REPLY TO PREBID QUERIES (PREBID MEETING HELD ON 28 NOV 23)
PROCUREMENT OF FIRE WARNING SYSTEM (FWS) FOR SINDHUGHOSH CLASS SUBMARINE
RFP NO - TM(M) / 0025 / DSMAQ / FWS DATED 17 OCT 23

Ser	Query	Page	RFP Reference	Reply / Clarifications
1	Number of compartments for the system	1	RFP heading : Request for Proposal by MoD GoI for procurement of Fire Warning System for Sindhughosh Class Submarine.	To be as per RFP and as clarified during Pre-bid meeting.
2	How the Factory Acceptance Test will be performed for the system	8	Para 9 of Part I of RFP.	To be as per RFP. Factory Acceptance Trials will be in accordance with ATP. The draft ATP will be submitted by the Bidder, the same will be vetted and approved by NHQ.
3	As Per Part - General Requirements Para 12 Warranty: The deliverables supplied shall carry a warranty for 12 months post completion of HATs onboard submarine or 36 months from the date of completion of JRI whichever is earlier . As Per Appendix C Para 2: the seller warrants fora aperiod of 12 Months from the date of successful installation and commissioning or 36 months fron the date of JRI whcihever is earlier. Request confirem that warranty shall be as per App C Para 2.	9	Part - I Para 12 of RFP	To be as per RFP. Commissioning of system will be on successful completion of HATs of system.

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Ser	Query	Page	RFP Reference	Reply / Clarifications
4	FET on board submarine may not be safe due to temporary laid cables requiring hatches and doors to be kept open. It is recommended that FET be conducted in Sellers premises on truncated system confirm.	13	Part - II Para 34 of the RFP	To be as per RFP. Venue and date for FET will be intimated to Technically compliant bidders in accordance with guidelines promulgated in DAP 2020.
5	It is understood that offering of equipment would be required for user trials, technical trials etc. after submission of bid. Please specify the tentative schedule of start of field evaluation trials.	14	RFP - Part-II Para 40	To be as per RFP. Venue and date for FET will be intimated to Technically compliant bidders in accordance with guidelines promulgated in DAP 2020.
6	(a) How many equipment would be requested to be provided? (b) Will there be manpower required along with the system? (c) How many systems are required? (d) What is the duration of test and outcome? (e) Should bidder take care of the logistics if the system is to be deployed in different locations	14	Para 40 of RFP	To be as per RFP. All queries have been already addressed in relevant sections of RFP. Vendors / Bidders are requested to read the RFP in totality prior submitting their bids.
7	**RFP Section 41:** As per this section the equipment proposed will be technically evaluated in trials and then only the commercial bid will be opened, which means the FWS needs to be ready physically for Technical Evaluation or it is the Tech evaluation of the Proposal?	15	Para 41 of the RFP	To be as per RFP. Refer to Para 34 and Appendix G of the RFP for clarification regarding conduct and requisites of FET.

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Ser	Query	Page	RFP Reference	Reply / Clarifications
8	Distance between MCP & PS and type of communication to be used is not clear and if there is any suggestion on the type of controller to be used	20	Technical Parameters of Appendix A to RFP.	To be as per RFP and as clarified during Pre-bid meeting.
9	The Preference on the make for the display unit, if any.	20	Para 5 & 6 of Appendix A to RFP	To be as per RFP. Minimum specification required for the Display is placed at Annexure 'A'.
10	Specifications of the following sensors to be used:- a) IR-UV Sensor b) Motion Sensor c) Pressure Sensor d) Smoke Sensor	21	Para 4 of Appendix A to RFP	To be as per RFP. The details are placed at Annexure 'B'.
11	Number of sensors needed for the fire detection in each compartment	21	Para 4 of Appendix A to RFP	To be as per RFP. The details are placed at Annexure 'B'.
12	Degree of protection is mentioned IP 65 in RFP document. Please specify the standard (Scuh as IEC 60529) to be followed	21	Appendix A Para 3 (m)	To be as per RFP.

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Ser	Query	Page	RFP Reference	Reply / Clarifications
13	Water resistant & self cooling with IP 65 is difficult to manufacture Recommending IP 44	21	Para 3(l) & Para 3(m) of Appendix A	To be as per RFP. *Broad Operational Parameters* - Para 3(m) of Appendix A to RFP defines the generic requriement of the FWS system to be IP-65 compliant. Para 9(n) of the Appendix A to RFP explains the standard for ingress protection for control panel (CDU). Para 25 of Appendix A to RFP explains that, for equipment that are sealed are to be 'Water Tight' as mentioned at Para 25(a)(iv) and Para 25(b)(iv).
14	As per RFP the system configuration consists of 02 nos CDUs and 04 nos. of Planetary Units (PS). The use of planetary Units is not as per existing configuration fo systems fitted on Naval vessels. It is recommended that the system requirements be as per promulgated EED-50-23 Specification of addressable Automatic fire Detection System for Naval Ships	21	Para 4 of Appendix A	To be as per RFP
15	As per appendix A para 4 (d) (v) Pressure Sensor is part of Sensors used in configuration of Fire Warning System. Kindly clarify what type of data is to be displayed on CDUs panel from this pressure sensor and is it to be utilised in any function of fire Warning System.	21	Para 4 (d) (v) of Appendix A	To be as per RFP.
16	Elaborate on the Planetary subunits and the list of the items to be supplied	22	Para 5 & 6 of Appendix A to RFP	To be as per RFP. Refer to Para 6 of Appendix A of the RFP

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Ser	Query	Page	RFP Reference	Reply / Clarifications
17	Elaborate on manual call points and the items which are to be supplied	22	Para 5 of Appendix A to RFP	To be as per RFP.
18	Type of sensors is mentioned in the clause. However, quantity & location of each type of sensors is required to be included in offer. Please specify.	22	Appendix-A Para 4 (d)	To be as per RFP. The details are placed at Annexure B
19	Quantity to be define in each category of sensors	22	Para 4(d) of Appendix A	To be as per RFP. The details are placed at Annexure B
20	Clarify the demand of higher atmospheric pressure 10kg/cm2	22	Para 5(c) of Appendix A	To be as per RFP.
21	As per RFP the system configuration consists of 02 nos CDUs and 04 nos. It also states redundancy and control between cDUs and Planetary Units (PS). It is recommended that the system requirements be as per promulgated EED-50-23 specification of Addressable Automatic Fire detection system for Naval Ships.	22	Para 6 of Appendix A	To be as per RFP.
22	Aluminium 64430 may be better option considering corrosion resistance, Thermal Conductivity, Light weight, paint durability/finish for all electronics modules. For installation material SS 316 will be used. Please suggest.	23	Appendix A Para 8	To be as per RFP.

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Ser	Query	Page	RFP Reference	Reply / Clarifications
23	Required the supporting documents to analyse, IP 65 cabinet requirement to be confirmed since there are technical limitation to control the ventillation	23	Para 9(c), (k) and (n) of Appendix A	To be as per RFP. Broad Operational Parameters - Para 3(m) of Appendix A to RFP defines the generic requriement of the FWS system to be IP-65 compliant. Para 9(n) of the Appendix A to RFP explains the standard for ingress protection for control panel (CDU). Para 25 of Appendix A to RFP explains that, for equipment that are sealed are to be 'Water Tight' as mentioned at Para 25(a)(iv) and Para 25(b)(iv).
24	mentioned document to be provide for analysing the same	24	Para 10 (a) (b) (c) of Appendix A	To be as per RFP. (a) JSS - 55555 - N3-28-2.1 - Annexure 'C'. (b) JSS - 55555 - N3-28-2.2 - Annexure 'C'. (c) MIL-STD-810H - is an open source document. Bidders are requested to download the same from internet.
25	The mentioned document to be provided: DOA (N) ESS guidelines promulgated vide letter no. 66301/policy-07/DQA(N)/QA-07 dated 09 Aug 2016 for ESS	26	Para 12, 14 and 16 of Appendix A.	Reference letter placed at Annexure 'D'

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Ser	Query	Page	RFP Reference	Reply / Clarifications
26	Requirement of 580930/DQA(N)/EL dated 17 Feb 14, to be specified.	27	Para 12, 14 and 16 of Appendix A.	Reference letter placed at Annexure 'D'
27	The enclosure is IP 65 compliant (sealed) then requirement of forced Air Cooling through Blowers, Air Inlet Through EMI/EMC Filters, Heaters for Anti Condensation to be clarified.	29	Appendix A Para 25 (a) & Para 25 (b)	To be as per RFP. Broad Operational Parameters - Para 3(m) of Appendix A to RFP defines the generic requriement of the FWS system to be IP-65 compliant. Para 9(n) of the Appendix A to RFP explains the standard for ingress protection for control panel (CDU). Para 25 of Appendix A to RFP explains that, for equipment that are sealed are to be 'Water Tight' as mentioned at Para 25(a)(iv) and Para 25(b)(iv).

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Ser	Query	Page	RFP Reference	Reply / Clarifications
28	Physical dimention recomending to 500 x 440 x 170 (CDU) and 300 x 160 x 300 (PS)	29	Para 25 of Appendix A	To be as per RFP.
29	Need to clarify offering FET to post submission of techno bid submission	34	Annexure II to Appendix A	To be as per RFP. Venue and date for FET will be intimated to Technically compliant bidders in accordance with guidelines promulgated in DAP 2020.
30	(a) How long is the training expected? (b) Will training be repeated? (c) Will training be an ongoing process? (d) Will there be a requirement for handholding process?	49	Annexure IV to Appendix F	To be as per RFP. All queries have been already addressed in relevant sections of RFP. Vendors / Bidders are requested to read the RFP in totality prior submitting their bids.
31	Installation and integration work is subject to site readiness and availability of submarines after delivery. Hence, it is proposed that the 3% contract value payment for each FWS Installation may be paid against Bank Guarantee, in case of delay in site readiness beyond 120 days post JRI.	55	Appendix H Para 1.4.5	To be as per RFP.
32	It is submitted that for DPSUs, Indeminity Bond in Bank Guarantee may be accepted towards Performance cum Warranty Bond.	55	Appendix H Para 1.4.5	To be as per RFP.

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33	As Per Part II - Technical Paramnerters Field Evaluation trials (FET) Para 40 (b) Technical Trials - It states that other parameters will be evaluated based on bidder certification duly supported by certification by NABL accredited laboratories. However, Para 13 of App A (ET) suggest that environmental tests are to be done on first of the type system. It is requested to clarify whether all qualification tests as per App A para 10 need to be completed for FET (i.e before order placement) or these tests are to be conducted post placement of order. (In this regard, please note that as per Appendix A para 11 EMI/EMC Tests: MIL 461 G EMI/EMC tests are to be done post placement of order)	14, 24, 26	Part - II Technical parameters Field evaluation trials (FET) para 40 (b) Technical trial; Para 13 of App A Appendix A Para 11 EMI/EMC Tests	To be as per RFP. Refer to Para 13 of Appendix A to the RFP. It reads as ".......test will be undertaken on the first of the type item". The tests at Para 10 of Appendix A of the RFP is for the first of the type item. EMI/EMC tests are to be undertaken as per Para 11 of Appendix A of the RFP.
34	(i) Cable **type** (ii) Architecture	21, 22	Para 3(r) and Para 6 of Appendix A	To be as per RFP. Cable / cable gland (type, no of core) - A 10 Core screened ATEX graded cable to be used. Two loop adressable architecture to be considered as the base architecture for system design.

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Annexure A

Display Unit Specification

Ser	**Design Parameter**	**Specification**	**Remarks**
1	Number of Loops supported (Loop Driver Modules)	06 (Minimum) Loop Drivers (127 units for each driver)	For future augmentation and spare
2	Number of Devices per Loop	99 devices (Sensors, Manual Call Point, Hooters)	For future augmentation
3	Display	Backlit Display with a provision to show important parameters at a time with 16 line display panel	Option to reduce brightness for various watches/ display suitable for full darkness operation.
4	Additional Features	Mute/ Silence Buttons Reset System Backlit Buttons	---
5	Built-in Test (BIT)	Automatic and Manual Built-in-Test functionality	To be a PLC based device having BITE automatic fault detection (Buzzer for defects) and diagnosis.
6	Dimension, Weight	As per Para 25(a) of the RFP.	CDU should be compact enough for fitment inside Control Room.
7	Input Voltage	127V, 50Hz single phase 220V, 50Hz single phase or 270 – 320 V DC	Standard voltages available onboard EKM submarines.
8	Degree of Ingress Protection	Minimum IP 65 or above	For reliable operation in unwarranted conditions

Annexure B

FWS - DISTRIBUTION OF SENSORS

Compartment	Levels/ Decks	Smoke Sensor	Fire Sensor	Temperature	Motion / IR UV	Pressure Sensor	Deck Specific
I	Top Deck	4	4	0	2	1	11
I	Middle Deck	9	0	9	9	1	28
II	First Deck	4	4	0	5	1	14
II	Middle Deck	5	2	2	5	0	14
II	Bottom Deck	4	0	2	3	0	9
III	First Deck	3	2	0	4	0	9
III	Middle Deck	4	0	4	4	1	13
IV	First Deck	5	5	0	4	1	15
IV	Hold	5	5	0	3	0	13
V	First Deck	3	3	0	5	1	12
V	Hold	3	3	0	4	0	10
VI	First Deck	3	3	0	2	1	9
VI	Hold	3	3	0	2	0	8
Total as per sensor type		55	34	17	52	7	165

Note :

(a) The number of sensor can be less in case of using Multi function Sensor. However, the funcitonality and capability are not to be compromised.

(b) False alarm susceptability - Direct reflected light, fluorescent light, Electronic Camera flash

(c) Positioning of the sensors has to be in accordance with the capability of the sensor and its ability to meet the requisites as described at Appendix A to the RFP

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):

ENCL
ANNEXURE-C

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/s²

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 recectilinear 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/s^2 constant acceleration
	Level 2	5 to 13 Hz	±6 mm constant displacement
		13 to 142 Hz	±40 m/s^2 constant acceleration
		142 to 201 Hz	±0.05 mm constant displacement
		201 to 2000 Hz	±80 m/s^2 constant acceleration
	b) Equipment installed in Wheeled Vehicles and Trailers	5 to 8 Hz	±6 mm constant displacement
		8 to 500 Hz	±15 m/s^2 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			B		
	f_1 Hz	f_2 Hz	Cate-gory	f_1 Hz	f_2 Hz	Cate-gory
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 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.

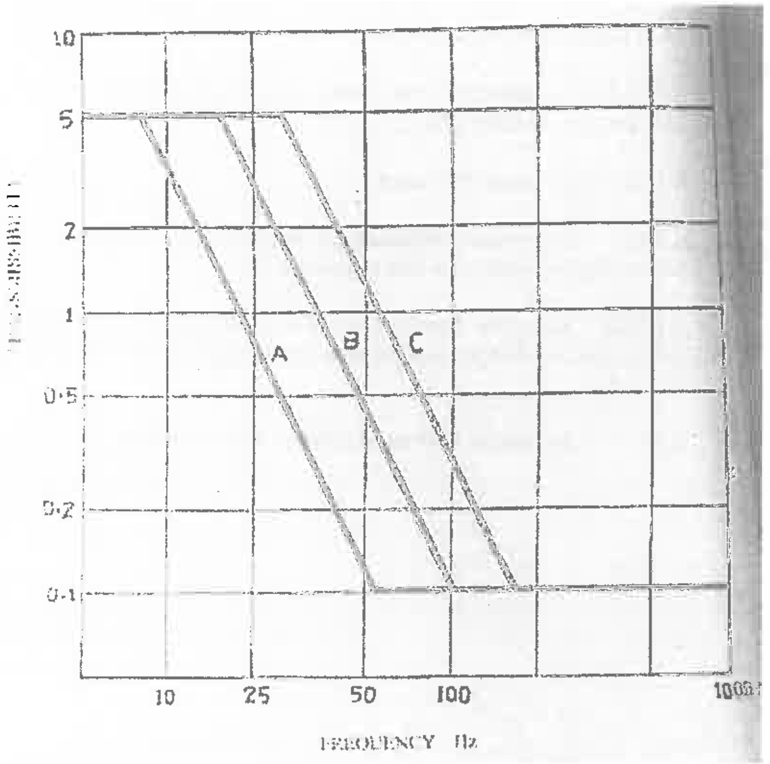


FIGURE 4.28-1GENERALISED TRANSMISSIBILITY FACTOR FOR ISOLATORS

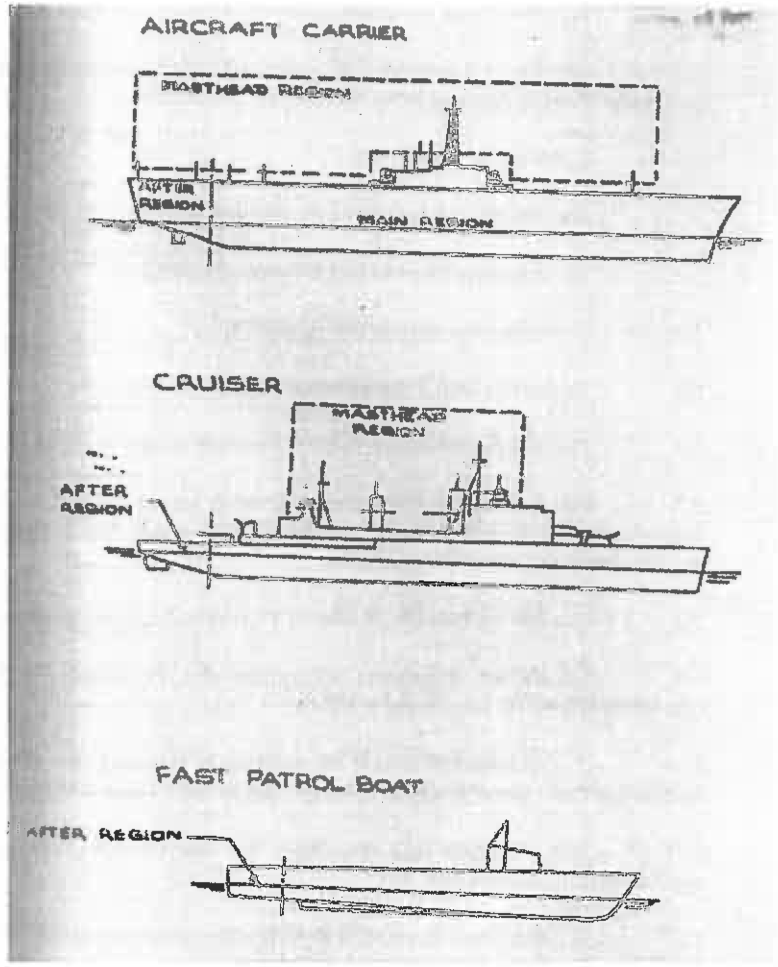


FIGURE 4.28-2 SUB DIVISION OF SHIPS FOR VIBRATION TESTS (PROCEDURES)

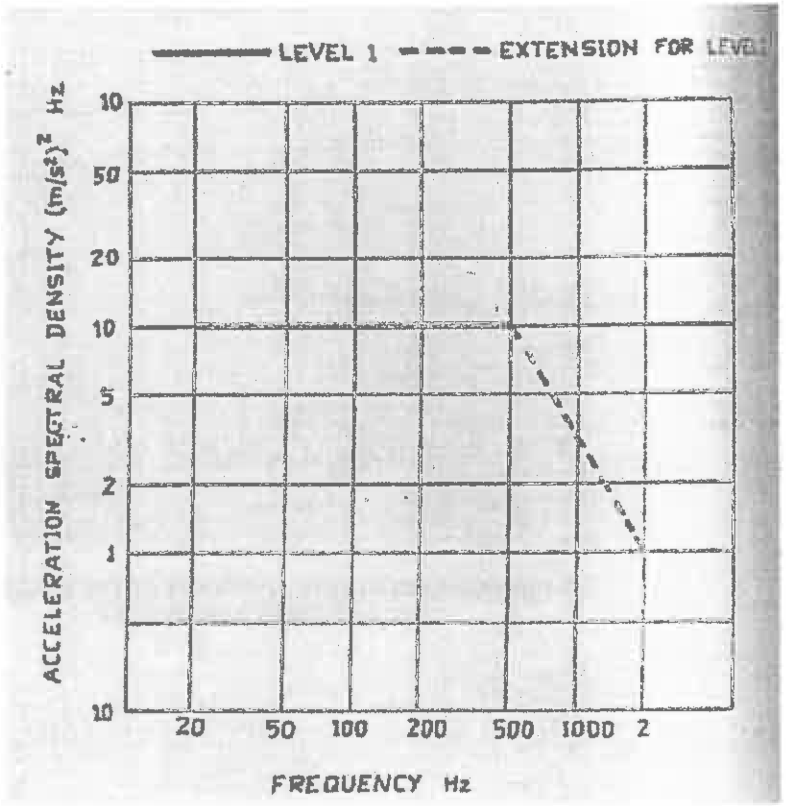


FIG. 4.28-3 RANDOM VIBRATION LEVELS FOR TRACKED VEHICLES

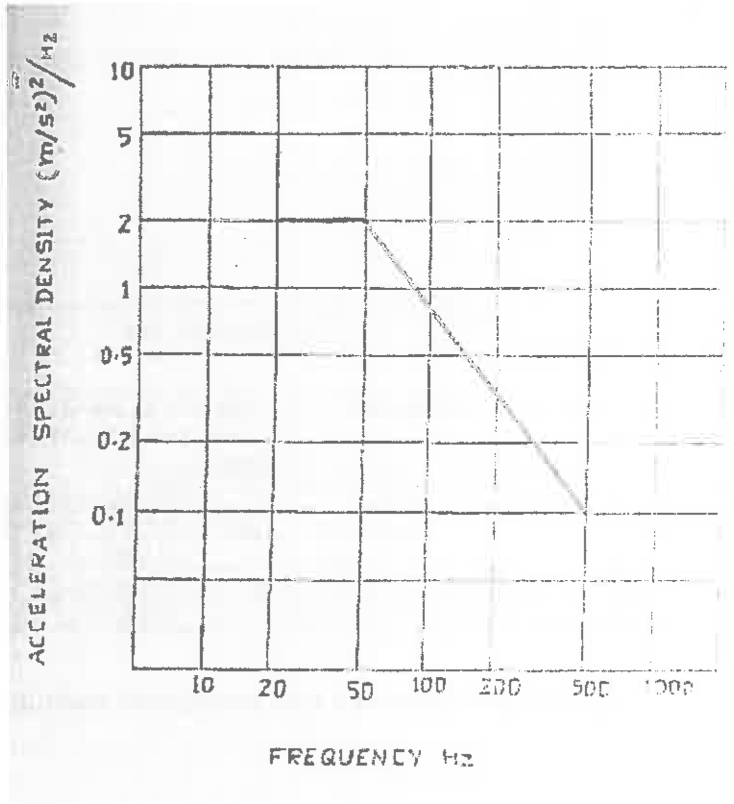
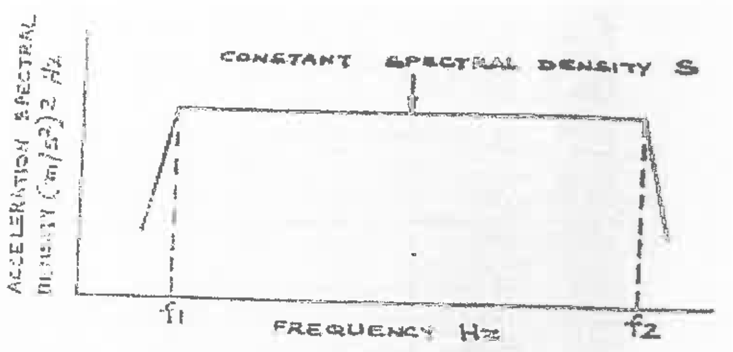


FIG. 4.28-4 RANDOM VIBRATION LEVELS FOR WHEELED VECHICLES AND TRAILERS



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

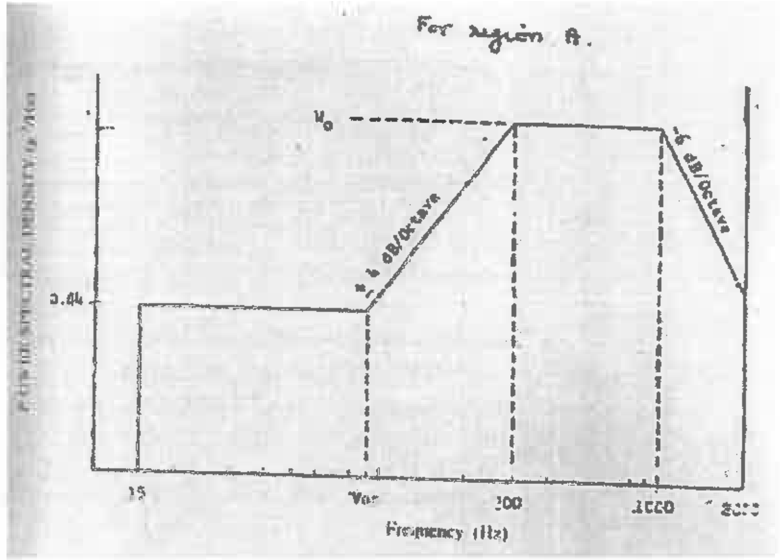
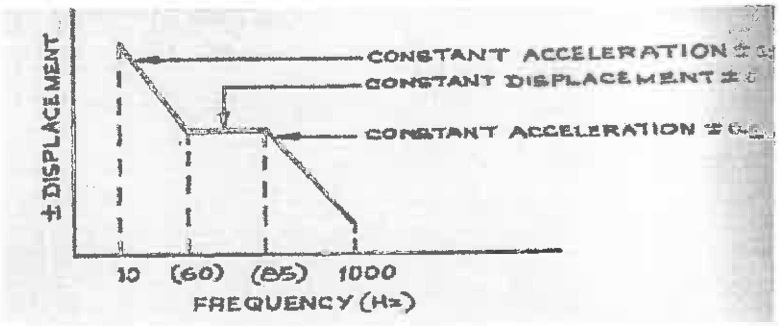


FIGURE 4.28-6 SUGGESTED VIBRATION SPECTRUM FOR JET AIRCRAFT EQUIPMENT



CATEGORY	a1 m/s²	d mm UNITS	a2 m/s²	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

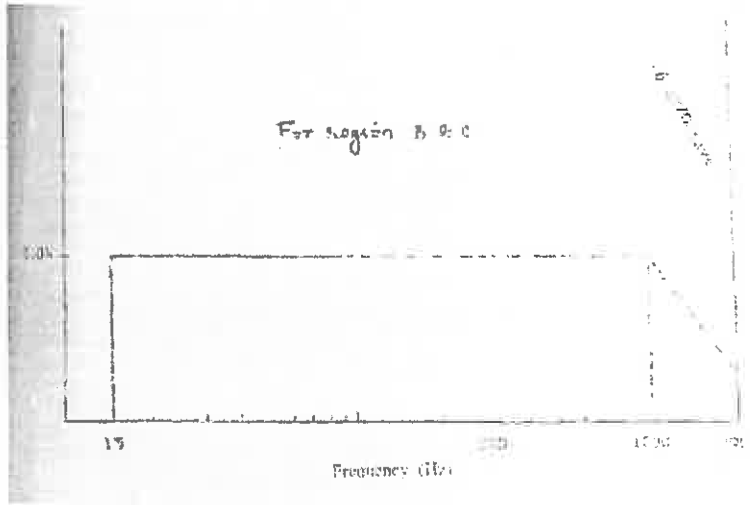


FIGURE 4.28-8 SUGGESTED VIBRATION SPECTRUM FOR JET AIRCRAFT EQUIPMENT

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 :

$$12 + 0.177 \times 30 + 0.00056 \times 2877$$
$$= 12 + 5.3 + 1.6 = 18.9 \text{ hours}$$

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 x 10) + (0.031 x 100) + (0.031 x 30) +
(0.000 56 x 120) ≃10 + 1.8 + 3.1 + 0.9 + 0.1 = 15.9 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 x 120) ≃ 42.2 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) ≃ 6.4 hours, category 4, 10 to 60 Hz.

ii) (42.2 x 0.6) ≃ 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	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	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

ANNEXURE - D

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No.: 66301/Policy-10/DQA (N)/QA-10

14 Jun 2013

BURN IN TESTING OF NAVAL ELECTRICAL/ELECTRONIC EQUIPMENT

1. Refer to DQA (N) letter 66301/Policy-17/DQAN/QA-11 dated 15 Mar 12 (not addressed to all).

2. **Introduction**. Burn-in test is a technique used to assess the capability of equipment to perform reliably by operating it continuously for prolonged duration under normal or accelerated environmental conditions. Burn-in testing is normally conducted at OEM's premises immediately after satisfactory completion of FATS but prior to delivery of the equipment. Essentially, burn-in testing is a form of Environmental Stress Screening (ESS) which was initially devised for systems using vacuum tube technology, with the aim to ascertain impact of 'component drift' on the overall performance characteristics of the system. The concept was subsequently extended to equipment utilizing transistor/IC based component technology despite the fact that it offered relatively higher stability/reliability. It was considered that for these products, high temperature burn-in was the best stimuli for precipitating latent defects. Over the years, burn-in testing has been further extended to new generation equipment and systems and the present policy is governed by DQA (N) letter ibid.

3. **Study Undertaken on Burn-in Testing.** A detailed study on the burn-in testing as a concept was undertaken at this Headquarters keeping in view the advancement in technology and other related issues and the outcome/conclusions arrived at are contained in succeeding paragraphs.

4. **Component/Assembly Technology.** Over the years the electronics industry has matured and component technology/assembly techniques have improved profoundly. Components procured from renowned manufacturers guarantee reliable, pre-screened and ESS compliant products. Similarly, manufacturing technology for PCBs/sub-assemblies has also improved over the years. These changes, as studies reveal, have resulted in significant changes in product fault spectrum. Experimental data gathered during last several years on this subject indicates that the screening stimuli, through traditional burn-in testing, is no longer an effective method for precipitation of latent defects. For this reason, many modern electronic system manufacturers have abandoned constant temperature burn-in as a defect precipitation screen.

Cont. 2/-

5. **Infrastructure Requirement.** For burn-in testing to be effective, it is essential that the equipment under test be continuously operated for prolonged duration in *fully integrated mode,* in non-ac conditions or under higher temperatures for proportionately lesser duration. Also, for optimal results, 'interactions' with the system should also be performed to simulate the actual operating scenario. Considering that the current guidelines specify 168 hrs (7 days) of continuous operation, the infrastructure and manpower requirements are generally substantial.

6. **Undesirable Effects of Burn-in Testing.** It is a fact that there are a number of components, especially high power microwave components, which are 'life-limited' and every hour of operation of such components, reduces their overall operational life. Though this is obviated during burn-in testing by switching on such devices for limited duration only (and not to 168 hrs), the overall life of equipment does get affected.

7. **Feedback on Burn-in Testing.** As per the policy in vogue, all electronic and weapons systems undergo burn-in testing prior to delivery from OEMs premises. Failures observed during the process have been compiled and it is evident that most defects observed are attributable to workmanship, utilization of components from non-qualified vendors/spurious sources and inadequacies in internal quality control and not consequent to burn-in testing as such. In fact, majority of such defects would surface if the ESS is conducted meticulously. Further, difficulties during conduct of Burn-in testing for 168 hrs such as monitoring/checking of parameters for extended duration, manpower constraint, availability of continuous power, requirement of additional infrastructure (in case of large quantity of equipment) have also been brought out by the field agencies/manufacturers in the past.

8. **Procedures in Vogue**. In accordance with this Headquarters letter ibid, burn- in testing is required to be carried out on **all** systems/equipment by continuous operation for a period of 168 hrs prior shipment. The guidelines also cater for switching on of microwave power devices for limited duration only.

9. **Conduct & Applicability of Burn-in Testing**. In light of above, it would be more prudent to carry out Burn-in test with the aim to ascertain the ability of the equipment to perform satisfactorily for prolonged duration by operating it continuously for 'sufficiently long duration' rather than as a test to weed out infant mortality defects. However, it may also not be appropriate to do away with this method of testing for all manufacturers/types of equipment altogether.

10. **Revised Guidelines fo Burn-in Testing.** Following are the revised guidelines to be adhered to for the purpose of conduct of burn-in testing of equipment/systems:-

Cont. 3/-

(a) In case of major equipment such as weapons, sensors, CMS, AISDN etc., the first-of-type system is to be subjected to Burn-in testing. The conduct of the test on the subsequent systems is to be reviewed by the QA agency, in consultation with DQA (N) HQ, depending on the performance of the first system. In taking a decision on this aspect, the capability of the OEM to implement effective ESS processes would be an important criterion. Further, if the first-of-type system has undergone Burn-in testing successfully, the additional systems to be supplied under repeat orders are also to be exempted from Burn-in testing.

(b) In case of electrical/electronic equipment ordered in bulk quantities (greater than 10), burn-in test is to be conducted on the first 10 % of the systems being supplied. Thereafter, depending upon the performance/defects observed, conduct of burn-in test on the subsequent systems to be reviewed. If one batch of supplies have undergone Burn-in testing successfully, the additional batch/systems to be supplied under repeat orders are also to be exempted from Burn-in testing.

(c) **Duration Of Burn-In Testing**. The duration of the 'Burn In' test is to be decided considering the duration of continuous operation envisaged during operational exploitation. The following criteria may be followed:-

> (i) **Systems Requiring Continuous Operation for Prolonged Duration**. In case of equipment requiring continuous operation for prolonged periods (24 X 7 operation like CMS, EW, AISDN, Communication systems etc.) , the burn-in test is to be conducted for 168 hrs at room temperature or 48 hrs at + 55 deg C elevated temperature. Battery operated equipment such as portable WT sets should also be subjected to endurance test of 168 hrs by providing alternate supply arrangement. Transmitting equipment (except SONAR) having life limited elements such as Magnetrons, TWTs, Laser elements should be subjected to 24 hours of endurance test with active elements powered up for 2 hours at a time totaling to 8 hours and equipment in passive/stand-by mode for balance time.
>
> (ii) **Systems Operated Intermittently.** In case of equipment which is operated intermittently, the duration of the burn-in is to be examined on case-to-case basis and finalized in consultation with the OEM. This duration should however be not less than 8 hrs. The duration should be adequate to provide a degree of confidence of system capability to operate continuously for the requisite period. The burn-in test for this category could also be conducted at room temperatures or elevated temperatures as deemed appropriate.

(d) **Performance Monitoring**. System performance should be monitored and health checks to be conducted at regular intervals.

Cont. 4/-

11. In view of the above, following is requested:-

(a) Guidelines at Para 10 above be referred for conduct of burn-in testing of all naval electrical/electronic equipment being inspected.

(b) Comments, if any, which warrant amendment/modifications to these policy directives/guidelines be forwarded to this directorate by 31 Jul 13 for further necessary action.

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No.: 66301/Policy-07/DQA(N)/QA-07 09 Aug 16

All the Establishments under DQA (N)

GUIDELINES FOR ENVIRONMENTAL STRESS SCREENING (ESS) OF NAVAL ELECTRICAL/ELECTRONIC EQUIPMENT

Background

1. Refer to this Directorate letter of even number dated 14 Jun 13.

2. This Directorate, vide letter ibid, have brought out the requirement of carrying out Environmental Stress Screening (ESS) on Electronic items and emphasized about the methodology to be adopted for conduct of ESS. ESS is a product specific programme and therefore, specific screen strength needs to be defined for type of product. Stress screening is a part of manufacturing process in which the simulated environmental stresses are used to screen out those failures that would otherwise occur in the field. The stress should be closely tailored to the equipment's design capability to provide an effective screen without damaging good components.

3. Difficulties in formulating ESS plan has, however, been reported by few manufacturers as per the letter ibid. Most of the manufacturers resorted to use of sample screen strengths of ESS indicated in the letter ibid (for the purpose of guidance), for their ESS programs which were observed to be difficult for implementation on their products.

Aim

4. The aim of this letter is to lay down guidelines for formulation of effective ESS programme and methodology for conduct of ESS on Electronic Components/Units/PCBs/Modules. The guidelines also provide directions to manufacturing agencies to incorporate tests at the design and manufacturing stage to weed out such deficiencies, which can manifest at a later stage causing avoidable down time of the equipment and expensive corrective action thereupon.

Applicability of ESS

5. **Indigenous Manufacturing**. The ESS is to be applied to 100% electronic components/units/assemblies as part of manufacturing process for indigenously manufactured electronics. Hardware incorporating purely mechanical system/elements including wire wrapped backplanes and fragile electronic items viz. LCD panels, Hard Disk Drives etc. may be exempted from ESS.

6. The present guidelines will be applicable for the new POs placed after promulgation of this policy. For all previous POs, ESS plan as per approved QAP may be followed. For new orders pertaining to spares of Systems/Equipment supplied earlier, ESS scheme as per guidelines in vogue/as conducted at the time of delivery of the system would be applicable.

7. **Applicability for Imported/COTS Items**. In case of imported and COTS items, following guidelines will apply:-

(a) During the course of production, a variety of imported/COTS items (components/PCBs/modules) may be used by the manufacturer of main system. ESS on such items is to be carried out at the next higher indenture level. The severities are to be decided based on designed parameter of weakest component as per data sheets of components in order to ensure that there is no damage to the used part whilst conduct of ESS.

(b) However, in case the Imported items are being supplied by the manufacturer in 'As It Is' condition with no addition/alternations, such items are to be accepted based on CoCs clearly endorsing the standards to which the items comply and physical values of test conditions the items have been subjected to ESS.

(c) Use of fully finished COTS items needs to be specifically approved by IHQ MoD(N)/(Professional Dtes)/OPA and are to be accepted against CoCs as in case of 'As It Is' imported items.

ESS Programme

8. It is necessary to conduct ESS at the earliest possible stages where it is possible to reveal latent defects and initiate necessary corrective actions. Following needs consideration while devising effective ESS programme:-

(a) A viable ESS program must be dynamic wherein the screen parameters must be actively managed and tailored to the particular characteristics of the equipment being screened.

(b) Effective ESS program generally involve more than one type of screen.

(c) Thermal cycling and random vibration are considered the first and second most effective screens respectively in identifying latent defects.

(d) While severity of the applied stress screen must be strong enough to effectively reveal the latent defects, care must also be taken not to over-stress the item which could either cause damage or reduction in residual life. At the same time, non-precipitation of latent defects is indication of weak stress level. The stress must conform to stringent level within designed parameters of the weakest component. Design parameters are generally much higher than the operating parameters.

(e) ESS is applied to 100% of the units manufactured including spares and repaired units.

ESS Process Sequence

9. The electronic hardware is recommended to be screened as per the following sequence:-

Stage-1 : Perform thermal cycling screening at PCB level

Stage-2 : Perform random vibration at PCB level or higher indenture

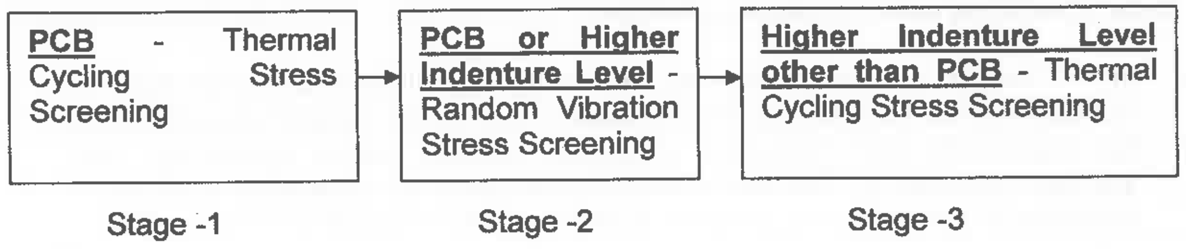
Stage-3 : Repeat thermal cycling screening at an indenture higher than PCB level

10. The conduct of thermal cycling prior to random vibration pre-stresses potential defects which can then be surfaced more effectively by random vibration. Random vibration also conditions some defects to the point of failure which are detected by a subsequent thermal cycling with performance monitoring. All ESS requirements must be accomplished at the lowest feasible level of assembly. The following three indenture levels have been identified for conduct of ESS: -

(a) PCB level

(b) Module/ sub-unit level

(c) Unit/Cabinet level



ESS Flow Diagram

11. **Screens for Conduct of ESS**. A tailored screen requires that specific parameters of equipment being screened, be reviewed such that defects are detected and removed without incurring undue damage to the equipment. The screening levels should not exceed design limits, but they must be of sufficient strength to precipitate failures due to weak parts and manufacturing defects at the earliest time such that corrections are most cost effective. Two screens each for Thermal Cycling Stress Screening (TCSS) and Random Vibration Stress Screening (RVSS) have been defined at **Encl 1 & 2** respectively. **In case a screen with severity below the above two screens is proposed for any item, approval of *Professional Directorate* is to be sought for use of such items with suitable justification. The screen for such cases would then be worked out based on the limitations imposed by the specifications of the items approved to be used.** Accordingly, the applicable screen severities can be categorized as follows: -

(a) **Screen-A (Severe)**. This would be the default screen with most stringent severity based on design parameters of weakest component for effective precipitation of latent defect.

(b) **Screen-B (Moderate)**. To be selected based on parameters of the items necessitating use of screen severity below the above Screen 'A' category. Prior approval for use of such items has to be obtained by the firm from Professional Directorate. The tailored screen would accordingly be specified in the QAP with suitable justifications. Reason for application of this screen for the item instead of Screen 'A' is to be justified in the QAP and list to be attached with QAP.

12. Based on the above process sequence and categorisation of screens, it is proposed to denote the stress severity of products as per the notation "Product (XXX)", where the first "X" represents thermal screen severity for Stage-1, the second "X" represents screen severity for random vibration at Stage-2 and third "X" represents thermal screen severity for Stage-3. For example "Item (ABB)" would indicate that the item is to be subjected to thermal stress as per screen 'A' in Stage-1, random vibration as per screen B in Stage-2 and thermal stress as per screen B in Stage-3. A proposed format for ESS plan is placed at Encl. 3.

13. **Thermal Cycling Stress Screening (TCSS)**. The following aspects are to be considered whilst conducting TCSS:-

(a) The temperature range for thermal cycling should be established by considering the component characteristics and the equipment specifications for maximum and minimum designed values under operating and storage conditions. The temperature range should be as large as component characteristics will permit regardless of the products intended operational limits.

(b) The rate of change of temperature between the extremes must be as rapid as possible to create the optimum level of thermal stress. The minimum acceptable rate of change is 5° C per minute.

(c) The number of cycles is more closely related to the temperature range and rate of change than to the equipment complexity or number of parts. Tailoring of this parameter is generally done based on the analysis of failures observed with the incremental number of cycles.

(d) Dwell time at maximum and minimum operating and storage temperatures should be only enough to achieve thermal stability.

14. **Random Vibration Stress Screening (RVSS)**. The following aspects are to be considered whilst conducting RVSS:-

(a) Random Vibration Stress Screening may be performed preferably at lower indenture level.

(b) The attitude or orientation of item for RVSS shall be decided based on the plane which provides maximum shear force to the soldered joints and components during random vibration. The RVSS is to be conducted preferably in all three axes.

(c) For a module level testing, the fixture shall be structurally rigid without causing resonance and further amplification to the Unit Under Test (UUT).

(d) EUT shall be subjected to sinusoidal sweep between 20-2000 Hz to identify the existence resonance prior to conduct of RVSS. If the equipment resonance frequencies fall within the input frequency range, excessive energy could be seen by the equipment and damage could occur. One of the following two measures may be taken in such cases: -

(i) Modify the equipment design to achieve a more rugged item to obtain a resonance falling outside the input frequency range.

(ii) Make a notch on the input profile eliminating frequency band of 5 Hz before and after the resonating frequency.

15. **Approval of ESS Programme**. The manufacturer is solely responsible for drawing up the ESS programme as the design parameters of the components are known to them. Once the ESS screen is finalized as per Encl.-1&2, the same is to be submitted to DQA(N) through respective field units for approval. Such ESS plan will be annexed to the QAP.

16. In view of the foregoing, following guidelines be adhered to regarding formulation and conduct of ESS: -

(a) Based on category of items viz. indigenously manufactured, Imported, COTS and applicability of ESS thereon, a draft ESS plan is to be submitted by the vendor to the Field Inspection agency as part of draft QAP and forwarded to DQA(N) for approval.

(b) The draft plan must conform to Screen Strength 'A' and 'B' of Encl. 1&2 and ESS severity plan as per Encl.3.

(c) Approval of IHQ MoD(N)(Professional Directorates) will be mandatory for use of item/component imposing restriction on default ESS screen 'A'.

(d) The draft ESS plan will be submitted alongwith draft QAP as an annexure for approval.

17. This letter supersedes all previous letters on ESS.

(Amit Rastogi)
Commodore
Deputy Director General
Quality Assurance (Naval)

Enclosure: As above

Copy to:-

The Addl DGQA (WP)
Directorate of Quality Assurance (WP)
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New Delhi- 110011

The Chief of the Naval Staff
{for ACOM(IT&S)/PDSP/PDWE/PDEE/PDSR/PDSMAQ}
IHQ MoD(N)
Sena Bhawan, DHQ Post
New Delhi-110011

The Chief of the Naval Staff
{for PDND(SSG}
IHQ MoD(N)
A-33, Kailash Colony
New Delhi-110048

The Director General
{for DDG (M&M)}
Coast Guard Headquarters
National Stadium Complex
New Delhi- 110001

Enclosure-1 to DQA(N) letter No.:
66301/Policy-07/DQA(N)/QA-07
dated 09 Aug 16

THERMAL CYCLING STRESS SCREENING (TCSS)

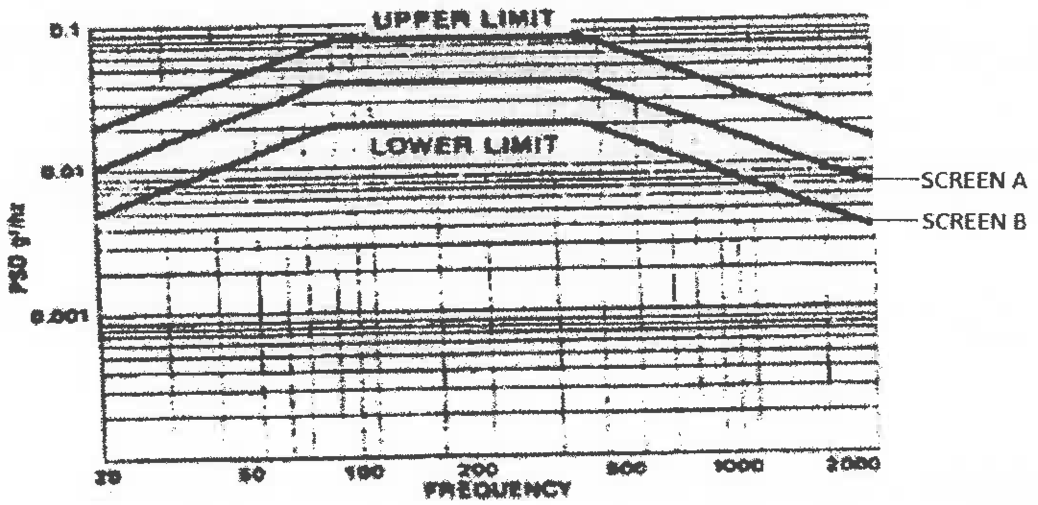
Sl. No.	Level	Screen	Test Details	Remarks
1	PCB Level	A	-40 °C to +70 °C, 10 Cycles (Ramp 10° C/min) or 20 Cycles (Ramp 5° C/min) Dwell: 10 min	Power OFF condition
		B	-20 °C to +55 °C, 10 Cycles (Ramp 10° C/min) or 20 Cycles (Ramp 5° C/min) Dwell: 10 min	
2	Sub Unit / Equipment	A	-30 °C to +55 °C, 6 Cycles (Ramp 10° C/min) or 12 Cycles (Ramp 5° C/min) Dwell: 10 min	Power ON condition
		B	-10 °C to +50 °C, 6 Cycles (Ramp 10° C/min) or 12 Cycles (Ramp 5° C/min) Dwell: 10 min	

Enclosure-2 to DQA(N) letter No.:
66301/Policy-07/DQA(N)/QA-07
dated 09 Aug 16

RANDOM VIBRATION STRESS SCREENING (RVSS)

Sl. No.	Level	Screen	Test Details	Remarks
1	PCB Level / Sub Unit / Equipment	A	20-80 Hz, +3db Octave 80-350 Hz, PSD 0.04 g²/Hz 350-2000 Hz, -3db Octave 10 min per axis, G rms = 6.06 (Profile given below)	1. On all three axes. 2. Power ON condition
		B	20-80 Hz, +3db Octave 80-350 Hz, PSD 0.02 g²/Hz 350-2000 Hz, -3db Octave 10 min per axis, G rms = 4.284 (Profile given below)	

Random Vibration Profile



Enclosure-3 to DQA(N) letter No.:
66301/Policy-07/DQA(N)/QA-07
dated 09 Aug 16

ESS: STRESS SEVERITY PLAN

Sl. No.	PCB Level/Sub Unit/ Equipment	Screen Parameters	Remarks
1	**SUB UNIT-1**		
	Nomenclature Part No.	XAA	
	PCB LEVEL		
(A)	PCB Assy – A (MIL) Part No.	AXX	
(B)	PCB Assy B(NON MIL) Part No.	BXX	
2	**SUB UNIT -2**		
	Nomenclature Part No.	XBB	
(A)	**PCB LEVEL**		
	PCB Assy – A (MIL) Part No.	AXX	
(B)	PCB Assy – B (NON MIL) Part No.	BXX	
3	**CABINET/EQUIVALENT LEVEL**		
(A)	Nomenclature – (MIL) Part No.	AAA	
(B)	Nomenclature – (NON MIL) Part No.	BBB	

Tel: 011-26193307

580930/DQAN/EL 17 Feb 14

रक्षा मत्रांलय/गु.आ.म.नि
MINISTRY OF DEFENCE (DGQA)
गुणता आश्वासन निदेशालय/नौ सेना
Directorate of Quality Assurance (Naval)

CONFORMAL COATING ON PCBs – ELECTRICAL/ELECTRONIC EQUIPMENT

1. Conformal coating is applied on PCBs in order to protect them against humidity, dust, moisture, air borne contaminants, abrasion/damage for longer life and better reliability. The JSG 0283 specifies the requirement of conformal coating for all PCBs for military applications. In addition, conformal coating has also been recommended in the JSG for non-military applications where the equipment is to operate in marine and humid environment. Therefore, the application of conformal coating on PCBs for Naval equipment is considered essential considering the humid conditions experienced onboard ship/submarines.

2. **Policy Directives**. The requirement of conformal coating was included in the ESS guidelines promulgated in Jul 06. However, whilst revising these guidelines in Mar 12/Jun 13, the aspects pertaining to conformal coating were deleted as the same did not pertain to the ESS specifications. It is pertinent to mention that the ESS guidelines promulgated by this directorate in 2003 also did not include conformal coating. No policy directives/guidelines on conformal coating have also been issued by IHQ, MoD(N). Therefore, as on date no explicit guidelines on conformal coating of electrical/electronic equipment being procured for IN applications is available.

3. Considering the criticality of conformal coating for Naval equipment, all QA agencies are making efforts to ensure that all electrical/electronic equipment are supplied with conformal coating. However, in the absence of explicit guidelines, the following difficulties are being experienced by the field agencies:-

(a) **Imported Equipment**. The majority of indigenous manufacturers are carrying out conformal coating on the PCBs. However, in the case of imported equipment, a large no. of manufacturers do not comply to conformal coating requirements. The justification provided is that, such procedures of conformal coating are not being followed in the respective countries. Further, it is claimed that the equipment being supplied by them for various other marine applications has been performing satisfactorily in the field for a number of years and no problem encountered. Thus, in the absence of a clear cut policy on conformal coating, ambiguity arises with respect to acceptance of the PCBs of imported equipment which do not have conformal coating.

(b) **COTS/Ruggedised COTS**. A large no. of equipment being supplied by the indigenous manufacturers is in the form of ruggedized COTS. As per the existing policy, the ruggedized COTS equipment are considered akin to MIL equipment with respect to the environmental and EMI/EMC specifications. However, at times the OEMs have shown apprehensions in carrying out conformal coating on the COTS PCBs which are being put into ruggedized enclosures. An example in this regard is the satellite modem for NEWN, where M/s Aayur, Bangalore supplied the in-house productionised PCBs without conformal coating. The requirement of conformal coating could not be insisted as the same were not included in the contract.

(c) **Ambiguous Specifications**. The contract/specifications of a large no. of systems include requirement of conformal coating for "non-COTS PCBs". This leaves ambiguity with respect to conformal coating on COTS PCBs being used in the system. In this regard, an example is of SDN 71. The contract includes conformal coating for "non-COTS PCBs". However, the QAP received from BEL, Bangalore indicates **conformal coating on 100 % indigenously manufactured PCBs and all pluggable COTS PCBs**. Relevant extract of the QAPs are placed at enclosure for reference. It may be seen that the firm has specified the conformal coating in the QAP as per their own interpretation. This needs to be avoided and clear cut policy directives on applicability of conformal coating need to be formulated.

4. It is appreciated that there is a need to evolve a policy on the use of conformal coating on PCBs of electrical/electronic systems being procured. Following issues need to be considered whilst formalizing the policy:-

(a) Conformal coating on PCBs of indigenous/imported and COTS/Ruggedised COTS systems as mentioned at Para 3 above.

(b) Type (Acrylic, Epoxy, Silicone etc.) and thickness of coating.

(c) Repair methodology of PCBs with coating and re-application of coating post repairs.

5. In view of the above, it is requested that issues brought out at Para 1 to 4 above be examined and policy directives with respect to requirement of conformal coating on Naval equipment may be issued.

(Ajay Singh Bisen)
Captain
Deputy Director General
Quality Assurance(Naval)

Encl : As above

IHQ,MoD(N)/PDEE

Copy to:-

IHQ, MoD(N)/ACOM(IT&S)

भारत इलेक्ट्रॉनिक्स BHARAT ELECTRONICS	QUALITY ASSURANCE PLAN		DOC CODE QAP	PART NUMBER 1121 802 157 90	
GBE SDN - P71			SH NO 35	PREPD. VANISHRI B	DATE 31 12 2013
	00	ORIGINAL	NO:OF SH 50	APPRD. RATHINAKARA ACHARY K	DATE 03.01.2014
	ISSUE NO.	ISSUE			

PART – III

3.3 ENVIRONMENTAL STRESS SCREENING (ESS) PLAN

ESS is the tailored application of electrical and environmental stresses for electronics parts, modules and units to identify and eliminate defective, abnormal or marginal parts and manufacturing defects. It is a production screen normally conducted on 100% of the manufactured items. The intent of ESS is to simulate infant mortality failures via accelerated aging without causing damage or inducing wear out to the product under development / manufacture. The ESS shall be applicable at three levels, namely at the assembled PCB / Sub unit / Module level, wired cabinet level and complete integrated system level. The production flow chart enclosed at Part-II indicates the tests to be carried out on different levels, agencies involved and stages of testing to be carried out.

The Environmental Stress Screening (ESS) Plan is detailed as below:

Table-1

SL NO.	TEST	APPLICABILITY	Remarks
1	Thermal Cycling	Indigenous modules / PCBs / Sub-assemblies /assemblies/ LRUs.	As per: DQA(N) letter 66301/Policy-07/DQA(N)/QA-07 dated 14 Jun 2013
2	Random Vibration	Indigenous modules / PCBs / Sub-assemblies / assemblies	
3	Endurance (Burn In)	Integrated System as per approved FATS document.	
4	Conformal Coating	100% ON indigenously manufactured PCBs	

भारत इलेक्ट्रॉनिक्स BHARAT ELECTRONICS	QUALITY ASSURANCE PLAN		DOC CODE QAP	PART NUMBER 1121 802 157 90	
GBE SDN - P71			SH NO. 39	PREPD. VANISHRI B	DATE 31.12.2013
	00	ORIGINAL	ND OF SH 50	APPRD. RATHNAKARA ACHARY K	DATE 03.01.2014
	ISSUE NO.	ISSUE			

ESS plan for the PCBs are as given below:

Table-3

Sl No	Equipment Description	Part No	
1	Dual Ethernet Discrete I/O card (Indigenous manufactured)	1124 004 951 90	**Thermal Cycling:** 0 to +50 °C 10 °C/Minute No. Of Cycles:10 PCB in OFF condition. Electrical test after screening **Random Vibration:** Acceleration level:6 G_{rms} Frequency: 20-2000 Hz Axes:3 axis, 10mins on each axis Equipment Powered & Monitored during test.
2	All pluggable COTS PCBs	-	Conformal coating only