

Methods for

Basic environmental testing procedures —

Part 2.1: Tests

**Test Fda. Random vibration — wide
band reproducibility high**

(This part should be read in conjunction with Part 1.1 General and it is recommended that references be made to Part 2.1Fd)

UDC [621.37/.39].001.4:620.169.1:620.178.53:539.433

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

BSI
Documents

AVA

Document Sharing Hub

Amendments issued since publication

Amd. No.	Date	Comments
2338	September 1977	
4467	June 1984	Indicated by a sideline in the margin

Contents

	Page
Foreword	ii
1 Object	1
2 Mounting and control	1
2.1 Mounting	1
2.2 <i>Text deleted</i>	1
2.3 <i>Text deleted</i>	1
2.4 Reference and control points	1
3 Frequency response measurements and resonance searches	1
3.1 Sinusoidal amplitude	1
3.2 Frequency response measurement procedure	1
3.3 Resonance search procedure	2
4 Vibration motion requirements	2
4.1 Basic motion	2
4.2 Distribution	2
4.3 Acceleration spectral density spectrum and total r.m.s. acceleration requirements	3
4.4 Total r.m.s. acceleration values within the specified frequency range	3
4.5 Displacement limitations	3
5 Choice of confirmation method	3
5.1 Criteria for choice	3
5.2 Applicability of the recommended confirmation methods	3
5.3 Mixed confirmation methods	4
6 Initial measurements	4
7 Excitation prior to conditioning	4
8 Conditioning	4
9 Final measurements	5
Appendix A Confirmation method by swept filter technique	11
Appendix B Confirmation method by fixed filter technique	15
Appendix C Confirmation method by swept sinusoidal technique	17
Figure 1 — Determination of peak-notch amplitude ratio A_p/A_n	8
Figure 2 — Peak-notch pairs	8
Figure 3 — Tolerance band for distribution of instantaneous acceleration value	9
Figure 4 — Acceleration spectral density spectrum and tolerance limits	10
Figure 5 — Illustration of accumulation of errors	13
Figure 6 — Analyser error in notch region	14
Figure 7 — Analyser error in peak region	14
Figure 8 — Remaining ripple after equalization	16
Table 1 — Acceleration spectral density and related sinusoidal amplitude	1
Table 2 — Tolerance limits for true acceleration spectral density and true total r.m.s. acceleration	3
Table 3a — Total r.m.s. acceleration values	6
Table 3b — Total r.m.s. acceleration values	7
Table 4 — Tolerances on sum of variations and errors	12
Table 5 — Tolerances on sum of ripple, deviation and errors	16
Table 6 — Variation in acceleration spectral density plus instrumentation errors	17

Foreword

This British Standard, incorporating Amendment No. 1 published in 1977 and Amendment No. 2 published in 1984, is technically equivalent to IEC Publication 68-2-35:1973 “*Basic environmental testing procedures, — Part 2: Tests — Test Fda: Random vibration wide band — Reproducibility High*”, published by the International Electrotechnical Commission (IEC).

The basic requirements for the random vibration test, wide band, are given in BS 2011-2.1. Test Fd: Random vibration wide band, general requirements. In addition, three possible degrees of Reproducibility have been specified called High, Medium and Low, and designated Test Fda, Fdb, and Fdc respectively. Each of these forms a separate test method complete with its recommended confirmation procedures:.

BS 2011-2.1, *Test Fda Random vibration: wide band, reproducibility high.*

BS 2011-2.1, *Test Fdb Random vibration: wide band, reproducibility medium.*

BS 2011-2.1, *Test Fdc Random vibration: wide band, reproducibility low.*

All the information required by the relevant specification writer is therefore contained in Test Fd General requirements, whilst that needed by the test engineer is contained in Tests Fda, Fdb or Fdc, whichever is specified.

Whilst the relevant specification writer need only read Test Fd General requirements and the test engineer the specified Test Fda, Fdb or Fdc, it is strongly recommended that all users read BS 2011-2.1Fd and that part of BS 2011 Test Fd containing the reproducibility required.

It should be noted that two terms of particular importance to the subject of random vibration testing are referred to frequently throughout the text of this publication. They are defined here to ensure that the text is made as clear as possible to the reader.

Acceleration spectral density (hereinafter abbreviated to A.S.D.) is the spectral density of an acceleration variable and is given in units of acceleration squared per unit frequency.

A.S.D. spectrum defines the way the A.S.D. varies within the frequency range.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 17 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Object

The object of this test method is to determine the ability of components and equipment to withstand specified severities of random vibration.

This random vibration test is applicable to components and equipment which may in service be subjected to conditions involving vibration of a stochastic nature. The purpose of the test is to determine mechanical weakness and/or degradation in specified performance and to use this information in conjunction with the relevant specification to decide whether a specimen complies with the requirements of that specification.

During the application of the environmental stress (conditioning) specified by this test, the specimen is subjected to random vibration of a given level within a wide frequency band. Due to complex mechanical reactions from the specimen and its fixture, this test requires particular care in its preparation and performance, and in the confirmation of the specified requirements.

2 Mounting and control

2.1 Mounting. The specimen shall be mounted on the test apparatus in accordance with BS 2011-4.1.

2.2 Text deleted

2.3 Text deleted

2.4 Reference and control points. The test requirements are confirmed by measurements made at a reference point and control points related to the fixing points of the specimen.

In the case of a large number of small specimens mounted on one fixture, the reference and/or the control points may be related to the fixture rather than to the fixing points of the specimens when the lowest resonance mode of the loaded fixture is above the upper test frequency limit f_2 .

2.4.1 Fixing point. A fixing point is defined as a part of the specimen in contact with the fixture or vibration table at a point where the specimen is normally fastened in service. If a part of the real mounting structure is used as the fixture, the fixing points shall be taken as those of the mounting structure and not of the specimen.

2.4.2 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 ones shall be defined in the relevant specification, these to be used as control points.

NOTE For large and/or complex specimens it is important that the control points are defined in the relevant specification.

2.4.3 Reference point. The reference point is the single point from which the reference signal is obtained to confirm the test requirements and is taken to represent the motion of the specimen. It may be a control point or a fictitious point created by manual or automatic processing of the signals from the control points.

If a fictitious point is used, the spectrum of the reference signal is defined as the arithmetic mean, at each frequency, of the A.S.D. values of the signals from all control points. In this case the total r.m.s. value of the reference signal is equivalent to the root mean square of the r.m.s. values of the signals from the control points.

The relevant specification shall state the point to be used or how it should be chosen. It is recommended that for large and/or complex specimens a fictitious point be used.

3 Frequency response measurements and resonance searches

The tolerances given in the sinusoidal vibration test BS 2011-2F Vibration, shall apply during the following sinusoidal test phases.

3.1 Sinusoidal amplitude. Unless otherwise stated in the relevant specification, the sinusoidal amplitude to be used for resonance searches and frequency response measurements is determined by the specified A.S.D. level (see Table 1). This amplitude shall be applied at the reference point. Where a fictitious reference point is to be used during the random vibration conditioning, this sinusoidal amplitude shall be applied at a control point.

Table 1 — A.S.D. and related sinusoidal amplitude

Specified A.S.D. level		Sinusoidal amplitude (peak values)	
$(\text{m/s}^2)^2/\text{Hz}$	Equivalent g^2/Hz	m/s^2	Equivalent g
< 4.8	< 0.05	9.8	1.0
4.8 – 19.2	0.05 – 0.2	14.7	1.5
> 19.2	> 0.2	19.6	2.0

3.2 Frequency response measurement procedure. The A.S.D. spectrum confirmation methods always require a frequency response measurement in the intended direction at the reference point with the specimen mounted.

The frequency range shall be swept with a sinusoidal signal from f_1 to f_2 and back, at a sweep rate not exceeding 1 octave/minute. During the sweep the sinusoidal amplitude at the reference point shall be kept constant in accordance with 3.1, while the a.c. input voltage to the power amplifier shall be measured.

The measured voltage as a function of frequency is an approximation of the inverse of the frequency response. To take care of the displacement limitations of the vibrator, the sinusoidal acceleration amplitude may be reduced at the low frequency end, and this shall be taken into consideration when calculating the frequency response.

The acceleration shall be measured at all control points. Transverse measurements should be made as stated in 4.3.

Exciter equalizers (instrumentation used to correct for the general response of the unloaded vibrator), low pass filters (to reject above f_2), high pass filters (to reject below f_1) and other broad band types are allowed when measuring the frequency response. Narrow band equalizers, such as peak-notch filters, are not to be inserted during this measurement.

The *peak-notch amplitude ratio* A_p/A_n (see Figure 1) is determined as the ratio between the maximum and minimum values of the frequency response. This quantity can be measured without using an accurate frequency meter.

The *peak-notch frequency ratio* (B_{pn}) (see Figure 2) is determined from the equation below where f_p is the frequency of the peak and f_n the frequency of the notch. This measurement can only be done with an accurate frequency meter.

$$B_{pn} = \frac{|f_p - f_n|}{\sqrt{f_p f_n}}$$

In the A.S.D. confirmation methods of Appendix A and Appendix B the “most severe peak-notch pairs” are mentioned. If the peak-notch frequency ratio is to be used, the quantities A_p/A_n and B_{pn} shall be measured for several pairs (four pairs in Figure 2) and the analysing errors and remaining ripple estimated for each pair in order to find the most severe one.

3.3 Resonance search procedure. If the relevant specification calls for resonance searches, the initial resonance search can, to some extent, be done at the same time as the frequency response measurement. A complete sinusoidal sweep (up and down) of the frequency range shall be carried out.

During the searches the specimen shall be examined in order to determine frequencies at which:

- 1) specimen malfunctioning and/or deterioration of performance are exhibited which are dependent on vibration;
- 2) mechanical resonances occur.

The sweep may be interrupted in order to examine the effects more carefully and find the exact frequencies.

During the initial resonance search, all frequencies and amplitudes at which these effects occur shall be noted for comparison with those found in the final search. The relevant specification shall state what action should be taken if any change of resonance frequency occurs.

The specimen shall be functioning during the resonance search, if appropriate. Where the mechanical vibrational characteristics cannot be assessed because the unit is functioning, an additional resonance search with the specimen not functioning shall be carried out.

Any arrangement made to detect the effect upon internal parts shall not substantially change the dynamic behaviour of the specimen as a whole.

It may be necessary to provide a period of time after the conditioning in which to allow the specimen to attain the same condition as existed at the commencement of the initial resonance search, e.g. as regards temperature.

4 Vibration motion requirements

4.1 Basic motion. The basic motion of the fixing points of the specimen shall be rectilinear and of a stochastic nature with a normal (gaussian) distribution of instantaneous acceleration values. They shall also have substantially identical motions.

4.2 Distribution. The distribution of instantaneous acceleration values at the reference point shall be normal within the tolerance band given in Figure 3. If a fictitious point is used the distribution applies to a control point.

NOTE For most random vibration testing the distribution falls within the tolerance band, therefore confirmation need only be done in exceptional circumstances. Nevertheless, where possible, it is recommended that the acceleration waveform be visually examined to ensure that peaks of at least $2\frac{1}{2}$ times the r.m.s. values of the signal are present.

4.3 A.S.D. spectrum and total

r.m.s. acceleration requirements. The A.S.D. spectrum shall be as shown in Figure 4. The A.S.D. level and frequency range shall be stated in the relevant specification. These quantities together determine the nominal total r.m.s. value of the acceleration. This value can be found in Table 3a and Table 3b.

The tolerances on the true A.S.D. and total r.m.s. acceleration are given in Table 2. As seen from this table the tolerances on the true total r.m.s. value are considerably tighter than the tolerance on the true A.S.D. value.

Table 2 — Tolerance limits for true A.S.D. and true total r.m.s. acceleration

Tolerance limits in dB for:			True total r.m.s. acceleration (f_1 to f_2) in the intended direction
True A.S.D.		Transverse direction	
Reference point	Control points	Control point(s)	Reference point
± 3	± 5	$< \pm 5$	± 1.0

Above the upper frequency limit f_2 the A.S.D. spectrum up to $2f_2$ is required to be below the 6 dB/octave slope shown in Figure 4. In addition the r.m.s. acceleration in the band from f_2 to $10f_2$, or 10 kHz, whichever is the less, shall not exceed 25 % (– 12 dB) of the total r.m.s. acceleration required within the specified frequency range.

Acceleration measurements for confirmation of the motion requirements shall be made in the intended direction at all control points and at the reference point. Measurements shall also be made in two perpendicular transverse directions at the control point furthest from the centre of the mounting plane. For large structures it is recommended that the transverse acceleration be measured at more than one control point.

Confirmation of A.S.D. tolerances may be performed with any method appropriate to the tolerances given. As the confirmation involves considerable engineering difficulties, however, it is strongly recommended that the choice is made from the confirmation methods given in Appendix A, Appendix B and Appendix C. Guidance to assist in making this choice is given in Clause 5.

NOTE In the special case where a shaped spectrum is specified the confirmation methods given in Appendix A, Appendix B and Appendix C may still be used.

It should be noted that automatic processing of the signals from the control points using a scanning technique to create the fictitious point is not permitted for confirmation of the A.S.D. level without correcting for such sources of error as analyser bandwidth, sampling time etc.

4.4 Total r.m.s. acceleration values within the specified frequency range.

The required total r.m.s. acceleration values are given in Table 3a and Table 3b. In order to confirm these values a low pass filter shall be used. This low pass filter shall have its cut-off frequency (3 dB point) at the frequency f_2 . If the 3 dB bandwidth differs by more than 2 % from the equivalent noise bandwidth obtained when measuring the output from the filter with a white noise input signal, this should be taken into consideration when using the calculated r.m.s. values of the table.

NOTE Automatic processing of the signals from the control points using a scanning technique to create the fictitious point is permitted for confirmation of the total r.m.s. acceleration.

4.5 Displacement limitations. All vibrators have displacement limitations. It may be necessary to insert a high pass filter before the power amplifier in order to limit the peak displacements.

NOTE If it is necessary for the A.S.D. to be reduced in the low frequency region due to the displacement limits of the vibrator, the reduction is to be noted and agreed between the customer and the supplier.

5 Choice of confirmation method

Three methods for comprising the A.S.D. are given in Appendix A, Appendix B and Appendix C.

5.1 Criteria for choice. The following criteria will need to be considered when choosing a confirmation method:

- specified frequency range;
- special requirements in relevant specification;
- mechanical response characteristics of the specimen;
- force of vibrator;
- size, rigidity and weight of vibrator moving element;
- rigidity and weight of fixture;
- characteristics of available instrumentation (e.g. filter bandwidth, dynamic range, frequency range, available sweep rates, hum and noise).

5.2 Applicability of the recommended confirmation methods. The recommended confirmation methods given in Appendix A, Appendix B and Appendix C are applicable provided that the fundamental errors involved in their use do not invalidate the test.

The confirmation method by the swept filter technique given in Appendix A is very time consuming. Confirmation of the A.S.D. spectrum, using tape recorders to record the acceleration-time history during conditioning and subsequent analysis, may be required if the frequency range is wide and duration of conditioning short.