplemented.

2.2 Not all the test listed are necessarily applicable to a particular equipment (for example, the low altitude high speed flight condition: procedure 4 of high temperature test).

2.3 Further more, although the tests are described here in the sequence (see Table 3-1 also) considered to be most practical and logical, it may not be ideal for a particular test programme. In these circumstances the relevant equipment specification should select from this standard the appropriate tests and state the sequence in which the tests are to be applied.

3. DEFINITIONS

3.1 For the purpose of this sub section (including low temperature, high temperature and altitude tests) the following definitions apply:

3.1.1 **Idle** - Isolated from the source or sources of power.

3.1.2 **Operate** - To cause an equipment to carry out some or all of the services and functions (as stated in relevant equipment specification) for which it is intended.

3.1.3 **Performance** - The demonstration in quantitative terms of the function(s) of an equipment to defined requirements.

4. CLASSIFICATION AND GRADING

4.0 For the purpose of this sub section the environmental tests applicable to equipment shall be guided as below; a completed description of the environmental tests require the main grade identification letter with suffix numeral (for example, C.3). Tables 5.20-1 and 5.20-2 state the environmental test parameters for each grade.

4.1 **Aircraft Classification** - The classes of aircraft specified in this sub section are as follows:

4.1.1 **Class 1: Rotorcraft and Low-Performance Aircraft** - This class includes all low-performance aircraft, such as helicopters, `club' aircraft, piston - engined executive aircraft and in general, all unpressurized aircraft with nominal ceiling of 6100m. It is probable that these aircraft will use outside air for cooling and having a simple heating system using waste engine heat.

4.1.2 **Class II: Subsonic Aircraft** - This class includes most passenger civil aircraft, flying up to speeds of Mach 0.95, and having ceilings of 15220 m. Certain compartments will be pressurized and/or provided with heating and cooling systems.

> Note - Procedure 4 of high temperature test is a special test that has been included for military aircraft that have low-level speeds up to about mach 0.95, although remaining subsonic at altitude. The reason for this special test is that the high temperature experienced at low level will not be encountered by high-altitude civil aircraft.

4.1.3 **Class III: Transonic Aircraft** - This class is primarily for military aircraft with maximum speed up to Mach 1.3 and altitudes up to 18300m but with low altitude speeds not greater than 1300 km/h (that is, Mach 1.06 at sea- level).

Note - Procedure 3 of altitude test has been introduced to this class of aircraft because the combination of flight temperature and air density can be a hazard not covered by the conditions of procedure 4 of High temperature test and procedure 4 of Altitude test.

4.1.4 **Class IV: Supersonic or High-Performance Aircraft** - This class includes all high performance aircraft, but for purpose of this standard is restricted to aircraft having in the main, light alloy airframes, the temperature limit of which is considered to provide a convenient boundary. This limit is taken as a temperature of 150°C and represents Mach numbers up to about 2.2 in cool ambient conditions. Short bursts of high speed may occur, but only equipment of low thermal capacity will be affected. Maximum low-altitude speed will be about 1500 km/h (that is, Mach 1.2 at sea-level) but for economic cruising Mach numbers of 0.9 and 0.95 would be more common. The maximum altitude is likely to be 21,300 m with minimum cruising speeds of Mach 0.7 to 0.9.

Note - For aircraft having a performance outside the maximum speeds indicated for class IV, there is insufficient evidence at present to give detailed temperature environments. Such aircraft would have airframes of heat - resisting material. However. it is not likely that temperature-and pressure-controlled zones will differ from Class IV. For unconditioned bays the temperature will depend upon the degree of insulation and flight time. For externally mounted equipment and for equipment in uninsulated bays temperatures will be of the following order.

Mach Number	**Temperatur-e**
2.5	185°C
3.0	290°C
3.5	415°C

This information is offered for guidance; the aircraft manufacturer should be consulted for more details.

4.2 Equipment Grading

4.2.1 Civil Grades

Grade A- Equipment mounted in the temperature controlled and pressurized region of Class II or IV aircraft, with pressure not lower than that corresponding to an altitude of 3000 m.

Grade B- Equipment in the temperature controlled by unpressurized region of a Class I aircraft.

Grade C- Equipment in the temperature controlled but unpressurized region of Class II aircraft.

Grade D- Equipment in the temperature controlled but unpressurized region of Class IV aircraft.

Grade E- Equipment in non-temperature controlled and unpressurized regions and in externally exposed locations of Class II aircraft.

Grade F- Equipment in non-temperature controlled and unpressurized regions and in externally exposed locations of Class I aircraft

Grade G- Equipment in non temperature controlled and unpressurized regions and in externally exposed locations of Class IV aircraft.

Grade H- Equipment located in the engine bay of a Class I aircraft .

Grade J- Equipment located in the engine bay of a Class II aircraft .

Grade K- Equipment located in the engine bay of a Class IV aircraft.

4.2.2 **Military Grades**

Grade Q- Equipment mounted in the temperature controlled and pressurized region of Classes II, III and IV aircraft, with pressure not lower than that corresponding to an altitude of 9100 m.

Grade R- Equipment in the temperature controlled but unpressurized region of a Class III, aircraft.

Grade S- Equipment in the temperature controlled but unpressurized region of a Class IV aircraft, but having prolonged capability of high performance flying at low or intermediate altitudes.

Grade T- Equipment in non-temperature controlled and unpressurized regions and in externally exposed locations of Class II aircraft, but having capability for prolonged high-speed flight at low altitudes.

Grade U- Equipment in non-temperature controlled and unpressurized regions and in externally exposed locations of Class III aircraft, but having capability for prolonged high speed flight at low and intermediate altitudes.

Grade V Equipment in non-temperature controlled and unpressurised regions and in externally exposed locations of Class IV aircraft, but having capability for prolonged high speed flight at low and intermediate altitudes.

Grade W- Equipment located in the engine bay of a Class III aircraft.

4.2.3 **Grade Suffix**

Grade 1 Equipment installed in aircraft intended for world wide use and with the equipment located in the aircraft such that when deployed in tropical regions the equipment would be significantly influenced by solar radiation (see Note).

Grade 2 Equipment installed in aircraft intended for world wide use and with the equipment located in the aircraft such that when deployed in tropical regions the equipment would be largely protected from the direct influence of solar radiation.

Grade 3 Equipment installed in aircraft intended for world wide use but excluding arctic regions and with the equipment located in the aircraft such that when deployed in tropical regions the equipment would be significantly influenced by solar radiation (see Note).

Grade 4 Equipment installed in aircraft intended for world wide use but excluding arctic regions and with the equipment located in the aircraft such that when deployed in topical regions the equipment would be largely protected from the direct influence of solar radiation.

Note - Equipment mounted outside the aircraft, in small enclosed aircraft zones under canopies, in pods not shaded from the sun.

5. EQUIPMENT TEMPERATURE

5.1 Where practicable during all high temperature tests, temperature sensors should be fitted to all components and assemblies that are known to be near their limiting temperatures. The temperatures at these locations should be monitored and recorded throughout each test.

6. TEMPERATURE STABILIZATION

6.1 As in clause 3.10 of Section 1.

7. AMBIENT TEMPERATURE

7.1 The ambient temperature specified in the following tests for heat-dissipating equipment may be determined in either of the following ways:

7.1.1. By measuring the test chamber temperature using a sensor located upstream of the equipment in an airflow having a velocity not exceeding 1 m/s.

7.1.2. By determining a temperature which is based upon the surface temperature of a specified part of the equipment under test.

8. MOUNTING OF EQUIPMENT IN TEST CHAMBER

8.1 The mounting of the equipment in the test chamber shall simulate as closely as practicable the installation arrangement existing in normal use, unnatural structural frames, abnormal orientation, unnatural thermal screening, etc., can all influence the behaviour of the equipment under test and these effects should be minimized .

8.2 Where equipment is supplied with cooling air care should be taken to ensure that the chamber conditions are not adversely affected.

9. SUPPLIES

9.1 In all tests, supplies and services (electrical power, air supplies, hydraulics, etc.) should where possible, be derived from or simulated by sources representative of those provided in operational use. The relevant equipment specification should state the supplies and services necessary. During each test, supply and input parameters should be adjusted as stated in the relevant equipment specification (usually to the limit of their tolerance so that they put the equipment at its greatest operational disadvantage).

10. INITIAL MEASUREMENTS

10.1 Where practicable these measurements shall be made when the equipment has been set up in the chamber ready for test.

11. PERFORMANCE CHECKS

11.1 A performance check shall be conducted as specified in the relevant equipment specification during and/or after each environmental procedure. A performance check includes a functional test on the equipment and a visual inspection to assess structural condition, or the development of any potentially damaging influences.

12. TESTS

12.1 The appropriate climatic conditions for an equipment shall be selected from Tables 5.28-1 and 5.28-2. The tests shall be applied in the order given, unless otherwise stated in the relevant equipment specification.

12.1.2 Low Temperature Tests- The temperature conditions for procedures 1,2 and 3 given in Tables 5.20-1 and 5.20-2 are ground conditions applicable to all aircraft types, but in procedure 1 of altitude test the level given for the uncontrolled temperature zones allow for the minimum temperature rise due to kinetic heating. In procedure 1 low temperature test temperature requirement for Grades A,B,C,D,Q,R and S is an arbitrary level selected as the lowest long term temperature likely to occur in a semi-stagnant area within temperature controlled regions (for example, the space behind an electronic equipment).

12.1.3 **Ground Survival (Procedure 1 Low Temperature Test)**

12.1.4 This test is applicable to all equipment irrespective of aircraft type and the lowest ground temperature experienced by aircraft in cold climates. The temperature specified should be considered applicable to all equipment irrespective of region, since an aircraft may be idle on the ground long enough to allow thermal stabilization.

12.1.5 Equipment is not normally expected to be capable of operation at these temperatures; but to survive themselves without damage.

12.1.6 The lowest temperature of -60°C applies to aircraft operating into and from arctic areas; the -40°C conditioning represents deployment into areas less severe than Arctic.

12.2 **Ground Operation (Procedure 2 and 3 Low Temperature Test)**

12.2.1 This test simulates the low temperature conditions under which an equipment may be required to be switched-on or started up and/or operated. For equipment grades A,B,C,D,Q,R and S (stated in Table 5.20-1 and 5.20-2) this condition would persist for a short period until the aircraft temperature conditioning plant become effective; for these grades of equipment, the long-term operating conditions of procedure 3 should be preceded by the short-term switch-on or start up and operate of procedure 2.

12.2.2 A successful demonstration of performance under procedure 2 may obviate the need to apply procedure 3 since they are more arduous conditions. For equipment Grades A,B,C,D,Q,R and S, however, it is expected that for procedure 2 warm-up period may be allowed, whereas for procedure 3 the warm-up period would be minimal. Although the equipment may have satisfied procedure 2, a demonstration of performance with a short warm-up period may be necessary to satisfy procedure 3.

12.2.3 For equipment in regions not temperature controlled, the lowest operating temperatures apply throughout the test.

12.2.4 As in the survival test –55^{o}C applies to Arctic deployment, and –40^{o}C to deployment in areas less severe than Arctic.

12.3 **Flight Operation (Procedure 1 Altitude Test)**

12.3.1 This test simulates the lowest operational temperature that is likely to occur under flight conditions up to maximum altitude.

12.3.2 Although the test simulates a realistic flight condition, it need not necessarily be applied in all cases, for example, where the low temperature conditioning is adequately covered by low temperature test (procedure 2 and 3) and the effects of altitude can be ignored. The test shall be applied, however, if it is to be followed by altitude test procedure 2 (Method A or B).

12.3.3 The test is essential where the effects of a pressure differential could accentuate potential defects arising from low temperature, as in a sealed equipment, although in equipment of this type it may be permitted to simulate the pressure differential if the failure mechanisms are known by applying a positive internal pressure within the equipment.

12.4 **Temperature/Humidity Sequence**

12.4.1 **Procedure 3 (Altitude Test)**

12.4.2 This test simulates the moisture breathing/condensation problems arising when an aircraft descends from a cold atmosphere. The resulting surface moisture may be significant in electrical circuits, and in partially closed equipment when the condensation and breathing effect produces a build-up of free water inside the equipment.

12.4.3 It should be noted that this test may not necessarily reveal defects arising from prolonged exposure to a tropical damp environment; in such instances the tropical exposure test (Test Number 27) shall be applied.

12.4.4 When local ice formation may be hazard (for example, through the failure of normally open contacts to close a circuit when required to do so) reference should be made to the icing test.

12.4.5 The appropriate test method shall be selected from the following and shall be stated in the relevant specification:

a) Method A- Applies to equipments whose performance could be immediately and adversely affected by moisture condensation. The method is particularly applicable to equipment of an enclosed or partially sealed construction, where the pressure change due to altitude arising from one flight descent phase could induce the ingress of moisture.

b) Method B- Applies to equipments for enclosed or partially sealed construction where the cumulative effects of condensation over a number of flight descents would be needed to adversely affect the performance of the equipment .

c) Method C - Applies to equipment of open construction whose performance could immediately and adversely be affected by moisture condensation, but where the pressure changes due to altitude would be of little significance.

12.5 **High Temperature Ground Conditions**

12.5.1 **Ground Survival (Procedure 1 High Temperature Test)**

12.5.2 The test is applicable to all aircraft irrespective of classification and simulates the maximum temperature likely to arise in an aircraft in a hot, dry, tropical climate. It may also be used to simulate the temperature conditions that may arise when the equipment is removed from the aircraft and exposed to direct solar radiation.

12.5.3 The equipment is not required to operate during this test but merely to survive without damage.

12.5.4 The test conditions have been selected as being applicable to the majority of equipments although the temperature of equipment located in a shielded area of aircraft may be lower.

12.6 **Ground Operation (Short Term) (Procedure 2 High Temperature Test)**

12.6.1 This test simulates the maximum temperature conditions in which an equipment could be operated, for example, immediately following a ground soak condition as simulated by procedure 1. It is expected that these temperature conditions would be of short duration, since the atmosphere inside the aircraft would be disturbed by opening canopies, circulation of cooling air, etc. The test requires that the equipment be capable of being operated for a short period.

12.6.2 Two levels of temperature are given : 85^{o} C applies to those regions that are exposed to direct solar radiation, for example, equipment mounted outside the aircraft, in small enclosed aircraft region, under canopies, in unprotected pods, etc. The 70^{o} C applies to all other aircraft zones not directly heated by solar radiation.

12.6.3 **Ground Operation (long term) (Procedure 3 High Temperature Test)**

12.6.4 This test condition represents the maximum temperature on the ground in which equipment could be operated for long periods, and is intended to immediately follow procedure 2 to simulate ground servicing and flight preparation.

12.6.5 The two levels of temperature stated in Tables 5.20.1 and 5.20.2 relate to the sub-divisions defined in clause 12.3.2.2 above.

12.7 **High Temperature - Flight**

12.7.1 The levels given for equipment Grades A,B,C,D,Q, R and S in Tables 5.20-1 and 5.20-2 are derived on an arbitrary basis and are estimated to be the maximum levels that could occur in semi-stagnant areas within the particular temperature controlled region (for example, in an enclosed space behind an electronic unit).

12.7.2 **Low Altitude (Procedure 4 High Temperature Test) -** This test simulates conditions occurring in an aircraft having a capability of near sonic speeds at altitudes close to ground level. The requirement for this special test becomes significant only in aircraft having this capability and should be applied selectively. In all other aircraft the ground operating conditions would adequately cover the low-altitude flight case .

12.7.3 **Intermediate Altitude (Procedure 3 Altitude Test)** - The temperature gradients within an equipment dissipating self heat are largely influenced by the combination of ambient temperature and air pressure. In some cases intermediate altitudes may produce a more adverse thermal condition than that existing at ceiling altitudes. In such instances the intermediate altitude test should be used.

12.7.4 **High Altitude (Procedure 4 Altitude Test)** - This test conditioning simulates the temperature/ altitude combination at the ceiling of the particular class of aircraft.

TABLE 5.20-1 TEMPERATURE AND PRESSURE PARAMETERS FOR EQUIPMENT ON CIVIL AIRCRAFT

EQUIPMENT	GROUND SURVIVAL PROCEDURE 1 1/	GROUND OPERATION (SWITCH ON) PROCEDURE 2 1/	GROUND OPERATION (LONG TERM) PROCEDURE 3 1/	FLIGHT OPERATION PROCEDURE 1 2/	TEMPERATURE HUMIDITY SEQUENCE FLIGHT PROCEDURE 2 2/	GROUND SURVIVAL PROCEDURE 1 3/	GROUND SURVIVAL (SHORT TERM) PROCEDURE 2 3/	GROUND SURVIVAL (LONG TERM) PROCEDURE 3 3/	LOW ALTITUDE PROCEDURE 4 3/	INTERMEDIATE ALTITUDE PROCEDURE 3 2/	HIGH ALTITUDE PROCEDURE 2/
	Low Temperature				High Temperature				High Temperature Fligh		
-1	-60ºC	-55ºC	-55ºC 4/			85ºC	85ºC	70ºC			
-2	-60ºC	-55ºC	-55ºC 4			85ºC	70ºC	55ºC			
-3	-40ºC	-40ºC	-40ºC 4			85ºC	85ºC	70ºC			
-4	-40ºC	-40ºC	-40ºC 4			85ºC	70ºC	55ºC			
A			-20ºC	-20ºC 3000m	From procedure 2/ conditions changed to 30ºC at r.h. > 95 per cent at sea level by method A B or C						40º 300
B			-20ºC	-20ºC 6100m							40º 610
C			-20ºC	-20ºC 15200m							40º 1520
D			-20ºC	-20ºC 21300m							55º 2130
E				-55ºC 6100mm							5º 610
F				-55ºC 15200mm							10º 1520
G				-55ºC 21300mm							15º 2130
H				-55ºC 6100mm							
J				-55ºC 15200mm						See Note 7/ re en bays	
K				-55ºC 21300mm							

TABLE 5.20-2 TEMPERATURE AND PRESSURE PARAMETERS FOR EQUIPMENT ON MILITARY AIRCRAFT

EQUIPMENT	GROUND SURVIVAL PROCEDURE 1 1/	GROUND OPERATION (SWITCH ON) PROCEDURE 2 1/	GROUND OPERATION (LONG TERM) PROCEDURE 3 1/	FLIGHT OPERATION PROCEDURE 1 2/	TEMPERATURE HUMIDITY SEQUENCE FLIGHT PROCEDURE 2 2/	GROUND SURVIVAL PROCEDURE 1 3/	GROUND SURVIVAL (SHORT TERM) PROCEDURE 2 3/	GROUND SURVIVAL (LONG TERM) PROCEDURE 3 3/	LOW ALTITUDE PROCEDURE 4 3/	INTERMEDIATE ALTITUDE PROCEDURE 3 2/	HIGH ALTITUDE PROCEDURE 2/
	Low Temperature				High Temperature				High Temperature Fligh		
-1	-60ºC	-55ºC	-55ºC5/			85ºC	85ºC	70ºC			
-2	-60ºC	-55ºC	-55ºC5			85ºC	70ºC	55ºC			
-3	-40ºC	-40ºC	-40ºC5			85ºC	85ºC	70ºC			
-4	-40ºC	-40ºC	-40ºC5			85ºC	70ºC	55ºC			
Q			-20ºC	-20ºC 9100m	As in Table 5.20.1						40º 910
R			-20ºC	-20ºC 18000m					70ºC 9/	55ºC 6100m	40ºC 183
S			-20ºC	-20ºC 21300m					70ºC 9/	55ºC 9100m	55º 2130
T				-55ºC 15200m					100ºC	--	10ºC 1520
U				-55ºC 18300mm					100ºC 9/	35ºC 6100m	40ºC 1830
V				-55ºC 21300mm					100ºC 9/	150ºC 9100m	150 2130
W				-55ºC 18300mm						See Note 7/ re-engine bays	

Notes to Table 5.20-1 and 5.20-2

1/ Low temperature test.
2/ Altitude test
3/ high temperature test
4/ Excepts grades A to D equipment.
5/ Excepts grades Q to S equipment.
6/ The temperature for equipment, located within the air-frame do not take account of any temperature rise that may result from heat generated in adjacent equipment
7/ The conditions may vary widely depending upon the precise location of the equipment relative to the engine shroud the requirements for these areas should be resolved in conjunction with the aircraft and engine manufacturers.
8/ The conditions are related to aircraft speeds of Mach 0.95.

9/ These conditions relate to the long-term flight capability of transonic aircraft. In aircraft capable of short-term high-speed bursts, short-period temperature overshoots in excess of the levels given may occur. These should be resolved with the aircraft manufacturer.

10/ The temperature level is based on an ambient condition of -40°C (the highest temperature on 5 days per year probability basis at altitude above 10,700 m) and an aircraft speed of Mach 1.3.

13. GROUND AND SHIPBORNE EQUIPMENT

13.1 Procedure 4 of low temperature test (Test Number 20) is intended for ground and ship borne equipment. It covers the minimum temperature conditions under which the ground and ship borne equipments are likely to operate.

13.2 TEST CONDITIONS

13.2.1 Four levels of temperatures have been specified.

Test condition H : -10° C

Test condition J : -20° C

Test condition K : -30° C

Test condition L : -40° C

13.2.2 Test conditions H, J and K are applicable to ground equipment and test conditions L is applicable to ship borne equipment.

13.2.3 In case of ground equipment, if the equipment is intended for operation in temperature and tropical conditions, test condition H or J applies, and if the equipment is intended for the extreme cold range, test condition K applies.

SUB SECTION 5.23

SEALING

1. GENERAL

1.1 Five procedures have been covered in the sealing test described in Section 4. The guidance on application of these procedures is given below.

2. AIRBORNE EQUIPMENT

2.1 Procedures 3,4 and 5 are intended for airborne equipment.

2.2 **Procedure 3 - Excess Pressure Test**

2.2.1 This test is applicable to equipment mounted within the pressurized zone of an aircraft, its purpose being to demonstrate that the equipment will not be deranged by positive air pressure applied when ground testing aircraft pressure cabins.

2.2.2 This test need only be applied to equipment having sealed enclosures (either pressurized or evacuated) or partially scaled enclosures having low leakage rates, which might be affected by an excess pressure condition.

2.3 **Procedure 4 - Rapid Decompression Test**

2.3.1 This test is applicable to equipment mounted within the pressurized zone of an aircraft. Its purpose is to demonstrate that, in the event of a pressurization supply failure or a structural failure of the aircraft causing a rapid but not explosive loss of pressurization, the equipment will survive or will fail in such a manner so as not to hazard the safety of the aircraft.

2.3.2 **Test Procedure**

2.3.2.1 The effects of pressure change only can be considered in the decompression phase of the test, for although temperature may change as a result of failure, such changes are unlikely to immediately influence equipment; furthermore, it is not practicable to reproduce a rapid temperature change simultaneously with the pressure change. If the effects of such temperature change are likely to be significant in the subsequent performance of the equipment, the temperature change to be applied will need to be stated in the relevant equipment specification (see clause 3.4.7).

2.3.2.2 It is expected that pressurization failure would be followed by descent of the aircraft to a more acceptable flight altitude; the very low air pressure following a failure would thus persist for a limited period only. If the effects of a descent to low altitude is significant to the equipment, the pressure changes to be applied will need to be stated in the relevant equipment specification (see clause 3.4.7).

2.3.2.3 For aircraft with a large cabin volume descent may be initiated before all pressurization has been lost, and equipment would therefore be subjected to a pressure change less than that stated above. In such cases the requirements would need to be based on known or estimated characteristics of the particular aircraft.

2.3.2.4 The rate of change of pressure required by clause 3.4.5 may be difficult to achieve in most test chambers. For many items of equipment this rate of pressure change would not be significant and in such cases the relevant equipment specification may relax the rate of change or pressure to that obtainable in the test chamber.

2.3.3 **Performance Evaluation**

2.3.3.1 In general the hazards resulting from rapid decompression can be defined as follows:

a) Physical break-up of an equipment interfering with either operation of adjacent equipment of any aircraft function;

b) Loss of operation of equipment necessary for flight safety during and/or following a pressurization failure.

2.3.3.2 Equipment requiring only a demonstration of mechanical integrity need only be subjected to the test in its idle or inert state. For equipment where mechanical or electrical functioning are to be demonstrated, these equipments should be operated and the performance assessed at appropriate phases of the test.

2.3.3.3 Equipment needing to operate without loss of function throughout the rapid decompression and subsequent phases, should be brought into operation before the decompression phase is applied. In the case of heat generating equipment it may be required to allow the temperature of the equipment to re-stabilize before applying decompression (see clause 3.4.5). The performance of such equipment will need to be monitored throughout the test.

2.3.3.4 In the case of equipment required to function only following decompression, temporary derangement of the equipment at pressures corresponding to maximum flight altitudes may be acceptable, provided function is restored after descent to a more acceptable altitude.

2.3.3.5 Equipment operating intermittently in flight should be demonstrated in the operational on inert state, whichever is the more adverse.

2.4 Procedure 5- Explosive Decompression Test

2.4.1 This test is applicable to some types of Grade Q equipment. Its purpose is to demonstrate that, in the event of a structural failure of the aircraft causing an explosive loss of pressurization, such equipment will survive or will fail in a manner that does not hazard the safety of the aircraft.

2.4.2 Test Procedure

2.4.2.1 The effects of pressure change only can be considered in the decompression phase of the test, for although temperature may change as a result of failure, such changes are unlikely to immediately influence an equipment; furthermore it is not practicable to reproduce a rapid temperature change simultaneously with the pressure change. If the effects of such temperature change are likely to be significant in the subsequent performance of the equipment, the temperature change to be applied will need to be stated in the relevant equipment specification (see clause 3.5.7).

2.4.2.2 It is expected that pressurization failure would be followed by descent of the aircraft to a more acceptable flight altitude; the very low air pressure following failure would thus persist for a limited period only. If the effects of a descent to low altitude is significant to the equipment, the pressure changes to be applied will need to be stated in the relevant equipment specification (see clause 3.5.7)

2.4.3 Performance Evaluation

2.4.3.1. In general the hazards resulting from explosive decompression can be defined as follows.

a) Physical break-up of an equipment interfering with either operation of adjacent equipment of any aircraft function;

b) Loss of operation of equipment necessary for flight safety during and/or following a pressurization failure.

2.4.3.2 Equipment requiring only a demonstration of mechanical integrity need only be subjected to the test in its idle or inert state. For equipment where mechanical or electrical functioning are to be demonstrated, these equipments should be made to operate and the performance assessed at appropriate phases of the test.

2.4.3.3 Equipment needing to operate without loss of function throughout the explosive decompression and subsequent phases, should be brought into operation before the decompression phase is applied. In the case of heat generating equipment, it may be required to allow the temperature of the equipment to re-stabilize before applying decompression (see clause 3.5.5). The performance of such equipment will need to be monitored throughout the test.

2.4.3.4 In the case of equipment required to function only following decompression, temporary derangement of the equipment at pressures corresponding to maximum flight altitudes may be acceptable, provided function is restored after descent to a more acceptable altitude.

2.4.3.5 Equipment operating intermittently in flight should be demonstrated in the operational or inert state, whichever is the more adverse.

3. GROUND AND SHIPBORNE EQUIPMENT

3.1 Procedures 1 and 2 are intended for ground and ship borne equipment. The purpose and applicability of these tests have been explained in Section 4 itself.

SUB SECTION 5.24

SHOCK OR IMPACT

1. GENERAL

1.1 Most of the service electronic and electrical equipment are liable to be subjected to shocks during use, handling and transportation. These shocks will be at widely varying levels and will also be of a complex nature.

1.2 The shock test is applied to establish the effects of non-repetitive shocks likely to be encountered by equipment due to their service environment or during transportation. This test may also be used to assess the structural integrity of an equipment. This test is intended for unpacked equipment and for equipment in transit cases where the case is an integral part of the equipment.

1.3 Two separate procedures are included in this test. Test procedure 1 is intended only for equipment installed on ships. Test Procedure 2 is intended mainly for equipment installed in ground vehicles and aircraft. Test procedure 2 can also be used for testing equipment installed in ships, in which case, the details of test such as pulse shape, pulse duration, amplitude of shock etc., are to be clearly specified in the relevant equipment specification.

2. TEST PROCEDURE

2.1 **Method of Mounting.**

2.1.1 For procedure 1, when an equipment weighs more than 275 kg dismantling of the equipment into sub-assemblies is allowed, if practicable. However, in case of equipment fitted with shock mounts, the intensity of shock transmitted to the sub-assemblies when they are directly mounted on the target plates may be higher than that normally expected on shock mounted equipment. In such cases it may be advantageous and desirable to examine whether a separate shock test machine with a larger load capability should be used for testing the equipment without resorting to dismantling the same into sub-units weighing less than 275 kg.

2.1.2 For procedure 2, the equipment is to be mounted on the shock test machine by its normal means of mounting either directly or by means of fixtures in its normal operational altitude. In order to subject the equipment to the required number of shocks in various axes and directions, in some instances, it may be necessary to fabricate elaborate mounting fixtures. In the case of equipment mounted on isolators, these fixtures may be somewhat elaborate and complicated if shocks are to be imparted to the equipment in various axes and directions.

2.1.3 The relevant equipment specification should also specify the axes and directions in which the shocks are to be imparted to the equipment after examining the physical design features of the equipment. This may, in some instances, result in less than 18 shocks (See clause 3.3.2.1(b) or less than 12 shocks (See clause 3.3.2.2(b) and 3.3.2.3(b)). Where the equipment is always mounted in a particular attitude in its service usage, the relevant equipment specification should specify this attitude clearly as well as the total number of shocks that should be applied to the equipment in this attitude.

2.2 **Procedure 1**

2.2.1 Two test methods are given in this procedure, when it is necessary to demonstrate only the structural integrity or survival of the equipment after subjecting to shocks, test method `A' is to be specified. Test method `B' is to be specified when the equipment is required to operate satisfactorily under conditions of shocks.

2.3 **Procedure 2**

2.3.1 In procedure 2, three test methods are given, each method has a specific purpose and the relevant equipment. Specification should clearly specify one or more of the methods for conducting the test. Test method `A' is a general purpose test which can be applied to all equipments including those normally fitted with isolators. This test method can be applied for evaluation of the performance capability of the equipment during shocks and survival of the equipment after being subjected to a specified shocks. Test method `B' is recommended to be used to evaluate the structural integrity of the equipment mounting means. For this test, therefore, either on equipment or a dummy loads can be used. Test method `C' is a high intensity shock test and it may be specified where high acceleration and shorter shocks are expected.

2.3.2 Two shapes of shock pulses which are in general use are applicable for all the three test methods. The relevant equipment specification may choose either of them. However, the final peak saw tooth pulse has the advantage for general purpose use over the half sine pulse because of the more uniform frequency spectrum. The half sine pulse is useful where the test is required to simulate shocks resulting from impact with or retardation by a linear rate system such as an impact involving a resilient structure. In the case of air borne equipments, half sine wave pulse is recommended for all shock mounted equipments and other equipments weighing 140 kg or more and the final peak saw-tooth pulse is recommended for all equipment not shock mounted and weighing less than 140 kg.

3. GUIDANCE ON SHOCK ON SHIP BORNE EQUIPMENT

3.1 Infinite variety of shock motions are possible under ship environment. It is neither practical nor desirable to construct a shock testing machine to reproduce each of the particular shock motions that are likely to be encountered on board ships. However, Naval equipment must be built sufficiently rugged to operate satisfactorily in the shock environment to which they will be exposed and also to survive transportation from site of manufacturing to site of ultimate use. To ensure that the equipment is sufficiently rugged and to determine what its mechanical faults are, it is subjected to controlled mechanical shocks on shock testing machines.

3.1.1. Mechanical Shock is a non-periodic excitation (e.g. A motion of the foundation or an applied force) of a mechanical systems that is characterized by suddenness and severities and usually causes significant relative displacements in the systems.

3.1.2. Shock in ships is caused by explosion of a shell on the ships structure apart from non-contact underwater explosion. The explosion of a shell can produce high acceleration at the source of shock but more severe damages or displacements occur by non contact underwater explosion. This is because of the highly transmissive nature of water medium as compared to air (gaseous) and land (solid) for shock waves. Mines or bombs which exploded at a distance from ships did not always rupture the hull, but even in these cases the shock pulse from the explosion was sufficient to cause the machinery and equipment inside the hull to be broken as if by a hammer blow and in some cases to be torn away from their seating. An underwater explosion will impart to the hull a wave which causes rapid local movement both of the hull structure and equipment attached to it. In these conditions there will be a simultaneous, but slower, whole body hull displacement. The rapid local movement first imposes a large acceleration on the item (equipment), which is followed by a smaller deceleration as the structural stiffness of the hull resists the initial movement propagated by the shock wave.

3.1.3. **Severity of Shocks** : For a given explosion severities, the magnitude of acceleration and deceleration imposed on an item depends on (a) its mass, (b) its position relative to the explosion, (c) its position in the vessel, (d) its mounting and (e) the type of hull structure. Generally the severest shock is experienced by light items rigidly attached to vessels bottom or side (below the water line) and closest to the explosion.

3.2. Basis Of Naval Shock Test Specifications/Standards

3.2.1. A large number of trials have already been conducted on various naval vessels by the Royal Navy. The trials data has been analysed and retained into a single mathematical idealization covering the range of shock motion which may be experienced in Ships, and against which it is required to protect the equipment. The summary of broad deductions from Ship trials are as follows:-

3.2.1.1. For an item secured to an internal structure, say a deck, the characteristics of the shock motion will depend upon the mass of the item and the stiffness of the structure. Within certain mass limits of the item, the effective mass of the exciting structure is large and dominates the shock motion applied to the item, so that the latter remains essentially independent of mass.

3.2.1.2. For items mounted on seating attached to the hull plating or framing, the shock acceleration and velocity can be related to the combined mass of hull, seating and item/unit area of hull controlling the motion. The deceleration associated with the motion depends upon more complex factors relating to the mode in which the structure arrests the motion of item and seating.

3.2.2. There is often considerable difficulty associated with defining the area of ship's hull structure which controls the motion applied to an item. Furthermore, this area can vary significantly, depending upon where and how the item is supported from the hull and in which ship it is fitted. These details are frequently unknown when the item is being designed. For these and other reasons it has been found more convenient to express the shock parameters in the form of curves drawn on a base of mass of the item.

3.2.3. A general shock specification for ship borne equipment, therefore, has to cover wide varieties of shocks, wide range of equipment, wide varieties of mounting arrangements and different locations in ship. At the same time, the specification must define a standard test to ensure a fair bit of confidence in the equipment during its service field environment. Therefore, a specification is a compromise between simplicity and standardization of test on one hand and realism in relation to the service environment on the other.

3.2.4. The Naval Shocks Standards were initially introduced in seven grades and has been, in the interest of standardization merged into two grades, namely NSS 1 (Naval Shock Standard Grade 1) and NSS II (Naval Shock Standard Grade II). The NSS 1 is more severe than NSS II.

3.2.5. The NSS (Naval Shock Standards) curves consist of the following parameters

plotted against equipment mass, on a logarithmic scale :

a) Dynamic acceleration
b) Maximum deceleration
c) Maximum velocity
d) Initial displacement associated with the initial velocity pulse
e) Time to maximum velocity

f) Time period of structural response
g) Duration of initial velocity pulse.

3.3. **Shock Testing of Equipments**

3.3.1. Equipment to be tested is dealt under the following three categories:

Light Weight	-	Up to 205 kg
Medium Weight	-	205 Kg to 1.9 tonnes
Heavy Weight	-	Over 1.9 tonnes

The shock testing machines are also classified as light, medium and heavy.

3.3.2. **Shock Testing of Light Weight Equipment.**

3.3.2.1. Light weight machines are capable of imparting shocks for light equipment weighing up to 205 kg to check the ruggedness only. (as per procedure 1 of shock test in JSS 55555, SES-5 and DEF 133).

3.3.2.2. Light weight shock machines are preferred for testing of small items like switch and control gear as the machines were able to reproduce typical damages.

3.3.2.3. The light weight items are shock tested under two classifications, as shock category 1 and shock category 2.

3.3.2.3.1 **Shock Category 1** : The equipment should survive shock test without any damage and remain capable of fulfilling its function after the test. (as per test method A, procedure 1 of JSS 55555).

3.3.2.3.2 **Shock Category 2** : The equipment should survive shock without any damage and continue to function with only a momentary and specific change condition throughout the test. It should also revert automatically to its original capability and condition after the test (as per method A, procedure 1 of JSS 55555).

3.3.3. There is no direct relationship between the "practical" blow provided by light weight shock machine and the shock levels appropriate to NSS 1 or NSS 2 or any other environmental grades which specify shock pulse of specified characteristics.

3.3.2. To impart the specific mathematically calculated shock accelerations and velocities (as in case of NSS curve) to the light weight equipment, they need to be tested on medium weight shock machines capable of producing controlled shocks.

3.4. Shock Testing of Medium Weight Equipment.

3.4.1. The light weight shock machines can also be used for testing the medium and heavy equipment by dismantling them into sub assemblies to weigh less than 205 kg, if possible. However, this type of dismantling and testing cannot establish reliability for deck mounted and bulkhead mounted items of large mass, or having a large overhang and is not normally recommended.

3.4.2. The practice of fabricating shock machines named as “Deck Shock Machines” for testing of equipment of mass up to 680 kg and “Two tonne Shock Machines” for equipment of mass up to 1.9 tonnes was in practice. The Deck Shock Machines were employed to test the equipment (mass up to 680 kg) to be mounted on decks or bulk heads remote from the ships bottom or on ships sides above the water line. The Two tonne Shock Machines were employed to test the equipment (mass up to 1.9 tonne) which are mounted on ship bottom positions below the water line.

3.5. **Shock Testing of Heavy weight equipment.**

3.5.1. Shock test vessels were used for testing very heavy items weighing above 1.9 tonne. These were also used for testing lighter items where the necessity arose to check the equipment in an actual underwater shock environment. In modern practice, the shock behaviour of monolithic heavy equipment can be analysed using various mathematical models available on computers.

3.6. **Classification of Shock Machines.**

3.6.1. Shock Machines can be fabricated according to a specification to produce a complex shock which is simulation of an approximation of a field condition in a ship. One of these machines is specified in clause 2.1 Page 4-104 which is used for conducting the test in accordance with procedure 1.

3.6.2. Shock machine can be fabricated to produce specified characteristics of a shock pulse. These machines are used to conduct shock test as per procedure 2.

3.7. **Limitation of Shock Testing on Shock Machines.**

3.7.1. The following limitations of shock testing are to be kept in mind while analyzing the shock test results.

3.7.1.1. Shock motions produced by a shock machine may be affected by mass and frequency characteristics of the item under test. This will be significant when the mass of the test item is very heavy. It is advisable to go in for testing on a shock vessel for very heavy items to be tested.

3.7.1.2. At times natural frequency of a test item and the shock machine may coincide resulting in failure of equipment of relatively good quality and passing of equipment of relatively poor quality. To overcome this, it is always advisable to design the jig and shock machine to be as rigid as possible.

3.8. **Advantages of Shock Testing on Shock Machines.**

3.8.1. Tests by Shock testing machines (Shock machines) are preferable to tests under actual field conditions or shock vessels for following reasons:

3.8.1.1. The nature of shocks is under good control, and shock can be repeated with reasonable exactness. These permit a comparative evaluation of equipment under test and allows exact performance specifications to be written.

3.8.1.2. The intensity and nature of shock motion that can be produced on a shock machine which represents an average condition for which production is practical, whereas a field test may involve only a specific condition that is a constituent of that average.

3.8.1.3. The shock machine is relatively inexpensive to operate so it is practical to perform a large number of developmental tests on components, sub-assemblies and equipment in a manner not otherwise practical or economical on a shock vessel and field conditions, i.e. underwater explosion.

3.8.1.4. This technique is additionally justifiable if the pulses are shaped so as to provide shock spectra similar to those obtained for a suitable average of a given type field condition.

3.9. **Failure Modes.**

3.9.1. Failure of equipment as a result of experiencing shock can be classified as permanent and temporary damages.

3.9.1.1. The permanent damage is so severe that the ability of the equipment to perform its intended function is impaired permanently.

3.9.1.2. Temporary damage is that temporary disruption of normal operation in a manner permitting restoration of service by subsequent adjustment of the equipment or termination of disturbance. Some of the possible common damages due to shock are:-

a) Mal operation of pivoted or hinged members
b) Opening or closing of circuit breakers or contactors
c) Chattering of electrical contacts of relays

d) Failure of principal structures and mounting brackets
e) Failure of incandescent lamps and cathode-ray tubes (breakage of glass)
f) Displacement of shafts of indicating instruments and motors
g) Misalignment or de-shaping of structural and mechanical items
h) Loosening or shearing of fasteners and rivets, cracking of welded joints etc.

3.9.2. These damages can be due to inherent properties/weaknesses of the component or due to improper installation of them.

3.9.3. However, the shock testing cannot induce any fatigue affecting the life of equipment. So, the yellow banding of equipment after shock test is generally not required for electronic equipment unless specifically recommended by design authorities. However, in the case of mechanical/electromechanical equipment such as pumps, motors, shafts etc. permanent misalignment or displacement may take place necessitating Yellow banding.

SUB SECTION 5.25

SOLAR RADIATION

1. GENERAL

1.1 Solar Radiation has two significant effects viz the surface heating resulting from absorption of the radiant energy and degradation of materials caused mainly by the ultraviolet radiation.

1.2 The object of this test is to determine the effects of solar radiation energy on electronic and electrical equipments in the earth's atmosphere. The limits and energy levels specified in this test for the solar radiation provide the simulated effects of natural sunshine.

1.3 This test is applicable to those equipments which are used in the open and are fully exposed to solar radiation.

1.4 This test is of a specialized nature. Expert advice should be sought before specifying the test requirements.

1.5 **Hazards to Personnel**

1.5.1 **Effect on Eyes** - In natural sunlight, the eyes are protected in two ways; the brightness of the sun makes it almost impossible to look directly at it, and the ultraviolet radiation is considerably attenuated by the atmosphere. These protections are not present in unfiltered artificial sources. Operators must be warned never to look at unfiltered sources. The eyes must be protected by filtered goggles, or viewing must be made through a filtered aperture.

1.5.2 **Effects of Ozone** - In the neighbourhood of sources such as compact xenon arc lamps there are high concentrations of ozone, which present hazards to personnel. The recommended safe level is 0.1 part per million, but experience suggests that it would be advisable to restrict the level to 0.06 part per million or less. It is most important that air-extraction cooling be provided near the lamps.

1.5.3 **Toxic Fumes** - The combined effects of heat and ultraviolet radiation on certain plastics and resins (e.g., melamine laminates) may produce toxic fumes. If the use of such materials is unavoidable, suitable means of prevention or disposal of fumes must be provided.

1.5.4 **Risk of Explosion**:- The pressure inside a high pressure xenon lamp rises from its cold value of 2 to 3 atmospheres to 20 atmospheres when hot. There may be a risk of explosion which is greatest when changing lamps, which must never be handled when hot. Suitable protection should be provided for the hands, e.g. gloves or rags. These will also prevent contamination of the glass covering in front of a lamp which serve dual purpose, in giving protection in case of a possible explosion and in acting as a corrective filter.

2. TEST EQUIPMENT

2.1 Lamps

2.1.1 A number of sources are recommended in the test under clause 2.2(c) note. The radiation source may comprise one or more lamps and their associated optical components such as reflectors and filters to provide the required spectral distribution and irradiations. The high power xenon arc lamp with filters can provide the best spectral match. Mercury vapour and xenon-mercury lamps have considerable deficiencies in matching which would lead to error. The carbon arc with specially doped electrodes had been widely used but presents difficulties as regards stability and maintenance and is, therefore, not generally favoured. Tungsten filament lamps may be used where only thermal effects are of interest but adjustment of the irradiance may be necessary to give the same heating effect.

2.2 Spectral Distribution and Irradiance

2.2.1 The irradiance shall have a maximum intensity of 1200 Watts/m^2 (+10%) with the spectral distribution given in clause 2.2(a) to (c). Where only thermal effects are to be assessed, deviation from this spectral distribution is permitted but the irradiance must then be adjusted, if necessary, to give an equivalent heating effect. The radiation shall, as far as possible, be directed on the equipment as a collimated beam and shall irradiate the surface(s) as required by the equipment specification. The value of 1200 W/m^2 shall include any radiation reflected from the test chamber walls and received by the equipment under test but it should not include long wave IR radiation emitted by the chamber walls.

3. TEST PROCEDURE

3.1 The relevant equipment specification shall clearly state the method of locating the equipment inside the chamber. It should also specify which of the surface of the equipment are to be irradiated, their orientation relative to the relative position of the radiation source (s) is required.

SUB SECTION 5.26

TOPPLING

1. GENERAL

1.1 This test is applied to equipments to demonstrate their ability to withstand the knocks and jolts likely to occur during servicing and use.

2. CONDITIONING

2.1 Application

2.1.1 This test should be invoked and applied only to those faces where there is a distinct possibility of the equipment being subjected to this hazard. In general equipment which is frequently handled and serviced (e.g. field equipments and units spares) can be considered to be at risk, whereas equipment forming an integral part of a permanent installation, would not be considered to be at risk and need not be tested. This test may not be applicable to fragile unprotected equipment or to equipment of irregular shape (e.g. aircraft nose radar) which, when removed from the installation would be contained in a handling frame or jig. For equipments which stand only on the face (e.g. normal base) this test need only be applied to that face.

2.1.2 While conducting this test, it is possible for the equipment to topple on to the next face instead of falling back on the test surface as intended. This shall be avoided by a suitable method.

2.1.3 No tolerance is specified for the heights and angles. However, this test is not intended to be a precise test and a tolerance of ± 10 percent can be allowed over the specified values.

2.1.4 A total of four topples are specified for the same horizontal face taking into account all the four edges as practicable edges. However, when the number of practicable edges are less than four for each horizontal face, the number of drops shall be limited to one for each practicable edge. The same procedure shall be applied for other practicable horizontal faces.

3. ACCEPTANCE STANDARD

3.1 The equipment should not be affected adversely by this test. Some damage (e.g. small dents) may be unavoidable but may be acceptable provided they do not affect the subsequent use of the equipment or degrade reliability or adversely influence maintainability.

SUB SECTION 5.27

TROPICAL EXPOSURE

1. GENERAL

1.1 The tropical exposure test is intended to determine the ability of electronic and electrical equipment to withstand exposure and/or operate in a highly humid environment. Corrosion is one of the principal results. Materials sensitive to moisture may deteriorate rapidly. Many insulation materials used in electronic/electrical equipments are hygroscopic and may suffer a degradation of their electrical properties. These effects are essentially long term and require exposure to the test conditions for long periods. It should be noted that the test conditions given in this test are not significantly more severe than the worst natural conditions and, therefore, this test is not an accelerated test. The test duration stipulated are arbitrary to some extent and are intended to merely indicate potential design weaknesses in the equipment.

2. TEST PROCEDURE

2.1 Test Conditions

2.1.1 Four test conditions are specified for this test. Test conditions `A' comprising of 7 cycles is applicable for equipments which are normally protected whether in a fully air conditioned building or by a fully desiccated handling container but which may be subjected to occasional surface condensation. Test Condition `B' comprising of 14 cycles is applicable to equipments which are used in partially protected conditions but which may occasionally be subjected to a humid atmosphere. Such equipments include base workshop test gear, equipments used in air-conditioned cabins etc. Test Condition `C' comprising of 28 cycles is applicable to equipment which are in exposed locations or subjected to a humid atmosphere in their normal usage locations such as field equipments, equipments mounted in unconditioned cabins armoured vehicles equipment etc. Test condition D comprising of 56 cycles is applicable to equipments which are fully exposed.

2.1.2 When this test is included in a test sequence, a separate equipment can be used to carryout this test as this is a long term test. However, consideration of cost of a second equipment should be borne in mind while doing so.

2.2 Performance Checks

2.2.1 Equipment should be operated at the most adverse phase of the test cycle, which for most applications, would be a switch on or start up at the commencement of the high temperature phase. Excessive operation of the equipment which generates heat, however, should be avoided since this could mitigate both long term and short term effects of this test.

2.2.2 For tests requiring demonstration of survival only, the equipment should be operated and a performance check should be carried out when the temperature and relative humidity of the equipment has been returned to standard atmospheric conditions.

SUB SECTION 5.28

VIBRATION

1. GROUND SHIPBORNE AND FLEET AIR ARM EQUIPMENT

1.1 **Sinusoidal Vibration**. - The vibration experienced by an equipment in the course of transportation and use is generally of a complex nature and is a function of the nature of the excitation source, the complex mechanical impedance linking the source with the mounting points of equipment, and the inherent characteristics of the equipment which often modify those of the structure to which it is connected. The cumulative effect of these variables is to produce an unique environment for each equipment which is rarely amenable to accurate simulation.

1.2 It is, therefore, usual to test an equipment using arbitrary procedures derived with The principal object of ensuring that an equipment tested to these procedures will be compatible with the use environment. For these reasons a degree of engineering judgement must be exercised when selecting the test requirements and interpreting the results.

1.3 **Test Methods**

1.3.1 **Endurance by Sinusoid with Frequency Sweep** - This test method is most appropriate for reproducing the stresses experienced by an equipment in use.

1.3.2 **Endurance at Fixed Frequencies** - This test method has application to a limited range of equipment whose installation is restricted to one or a few types of vehicles or aircrafts where the dominant frequencies are known or can be predicted. It may have application for the rapid accumulation of stress reversal to demonstrate the effects of fatigue; for example, arising from excitation of an antenna structure in a mobile ground radar equipment during transportation.

1.3.3 **Initial Resonance Search** - This test method either with or without endurance conditioning at fixed frequencies should be limited to those applications where sufficient information is available concerning the use environment to render the test meaningful. It is justifiable when it is known that the equipment will experience considerable vibration of a periodic nature; for example an environment found in ships, propeller- driven aircraft, rotor craft, where the vibration is directly related to engine and/or propeller unbalance.

Note - When this test is judged necessary, thought should be given to the desired objectives; in case of approval or acceptance testing the mere recording of dynamic response is pointless unless followed by endurance testing at fixed frequencies. However, as a development technique the test can yield information useful for the purpose of design improvement.

3.4 **Final Resonance Search** - This method may have application to equipments where fatigue is to be assessed. A comparison of the frequencies at which frequency dependent effects are manifested, before and after endurance conditioning will provide evidence of possible mechanical weakness. If there are no changes in the frequencies of such effects, the equipment can be assumed to have suffered no fatigue due to specified endurance. If, however, any change is observed, it will indicate that some damage may have been caused by the conditioning, and that the specimen may not be suitable for its Service environment. The relevant equipment specification should state what action should then be taken and changes in frequency which are acceptable.

1.4 **Test Sequence**

1.4.1 **Equipment Installed in Vehicles** - Random vibration more realistically simulates vehicle vibration and although, endurance by wide band random vibration (see clause 3.4.8) is to be preferred, test sequence (c) (see clause 3.4.2) or other sinusoidal test methods could be specified at the discretion of specification authority.

1.4.2 **Shipborne Equipment** - The preferred test sequence is initial resonance search followed by endurance at fixed frequencies (see clause 3.4.2[b]). If required final resonance search may also be specified.

1.4.3 **Equipment Transported** - User experience has shown that transport environment is adequately simulated by the endurance by sinusoid by frequency sweep test (see clause 3.4.2.[c]) and hence random vibration testing is not normally justified. Sinusoid test covers the transportation environment by road, rail, air or sea between ordnance depot and forward bases, it does not cover transportation in field. Therefore, equipment frequently transported by various types of vehicles in forward areas (for example, portable generator sets, field test gear) should be treated as installed equipment and vibration test should be accordingly specified.

1.5 **Severities**

1.5.1 **Frequency Range and Amplitudes** - The frequencies and amplitudes given for this test (see Table 4.28.2) have been selected to envelope the frequency response spectrum of a wide range of carriers within each particular grouping. When an equipment is intended for use in one type of carrier it is preferable to base the vibration test on the known or measured vibration characteristics of the carrier, if such data were available. In the absence of this data, however, the envelope characteristic may be used.

1.5.1.1 **Equipment Installed in Tracked Vehicles** - When selecting the severity for tracked vehicles, whether levels 1 or 2 account will need be taken of the equipment location, characteristics of transmission paths between vehicle structure and equipment, and the mass of Equipment in relation to that of the immediate vehicles structure. In general, level 2 is applicable to all equipment mounted rigidly with a short transmission path to the main structure of the vehicle (for example, sighting equipment mounted on turrets) or equipment whose mass will not significantly affect the high frequency vibrations induced in the vehicle structure (for example rigidly mounted instruments). Level 1 is applicable to all other equipment installed in racking or those attached to a structure which provides a complex or long transmission path to the vehicle main frame; it also applies to the equipments mounted on isolators.

1.5.1.2 **Shipborne Equipment** - The standard endurance test for ship borne equipment is limited to a series of one hour tests at frequencies determined by initial resonance search test or at the frequencies specified in the relevant equipment specification. This test duration is not intended to demonstrate adequate resistance to fatigue or brinelling effects. Such effects could be significant if resonances of structures within an equipment were excited at frequencies associated with cruising speeds, or where brinelling could be encountered. In these circumstances the test duration must be specified. For general use the frequencies specified in the relevant equipment specification for endurance conditioning are normally selected as 14, 23 and 33 Hz, applied in the plane that would produce the most adverse effect; if this plane cannot be identified the conditioning should be applied normal to the base of the equipment.

1.5.1.3 **Equipment Transported** (see 1.4.3 above) - Vibration should normally be applied along three major axes of the equipment except that for long items (length to width ratio greater than three to one) which would be transported resting on a side, the test may be limited to the planes normal to the two axes having the smaller dimensions.

1.5.2 **Duration**

1.5.2.1 Where the test is simply to demonstrate the ability of an equipment to survive and/or operate at the appropriate amplitudes, the test need only continue for a duration sufficient to demonstrate this requirement over the specified frequency range. In cases where the ability of an equipment to withstand the cumulative effects of vibration is to be demonstrated (fatigue brinelling, etc.) the test should be of a duration sufficient to accumulate the necessary number of stress cycles.

1.5.2.2 An equipment encounters vibration of varying amplitude and frequencies in the course of its life. The most severe levels against which an equipment must be designed occur only for a smaller proportion of that life of the equipment. Lower levels invariably persist for long periods and the cumulative damage caused by the varying vibration environments can, where there is an established relationship between stress and number of stress reversals, be simulated by a test of reduced duration applied at a level representative of the most severe conditions.

Note - At present this relationship has only been validated for Aircraft and similar structures (for example, see Table 4.28.6)

1.6 **Random to Sinusoidal Vibration Equivalence** - In those cases where the vibration environment is essentially random but a sinusodial test is acceptable to the responsible authority, conversion from the known random spectrum may be made by one of several procedures (for example, see Note in clause 3.4.6.2 and 3.4.7.5).

Note - There is no direct equivalence between random and sinusoidal vibration and in deriving a sinusoidal vibration level a number of assumptions need to be made which may not be technically valid for a particular equipment under test. Invariably, generalized assumptions can result in a severe overtest of many of the resonant responses within the equipment.

1.7 **Transmissibility Factor for Isolators**

1.7.1 Three levels of transmissibility factors have been included (see Fig. 4.28-1); these are:

a) Curve A relates to an isolator of high resilience having a natural frequency when considering a single degree of freedom of not exceeding 10Hz (for example, air damped aircraft isolator).

b) Curve B relates to an isolator of medium resilience having a natural frequency as qualified above in the range 10 to 20 Hz

c) Curve C relates to an isolator of low resilience having a natural frequency as qualified above in the range 20 to 35 Hz (for example, rubber shock mounting).

1.7.2 The transmissibility factors are estimated to envelope the transmissibility characteristics likely to arise in an installation in which modes are coupled. Factors determined by these curves, therefore, make an allowance for the vibration levels arising at the periphery of an equipment from the combined effects translatory and rotational motion. Curve B is derived from vibration measurements made on typical aircraft equipment fitted with damped all metal mounting having a natural frequency (considering a single degree of freedom) of approximately 15 Hz. Very little data was available for isolators represented by Curve A and C and these were derived by extrapolation from Curve B but considering a natural frequency of 8 Hz and 25 Hz respectively.

1.8 **Dynamic Response** - A major cause of vibration damage is the dynamic stress raised within an equipment at frequency(s) at which the structure and component parts have a large response. The classic example is the stress raised within a simple mass spring system when the system is attached to a vibrating body whose inertia is large in relation to that of the mass; at the frequency of resonance, the spring mass responds with an increase in amplitude inducing increased stress in the spring. In practice, with many items of equipment the support structure of the vehicle is neither of sufficient mass or stiffness to provide the reactive forces to support a resonance of large amplitude. When testing such an equipment using a frame or support jig not dynamically representative of the installation, the resulting responses (for example, levels of excitation of a resonance) may be excessive. The extent to which a response or resonance could be excited in use will need to be considered when planning the test and a degree of engineering judgment exercised in assessing test results. In situations where the mass of the equipment can significantly modify the response of the support structure consideration should be given to simulating more closely the mechanical characteristics of the actual installation; for example, by including in the test part of the structure to which the equipment would be attached in use or by limiting the drive force required during the test (see clause 2.1.2.3). Excessive excitation of resonance, which occurs when testing an equipment whose mass is large compared with that of the driving source, results from the considerable power input required to maintain the amplitude of the driven source at a specified level; this situation is often unrepresentative of the conditions that would exist in the equipment installation. The environment would be better simulated by implementing force limitation (see clause 2.1.2.3).

1.9 **Performance Evaluation**

1.9.1 Equipment should be operated either throughout the test or at appropriate phase(s) of the test in a manner representative of the most adverse duty cycle for the equipment. A demonstration of functional performance should be made towards the end of the vibration conditioning phase with further demonstrations as may be necessary to show continuing performance integrity (for example, at the start and at suitable intervals throughout the conditioning phase). The demonstration should continue for a minimum duration to ensure that the performance is demonstrated over the full frequency range of the test.

1.9.2 For equipment in which vibration may at certain frequencies interfere with an operational function (for example, due to excitation of resonance in a switching relay), the operational function may need to be repeated during the vibration response test to demonstrate performance either over the frequency range of the test or at those frequencies likely to cause malfunction.

1.9.3 The functional performance of equipment in which the test is to demonstrate survival only, should be assessed after completion of vibration conditioning.

1.10 **Random Vibration**

1.10.1 Most items of military equipment will be required to operate in or survive a vibration environment at some stage of their service life. In the majority of cases this vibration will be of a predominantly random nature, with the ASD spectrum exhibiting peaks and notches, considerably higher and lower than the mean level, present at various discrete frequency bands.

1.10.2 This environment is best simulated by a wide band random vibration test even though the use of a smooth spectrum as advocated in this specification could produce an overtest at some parts of the frequency spectrum. A test carried out to this specification may not accurately simulate the actual vibration environment encountered by an equipment in practice but it gives a measure of confidence that equipment surviving the test will survive service conditions.

1.10.3 Whenever possible and when the cost is justified, it is recommended that the actual vibration environment be measured prior to testing the equipment and the results used to formulate a more accurate spectrum shape and level. Allowances must be made for any modification in vibration level to relate the test time to the expected service life of the equipment (see clause 1.12.2.2 below).

1.10.4 Sinusoidal vibration test can be considered to supplement the random motion test for analytical and diagnostic purposes. Occasionally the relevant equipment specification may require a resonance search test before and after the random motion test to assist in determining any fatigue damage resulting from a random test.

1.11 **Test Procedure**

1.11.1 **Single Control Point** - The use of this procedure is recommended as the simplest test to perform while still applying wide band random vibration to the equipment under test. However, because the input vibration spectrum is measured and controlled at only one point it is probable that, with large equipments requiring complex rigs, the vibration at various fixing points will vary considerably from the desired input spectrum because of resonances and anti-resonances in the equipment and rig. This procedure should therefore, as far as possible, be restricted to small equipments or to those equipments or stores which do not have materially differing mechanical impedance at each fixing point.

1.11.2 **Use of Multiple Control Points** - This method is more complex than the previous method but it is sometimes essential where the equipment under test is large and has widely spaced fixing points. This method should only be specified where the use of a single control point would obviously result in a severe over or under test of parts of the equipment.

1.11.3 **Narrow Band Swept Random Test** - Where facilities do not exist for conducting a wide band random motion test, it may sometimes be permissible to make use of a frequency sweep with a narrow band random input. In exceptional cases, it may be permissible to make use of a frequency sweep with a narrow band swept random signal of higher amplitude on to a wide band random vibration base. This would have applications where power limitations of the test facility make it impossible to achieve the spectral density requirements with simple wide band random motion. This specification does not give requirements for the conduct of such tests and it is necessary that the authority approving such tests specify the requirements. The test is regarded as inferior to the wide band random vibration test.

1.12 **Severities**

1.12.1 **Frequency Range and ASD Level**

1.12.1.1 The preferred severities given in Table 4.28-3 have been selected to envelope the vibration environment occurring in a wide range of carriers. The use of these severities will result in a general test but, of necessity, the levels specified are the most severe cases within the group.

1.12.1.2 It follows then, that if a general severity level is selected from Table 4.28-3 and the equipment to be tested is not to be installed in the carrier producing the worst vibration environment, the equipment will be subjected to a degree of over test. If measured data is available of the vibration environment to which the equipment will be subjected to in use, this should be used to formulate the test level and spectrum shape.

1.12.1.3 **Equipment Installed in Tracked Vehicles**

a) When selecting the severity for tracked vehicles, whether levels 1 or 2, account will need to be taken of the equipment location, the characteristics of transmission paths between vehicle structure and equipment, and the mass of the equipment in relation to that of the immediate vehicle structure.

b) In general, level 2 is applicable to all equipment mounted rigidly with a short transmission path to the main structure of the vehicle (for example, sighting equipment mounted in turrets) or equipment whose mass will not significantly affect the high frequency vibrations induced in the vehicle structure, for example rigidly mounted instruments.

c) Level 1 is applicable to all other equipment installed in racking or those attached to a structure which provides a complex or long transmission path to the vehicle main frame. It also applies to equipment mounted on isolators.

1.12.2 **Duration**

1.12.2.1. Where the test is simply to demonstrate the ability of an equipment to survive and/or to operate at the appropriate amplitudes, the test need only continue for a duration sufficient to demonstrate this requirement. In cases where the ability of an equipment to withstand the cumulative effects of vibration is to be demonstrated (fatigue, brinelling, etc.) the test should be of a duration sufficient to produce these effects.

1.12.2.2 An equipment encounters vibration of varying amplitudes and frequencies in he course of its life. The most severe levels against which an equipment must be designed occur only for a small proportion of that life of the equipment. Lower levels invariably persist for long periods and the cumulative damage caused by the varying vibration environments can, where there is an established relationship between the stress and number of stress reversals, be simulated by a test of reduced duration applied at a level representative of the most severe condition. It should be pointed out that currently this relationship has only been validated for aircraft and similar structures (for example, see clause 4.2.3.2 [e]).

1.13 **Transmissibility Factor for Isolator-** As in clause 1.7 above.

1.14 **Functional Performance Testing** - Equipment should be operated either throughout the test or at appropriate phase(s) of the test in a manner representative of the most adverse duty cycle for the equipment. A demonstration of functional performance should be made towards the end of the vibration conditioning phase with further demonstrations as may be necessary to show continuing performance integrity (for example, at the start and at suitable intervals throughout the conditioning phase).

1.15. **Spectrum Analyzer and Equalizer Band Widths.**

1.15.1 This test procedure permits the use of any analyser having band width (above 100 Hz) of up to but not exceeding 1/3rd octave; this procedure has been formulated within the capabilities of a wide range of existing and commercially available facilities. For general application, the environmental test specification need not specify analyzer band width but should allow use of available facilities, provided these facilities satisfy the requirements of this test procedure. The procedure does not lay down specific requirements for equalization, but where necessary, equalization should be provided to meet the requirements of this procedure. In general the resolution of the equalizing equipment need not be better than that of the analyzer.

1.15.2 In circumstances where testing is required involving different test houses and types of facilities, for example, as part of equipment production acceptance or component procurement procedure, it is often essential to specify a test which ensures a high degree of reproducibility. Such reproducibility usually implies band width resolution for analysis and equalization considerably narrower than 1/3rd octave, depending upon the dynamic response of the test item, its jigging and the test facility.

1.15.3. For tests on many items of Service equipment, high reproducibility is neither practicable, depending upon size and construction of the equipment, nor is it necessarily representative of the environment in Service. Coarse control allows the structure on an equipment to respond in a manner more representative of the operational conditions without suppressing resonance or enhancing anti-resonance responses and for this reason may be preferred for items of equipment which have complex dynamic responses and/or where the mass of the equipment largely influences the severity of the vibration environment.

1.16 **Factors Affecting Equipment Response** - The inertia of the moving assembly of the vibrator, the attachment arrangements of equipment to the vibrator are factors which influence the response of an equipment to vibration, and should be taken into account when planning a test. For example, with a small equipment mounted to a relatively large vibrator, the inertia of the vibrated platform will largely dominate the test spectrum within the equalizer band width. Where it is necessary to allow the equipment to influence the test spectrum some consideration may need to be given to the size of the vibrator used for the test or the mechanical characteristics of the actual equipment installation may need better simulation (for example, by including in the test, part of the structure to which the equipment would be attached in use). In this later situation, the location of the measuring and control points must be considered, to achieve the required control.

2. AIRBORNE EQUIPMENT

2.1 A general specification for airborne electronic equipment has to cover a vide variety of complex vibratory environments and a wide range of equipment life times some of which are so great that it would be impracticable to specify a vibration test whose duration approached that of the life time of the equipment. At the same time, the specification must define standard tests to ensure reasonable confidence in the equipment during its life in the Service environment. The specification must, therefore, be a compromise between simplicity and standardisation of tests on the one hand and realism in relation to the Service environment on the other.

2.1.1 In this specification, practical requirements have been met by using an arbitrary maximum duration for the endurance test. This duration will, in general, be insufficient for the test to be accepted as demonstrating a fatigue free service life of long duration; nevertheless, it is sufficient to demonstrate what is thought to be an adequate measure of robustness. In the higher frequency range of the aircraft spectrum, the number of stress reversals applied is such that the fatigue properties of the equipment are severely tested.

2.2 Basis of the Specification

2.2.1 This specification has been prepared on the basic assumptions that the vibration may have two adverse effects on equipment; it may cause malfunction and it may produce fatigue damage. As a result of these assumptions the following conditions should apply to the vibration test:

a) The test environment must be representative of the Service environment.

b) The duration of the test must be related to the duration in the Service environment.

2.2.2 The vibration environment in aircraft depends on a large number of factors and no two environments will be identical. Therefore, to evolve a standard vibration test covering the whole range of airborne equipment and every type of aircraft, it becomes necessary to select parameters that are known to have the greatest influence on vibration conditions and to offer the specification user a range of values of these parameters which will be applicable to his particular test. The parameters chosen in this specification are:

a) the region of the aircraft where the equipment is located, and

b) the flight condition of the aircraft.

2.2.3 Existing data indicate that vibration spectra in aircraft are continuous over a wide frequency range, that a typical spectrum will have a number of peaks, and that the amplitude distribution of the waveform is approximately Gaussian. Since it is desirable that these characteristics shall also exist in the vibration test, wide band random motion test should be made. Also, since it is impracticable to specify in detail a spectrum shape for each and every type of aircraft, flight condition or equipment position, some simplified spectrum shape must be used. In this specification, the test spectra are envelopes of flight spectra for a number of aircraft they do not represent, the vibration conditions existing in a particular flight case, but they do represent limiting conditions that may exist in one or more regions of frequency. The use of envelope spectra will result in test vibration conditions that are more severe than the service conditions over some (possibly most) portions of the frequency range.

2.2.4 The generally accepted method of demonstrating that an equipment has an adequate fatigue life is to demonstrate by test that one or more samples can withstand the number and level of repeated loadings appropriate to the life. A second method is to demonstrate that the stresses produced by the repeated loadings are below those appropriate to a so called, fatigue limit (that the stresses are sufficiently low as not to cause fatigue damage). Neither method can be adopted in this specification because the duration of the tests required will, in general, be unacceptably long.

2.2.5 It is seen, however, from experience in the use of existing specifications that equipment subjected to much shorter duration, than would ideally be required, does function satisfactorily in service. Accordingly, in this specification a maximum limit of 50 hours has been imposed on the endurance test using wide band random motion. The vibration level at which this test is made is that appropriate to the most severe vibration level encountered in Service.

2.2.6 If a random motion test of 50 hours is made, then a hypothetical equipment resonance at 10 Hz would have experienced 1.8 million reversals, a resonance at 60 Hz, 11 million, and a resonance at 100Hz, 18 million, and so on. Whilst it cannot be stated with confidence (in view of the many types of materials involved) that a particular number of reversals of randomly varying stress amplitude is necessary to demonstrate on infinite fatigue life of an item of equipment, it is generally accepted that 10 million reversals without failure is a reasonable criterion for demonstration of fatigue robustness.

2.2.7 By this standard the 50 hour test will be acceptable for frequencies above 60 Hz, but where it is important to avert fatigue failures due to resonances below 60 Hz, it will be necessary for the relevant equipment specification to state what action (such as increased test endurance) should be taken.

2.3 **Derivation of Specification Data and Procedures**

2.3.1 **ASD Levels and Frequency Range** - The ASD levels given in Table 4.28-4 are based on measured spectra from a large number of records on a variety of jet and propeller- driven aircraft. The flight conditions are those which are known to cause vibration, and the frequency limits associated with each condition (see Table 4.28-5) are based on considerations of the input spectra causing the vibratory response.

2.3.2 **Equipment Location**

2.3.2.1 Aircraft vibration measurements have shown that where equipment is mounted close to the main structure, vibration levels are higher than for equipment which is mounted well within the structure (where the vibration transmission paths are long). Accordingly, two of the regions of equipment location used in the specification (Regions

A and B) are defined rather loosely in terms of transmission path length. It may be objected that a loose definition is undesirable but it is felt that the possibility of equipment being classed in the wrong region is less with the definition given than it would be if the regions were defined in more rigid terms.

2.3.2.2 Two further equipment regions, Regions C and D, are included to cover the special cases of equipment mounted in racks and equipment mounted close to power plants. Where equipment is rack-mounted, the vibration environment will be a function of the dynamic characteristic of the rack and of other equipments in the rack. Vibration levels for these regions are under consideration.

2.3.3 **Duration**

2.3.3.1 It is intended that wherever possible, the duration of the vibration endurance test shall be directly related to the duration in the environment which the equipment will have to withstand in service. However, in many cases, the endurance test would then be unacceptably long and maximum of 50 hours endurance has been specified.

2.3.3.2 Once the equipment life in each of the flight conditions has been specified, a test schedule can be drawn up which will require so many hours testing in each of a number of vibration categories and band widths. The duration of the vibration test will depend on this schedule, subject to the 50 hours maximum mentioned above.

2.3.3.3 It is anticipated that a test duration equal to the equipment service life will in most cases be impracticable. The procedure to be adopted is to limit the endurance test to 50 hours. If the service life includes 50 hours or more in the most severe category of vibration, then the endurance test will have a duration of 50 hours in that category. If the service life in the most severe category is less than 50 hours, then the service lives in the other categories should be expressed in terms of equivalent lives in the most severe category and added to the service life in that category. The total life thus sustained will be the duration of the endurance test, subject to a maximum of 50 hours. The method of calculating the equivalent life in the most severe category is based on the assumption that for equal fatigue damage at different vibration levels the test duration varies inversely as the fifth power of the displacement or acceleration level. (Where the vibration level is quoted in terms of acceleration spectral density [that is, acceleration^2 per cycle per second] the power relationship is 2.5) The choice of the fifth power is based on experience of equipment failures, though it must be admitted that convincing quantitative evidence supporting a fifth power law (rather than, say fourth or sixth power law) is lacking.

2.4 Alternative Test Procedures

2.4.1 **Narrow Band Random Sweep** - A narrow band sweep test is often an attractive alternative to a wide band random test because the control equipment is a good deal cheaper and the power requirements of the exciter are smaller. For items of commercial equipment designed for this type of test the control problem is approached in various ways, and it would not be possible to specify precisely how the various parameters such as sweep rate and band width should be controlled without restricting the development of improved techniques by manufactures of test equipment. It may be noted, however, that in general the narrow band random sweep test takes longer than the wide band random test and it has the disadvantage of exciting only one mode at a time.

2.4.2 Sinusoid with Frequency Sweep

2.4.2.1 As this type of test is the type most commonly used in the vibration testing of aircraft equipment at the present time, it is likely that it will continue to be in wide use until equipment manufactures are able to take advantage of more realistic vibration conditions obtainable with random motion test facilities. Nevertheless, the need to include, in general specification, a sinusoidal test which purports to be the equivalent of a random motion tests, (and there have been many such derivation) succeeds only if a number of assumptions are made about the fatigue and dynamic characteristics of the item tested, and fails because in the vast majority of items the assumptions are not valid.

2.4.2.2 The derivation of the sinusoidal tests of this specification is based firstly, on the need to ensure that the sinusoidal test is no less severe than the random test for which it is substituted and secondly, that the sinusoidal test is one which can be easily carried out on conventional test rigs with commercially available equipment .

2.4.3 **Endurance at Fixed Frequencies** - There are certain items of equipment that have well-defined mechanical resonances whose source may readily be detected. For such items there is no need to make a frequency sweep endurance test, since the frequencies at which the item is susceptible to vibration damage are known and the test can be made at these frequencies. Moreover, since the resonance frequencies can be detected, it follows that, in general, it will also be possible to measure the Q values of the resonances, and these values may then be used to calculate the amplitude levels for the test. Because of this, tests at resonance frequencies should be more realistic than sweep frequency tests whose amplitude levels are based on assumed values of Q. It may be noted that tests at resonance frequencies will be of shorter duration than sweep frequency tests because the whole of the test is made at the damaging frequencies whereas proportion of the sweep frequency test is occupied in sweeping through frequency bands where there are no resonances to cause damage.

2.5 **Test Sequence**

2.5.1 **Resonance Search Tests** - his specification calls for resonance search tests both before and after the endurance test. The object of the resonance search tests is three fold:

a) To enable a comparison to be made of the dynamic characteristics of the item before and after endurance testing so that vibration damage can be assessed.

b) To pinpoint resonance frequencies and other such frequencies at which malfunction occurs so that they may, if necessary, be compared with aircraft natural frequencies.

c) To check resonances that occur below 10 Hz.

2.5.1.1 A desirable feature of any aircraft equipment is that its resonance frequencies should not coincide with the resonance frequencies of the aircraft in which it is installed. It is frequently impracticable to make this an aim in equipment design, because the equipment may be designed for installation in a range of aircraft, or because aircraft resonance frequency data are not available. One of the benefits of a resonance search test is that it establishes the resonance frequencies of the equipment so that the aircraft/equipment comparison can be made as and when aircraft data become available.

2.5.1.2 The specification aim that no resonances of the equipment shall occur below 10 Hz has been included partly because it is advisable to avoid equipment resonance which are in the frequency range of the fundamental wing and fuselage modes of the aircraft, and partly because there is a very wide variation of vibration levels at very low frequency. Experience shows that where equipment suffers damage from vibrations with frequencies less than 10 Hz, it is generally because there is an equipment resonance whose bandwidth overlaps the bandwidth of an aircraft resonance, and the equipment resonance can often be eliminated by a minor change in design.

2.5.2 **Malfunction** - As the vibration test has been considered as a fatigue test the specification may appear to have bias towards equipment failure caused by fatigue. Nevertheless, from the reliability viewpoint, failure of any sort cannot be tolerated, and many items of equipment may malfunction in a vibratory environment without suffering a fatigue failure. It is important in the testing procedure therefore, to check that the equipment does not malfunction throughout the levels of vibration that it will experience in service. The tolerances on equipment performance that are permitted must of course, be stated in the relevant equipment specification.

2.6. Guidance on the use of the Specification

2.6.1 **Data Required** - For full use to be made of this specification, the relevant equipment specification should supply details under the heading shown in Item 5 (Section 4) which lists the nature of the information required and the clause of the specification in which the detailed requirements may be found.

2.6.1.1 Much of the data required is straight forward to supply and is common to many vibration test specifications. Guidance may, however, be needed on the data relating to the flight environment and on the way in which the data are converted into a practical test schedule.

2.6.1.2 It is attempted here to give such guidance, firstly by discussing in general terms how the test details should be arrived at, and secondly, by giving numerical examples. For brevity it is based on the assumption:

a) That the vibration test sequence consists of an endurance test, preceded and followed by resonance search test, and that the only outstanding question is to define the conditions for the endurance test;

b) That the flight environment has been designed in term of a number of hours in each of the flight conditions listed in Table 4.28-5 and that equipment region has been specified as in clause 4.2.2.2(a).

2.6.2 Details of Test procedure

2.6.2.1 Although the availability of test equipment will largely determine the nature of the endurance test, in particular whether a random or sinusoidal test can be made, it is emphasized that where possible the test should be made with random input. It may appear more attractive to make a sinusoidal test because, in general, shorter test times are required. This should not be allowed to obscure the fact that the sinusoidal test will be less representative of the aircraft environment, and may also be more severe than the random motion test because of the assumption that must be made in deriving and `equivalent' sinusoidal schedule.

2.6.2.2 If, however, a sinusoidal test must be made, there is a choice between a frequency sweep and a test at each resonance frequency. The latter test is preferred if the equipment is of such simple structural design that all the resonances in the relevant frequency range can be identified. If each resonance can be identified, it is probable that the Q of the resonance can be measured, and this additional data allows a more realistic test level to be calculated (from the formula given in clause 3.4.7.5) than that obtained from the sinusoidal test curves (for which conservative values of Q were assumed).

2.6.2.3 It is important that tests at resonance frequencies should not be made on equipment whose design is such that there may be difficulty in identifying every resonance. Thus `black-box' equipment, or indeed, any type of structurally complex equipment, should not be tested solely at identifiable resonance frequencies but should be subject to a frequency sweep. Simple equipment consisting of one of two structural members can most appropriately be tested at resonance frequencies.

2.6.2.4 There is frequently confusion about the measurement of Q, which is described in the specification as `dynamic magnification factor. The description is not universally adopted, but Q is always defined numerically in the same way, namely:

$$Q = \frac{f_0}{f_2 - f_1}$$

Where f_0 is the frequency of maximum displacement response known as the resonance frequency, and f_2 and f_1 are frequencies immediately above and below f_0 at which the displacement response is $(1/2)^{1/2}$ that at f_o (f_2-f_1 is the bandwidth at the half power points f_2 and f_1).

2.6.3 **Numerical Examples Illustrating the Method of Evolving Vibration Severity for Airborne Equipment**

2.6.3.1 Example 1

2.6.3.1.1 Data supplied

a) The equipment is in reverberant enclosure in Region A of a subsonic jet transport aircraft having a mean flight duration of 5 hours.

b) Equipment life required is 3 000 hours made up as follows:

Atmospheric turbulence (normal)	30 hours
Normal runway operation	51 hours
High external noise > 140 dB	30 hours
High external noise > 150 dB	12 hours
Cruise (subsonic)	2877 hours

2.6.3.1.2 **Conversion of Data using Table 4.28-5**

Time (Hours)	Vibration Category	Frequency Range (Hz)
30	3	10-60
51	3	10-60
30	3	60-1000
12	4	60-1000
2877	1	10-1000

Which reduces to :

81	3	10-60
30	3	60-1000
12	4	60-1000
2877	1	10-1000

2.6.3.1.3 **Determination of Endurance Test Conditions**

a) For the frequency range 10-60 Hz the most severe category is 3 and since 81 > 50, the duration will be 50 hours.

b) For the frequency range 60 - 1000 Hz the most severe category is 4, but since 12 < 50, it will be necessary to evaluate what duration in category 4 are equivalent to 30 hours in category 3 and 2877 hours in category 1, using Table 4.28-6 the total duration in category 4 will be :

$12 + 0.177 \times 30 + 0.00056 \times 2877$
$= 12 + 5.3 + 1.6 = 18.9$ hours

As 18.9 < 50; the test for frequency range 60 to 1000 Hz will be 18.9 hours at category 4 level.

c) Thus, the wide band random vibration test severity will be :

i) 10 - 60 Hz, category 3, 50 hours.

ii) 60 - 1000 Hz, category 4, 18.9 hours

d) If a sinusoidal sweep test is to be made, the duration (see Note in clause 3.4.6.2) will be

i) (50 x 0.4) = 20 hours, category 3, 10 - 60 Hz .

ii) (18.9 x 0.6) = 11.3 hours, category 4, 60 - 1000 Hz.

e) The amplitudes of sinusoidal vibration, corresponding to category 3 and 4 can be deter-mined from Fig. 4.28-7. These are:

Category	Frequency Range Hz	Constant Amplitude Displacement/ Acceleration
3	10-60	$10 m/s^2$
4	60-85	0.10 mm
4	85-1000	$28.3 m/s^2$

2.6.3.2 **Example 2**

2.6.3.2.1 **Data Supplied**

a) Equipment is in an absorptive enclosure in Region B of a supersonic low level strike aircraft.

b) The equipment life required is 1 000 hours made up as follows:

Atmospheric turbulence (severe)	10 hours
Atmospheric turbulence (normal)	20 hours
Unprepared runway operation	10 hours
Normal runway operation	80 hours
High external noise > 150 dB	10 hours
Aerodynamic buffeting	10 hours
Low level high speed flight	20 hours
Cruise (supersonic)	120 hours
Cruise (subsonic)	720 hours

2.6.3.2.2 **Conversion of Data using Table 4.28-5.**

Time (Hours)	Vibration Category	Frequency Range (Hz)
10	3	10-60
20	2	10-60
10	4	10-60
80	2	10-60
10	2	60-1000
10	2	10-1000
20	2	10-1000
120	1	10-1000
720	(negligible)	

Which reduces to :

10	4	10-60
10	3	10-60
100	2	10-60
10	2	60-1000
30	2	10-1000
120	1	10-1000

2.6.3.2.3 **Determination of Endurance Test Conditions**

a) For the frequency range 10 - 60 Hz the most severe category is 4 and using Table 4.28-6, the total duration will be:

$$10 + (0.177 \times 10) + (0.031 \times 100) + (0.031 \times 30) + (0.000\,56 \times 120) \simeq 10 + 1.8 + 3.1 + 0.9 + 0.1 = 15.9 \text{ hours.}$$

Since 15.9 < 50, the total duration for endurance in category 4 for the frequency range 10 - 60 Hz should have a duration of 15.9 hours.

Note - The fourth and fifth terms above are obtained from the 30 and 120 hours in categories 2 and 1 respectively, both of which include the frequency range 10 to 60 Hz.

b) For the frequency rang 60- 1 000 Hz the most severe category is 2, and the total duration will be :

$$10 + 30 + (0.018 \times 120) \simeq 42.2 \text{ hours.}$$

As 42.2< 50, the endurance test at category 2 level for the frequency 60 to 1 000 Hz should have a duration of 42.2 hours.

c) Thus , the wide band random vibration test severity will be :

i) 10 - 60 Hz, category 4, 15.9 hours.

ii) 60 - 1 000 Hz, category 2, 42.2 hours.

Note - To save test time, it is possible to combine the tests in both frequency bands so that 15.9 hours of test is made to a spectrum having an ASD level of 2 $(m/s^2)^2$/Hz from 10 to 60 Hz, and 0.5$(m/s^2)^2$/Hz from 60 to 1000 Hz followed by 26.3 hours to a spectrum of zero from 10 to 60 Hz and 0.5 $(M/s^2)^2$ /Hz from 60 to 1000 Hz

d) If a sinusoidal sweep test is to be made, the test severity will be :

i) (15.9 x 0.4) $\simeq$ 6.4 hours, category 4, 10 to 60 Hz.

ii) (42.2 x 0.6) $\simeq$ 25.3 hours, category 2, 60 to 1 000 Hz.

2.6.3.3 **Example 3**

2.6.3.3.1 **Data Supplied**

a) Pilot static boom externally mounted on a research aircraft.

b) Boom life is 500 hours made up as follows:

Atmospheric turbulence (normal)	20 hours
Normal runway operation	50 hours
Low level high speed flight	100 hours
Cruise (supersonic)	100 hours
Cruise (subsonic)	230 hours

2.6.3.3.2 **Conversion of data using Table 4.28-5.**

Time (Hours)	Vibration Category	Frequency Range (Hz)
20	3	10-60
50	3	10-60

100	3	10-1000
100	2	10-1000
230	1	10-1000

Which relates to:

70	3	10-60
100	3	10-1000
100	2	10-1000
230	1	10-1000

2.6.3.3.3 **Determination of Endurance Test Conditions**

a) For the frequency rang 10-60 Hz the most severe condition is category 3, and since 70> 50, the duration will be 50 hours.

b) For the frequency range 60- 1 000 Hz (which is included in 10 - 1000 Hz) most severe condition is again category 3 and since 100 > 50 the duration will be 50 hours.

c) Thus, the wide band random motion severity will be:

i) 10 - 60 Hz, category 3, 50 hours.

ii) 60 - 1 000 Hz, category 3, 50 hours.

Since the category and duration are same for the two frequency ranges, the test severity will be 10 to 1 000 Hz, category 3, 50 hours.

d) If a sinusoidal sweep test is to be made, the test severity will be:

(50 x 1.0) = 50 hours, category 3, 10 - 1000 Hz.

e) If a sinusoidal test at resonance frequencies is made, it will first be necessary to measure the resonance frequencies, and Q of the resonance may be measured at the same time. Supposing that the results of these measurements are:

Mode	Frequency Hz	Q
1st	15.0	160

2nd	54.2	107
3rd	72.1	184
etc.	etc.	etc.

Then using the formula for amplitude level given in clause 3.4.7.5 (a) for the mode at 15.0 Hz gives:

(50 x 0.025) = 1.25 hours at an amplitude of :

$d = 118.4\ [1.0/160\ (15.0)^3]^{1/2} = 0.160$ mm

For the modes at 54.2 Hz, 72.1 Hz and higher order, similar schedules are obtained.

2.6.3.4 **Example 4** Table 5.28.2-1 and 5.28.2-2 derive test times on the lines of the previous examples for equipment in a subsonic jet transport aircraft having a mean flight duration of one hour.

2.6.3.5 **Example 5** Table 5.28.2.-3 and 5.28.3-4 derive test times on the lines of the lines of the previous examples for equipment in a light piston engined propeller driven aircraft having a mean flight duration of one hour.

TABLE 5.28.2-1 SUBSONIC JET TRANSPORT AIRCRAFT MEAN FLIGHT DURATION 1 HOUR EQUIPMENT REGION A (Clause 2.6.3.4)

CONDITION	CATEGORY	TIME FOR 1000 HOURS LIFE (Hours)	FREQUENCY RANGE (Hz)	RANDOM VIBRATION TEST TIME AT HIGHEST CATEGORY IN FREQUENCY RANGE (Hours)
Atmospheric turbulence (severe)	-	-	-	-
Atmospheric turbulence (normal)	3	50	10-60	50
Unprepared runway operation	-	-	-	-
Normal runway operation	3	85	10-60	85
High external noise (> 140 dB)	2	50	60-1000	8.75
High external noise (> 150 dB)	3	20	60-1000	20
High external noise (> 160 dB)	-	-	-	-
Aerodynamic buffeting	-	-	-	-
Low level high speed flight	-	-	-	-
Cruise (supersonic)	-	-	-	-
Cruise (subsonic)	1	795	10-1000	2-5

Total test time (wide band random vibration)

50 hours, category 3, 10-60 Hz
31.25 hours, category 3, 60-1000 Hz
That is 31.25 hours, category 3, 10-1000 Hz
18.75 hours, category 3, 10-60 Hz

TABLE 5.28.2-2 SUBSONIC JET TRANSPORT AIRCRAFT MEAN FLIGHT DURATION 1 HOUR EQUIPMENT REGION B (Clause 2.6.3.4)

CONDITION	CATE GORY	TIME FOR 1000 HOURS LIFE (Hours)	FREQUENCY RANGE (Hz)	RANDOM VIBRATION TEST TIME AT HIGHEST CATEGORY IN FREQUENCY RANGE (Hours)
Atmospheric turbulence (severe)	-	-	-	-
Atmospheric turbulence (normal)	2	50	10-60	50
Unprepared runway operation	-	-	-	-
Normal runway operation	2	85	10-60	85
High external noise (> 140 dB)	2	50	60-1000	55 min
High external noise (> 150 dB)	3	20	60-1000	20
High external noise (> 160 dB)	-	-	-	-
Aerodynamic buffeting	-	-	-	-
Low level high speed flight	-	-	-	-
Cruise (supersonic)	-	-	-	-
Cruise (subsonic)	-	795	-	-

Total test time (wide band random vibration)

50 hours, category 3, 10-60 Hz
20 hours 55 minutes, category 3, 60-1000 Hz

NOTE : Tests could be made simultaneously, as suggested in the Note in 2.6.3.2.3 (c)

TABLE 5.28.2-3 LIGHT PISTON-ENGINED PROPELLER DRIVEN AIRCRAFT MEAN FLIGHT DURATION 1 HOUR EQUIPMENT REGION A

(Clause 2.6.3.5)

CONDITION	CATE GORY	TIME FOR 1000 HOURS LIFE (Hours)	FREQUENCY RANGE (Hz)	RANDOM VIBRATION TEST TIME AT HIGHEST CATEGORY IN FREQUENCY RANGE (Hours)
Atmospheric turbulence (severe)	-	-	-	-
Atmospheric turbulence (normal)	3	10	10-60	1.75
Unprepared runway operation	4	10	10-60	10
Normal runway operation	3	90	10-60	16
High external noise (> 140 dB)	-	-	-	-
High external noise (> 150 dB)	-	-	-	-
High external noise (> 160 dB)	-	-	-	-
Aerodynamic buffeting	-	-	-	-
Low level high speed flight	-	-	-	-
Cruise (supersonic)	-	-	-	-
Cruise (subsonic)	1	890	10-1000	0.5 (10-60 Hz) 890 (60-1000 Hz

Total test time (wide band random vibration)

28.25 hours, category 4, 10-60 Hz
50 hours, category 1, 60-1000 Hz

TABLE 5.28.2-4 LIGHT PISTON-ENGINED PROPELLER-DRIVEN AIRCRAFT MEAN FLIGHT DURATION 1 HOUR EQUIPMENT REGION B (Clause 2.6.3.5)

CONDITION	CATE GORY	TIME FOR 1000 HOURS LIFE (Hours)	FREQUENCY RANGE (Hz)	RANDOM VIBRATION TEST TIME AT HIGHEST CATEGORY IN FREQUENCY RANGE (Hours)
Atmospheric turbulence (severe)	-	-	-	-
Atmospheric turbulence (normal)	2	10	10-60	0.25
Unprepared runway operation	4	10	10-60	10
Normal runway operation	2	90	10-60	2.75
High external noise (> 140 dB)	-	-	-	-
High external noise (> 150 dB)	-	-	-	-
High external noise (> 160 dB)	-	-	-	-
Aerodynamic buffeting	-	-	-	-
Low level high speed flight	-	-	-	-
Cruise (supersonic)	-	-	-	-
Cruise (subsonic)	-	890	-	-

Total testing time (wide band random vibration)

13 hours, category 4, 10-60 Hz

SUB SECTION 5.29

ROADABILITY TEST

1. GENERAL

1.1 This sub-section together with the procedure 1 and 2 specify Roadability Test requirements for military systems having a mobile ground role. The guidance on application of these procedures are given below.

2. SCOPE

2.1 In general, repeated shock and jolting of moderate level can occur in wheeled vehicles (i.e., system shelter assemblage) travelling over various types of tracks. The cross country courses produce severe but infrequent shock conditions. In formulating a test, the courses and distances selected should take account of the anticipated use of the vehicle. Roadability Test formulated to include the movement over the types of terrain representative of more severe conditions of deployment, are more realistic than laboratory tests since they reproduce the combination of vibration and shock stressing that occurs in the field. Such tests should be used to supplement the vibration test and the Bump and Bounce tests. The Roadability Test may be used in lieu of these laboratory tests, where the system or parts are too large to be accommodated in laboratory test facilities, or for the purpose of formal approval where sufficient depth of laboratory testing has been carried out during development to establish confidence in the design. It is important to reproduce during test the more adverse stowage arrangements which could arise in normal use. For example, excessive tightening of webbing straps could prevent equipment movement during the test and limit the damaging effects, whereas in field use relaxation of the tension in the straps or inadequate tightening could produce the repeated shock effects described above.

3. TRIAL PROCEDURE

3.1 The equipment in the system shall be stowed and prepared in the manner in which they would be transported in use and shall be subjected to a Roadability Test as detailed in the equipment specification. Unless otherwise specified, the test shall be carried out in a series of cycles, standardised combination of distances, and courses. The relevant specification shall specify the Test severities (number of cycles) appropriate to the vehicle and the terrain of deployment.

4. INFORMATION TO BE SPECIFIED

4.1 The relevant specification states :-

4.1.1 The preparation and stowage requirements

4.1.2 Test severities (number of cycles to be applied)

4.1.3 Requirements for operational and performance demonstrations.

5. TRIAL DURATION

5.1 For wheeled vehicle equipment a trial consisting of one cycle would be applied for purposes of establishing design confidence during development or for application to equipment subject only to occasional movement in the field. A trial consisting of three cycles would normally be applied to equipment subject to prolonged movement, in order to demonstrate an adequate life.