

Environmental testing —

Part 3: Guidance —

Seismic test methods for equipments

This Part should be read in conjunction with Part 1.1 General and guidance
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Committees responsible for this British Standard

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- Directorate of Telecommunications
- EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)
- Electronic Components Industry Federation
- Ministry of Defence
- National Supervising Inspectorate
- Society of Environmental Engineers
- Society of Motor Manufacturers and Traders Limited

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Association of Manufacturers of Domestic Electrical Appliances BEAMA Ltd.
- British Telecommunications plc
- Department of Trade and Industry (National Engineering Laboratory)
- Electrical Installation Equipment Manufacturers Association (BEAMA Ltd.)
- United Kingdom Atomic Authority

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National foreword

This Section of BS 2011 has been prepared under the direction of the General Electrotechnical Standards Policy Committee. It is identical with IEC Publication 68-3-3:1991 “*Environmental testing Part 3: Guidance — Seismic test methods for equipments*”, published by the International Electrotechnical Commission (IEC).

In 1993 the European Committee for Electrotechnical Standardization (CENELEC) accepted IEC 68-3-3:1991 as European Standard EN 60068-3-3:1993. As a consequence of implementing the European Standard this British Standard is renumbered as BS EN 60068-3-3 and any reference to BS 2011-4.3 should be read as a reference to BS EN 60068-3-3.

The title of BS 2011 has been changed to “*Environmental testing*” to correspond with the change in the title of IEC Publication 68. This change reflects the fact that IEC Publication 68 and BS 2011 are concerned with the whole subject of testing, and avoids any possible confusion over whether it is the “procedures” or the “testing” that are basic. Amendments are not being issued to the other Parts of BS 2011, but their titles are being changed when these Parts are revised.

Cross-references

International standard ^a	Corresponding British Standard
	BS 2011 Environmental testing
IEC 68-1:1988	Part 1.1:1989 General and guidance (Identical)
IEC 68-2-6:1982	Part 2.1Fc:1983 Test Fc. Vibration (sinusoidal) (Identical)
IEC 68-2-47:1982	Section 4.1:1983 Specification for mounting of components, equipment and other articles for dynamic tests (Identical)
IEC 68-2-57:1989	Part 2.1Ff:1989 Test Ff. Vibration — time-history method (Identical)
IEC 68-2-59:1990	Part 2.1Fe:1991 Test Fe and guidance. Vibration (sine-beat method) (Identical)

^a Undated in the text.

The Technical Committee has reviewed the provisions of ISO 2041:1975 to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard. A British Standard related to ISO 2041:1975 is BS 3015:1976 “*Glossary of terms relating to mechanical vibration and shock*”.

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.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 32, an inside back cover 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.

English version

Environmental testing
Part 3: Guidance
Seismic test methods for equipments

(IEC 68-3-3:1991)

Essais d'environnement
Troisième partie: Guide
Méthodes d'essai sismiques applicables aux
matériels
(CEI 68-3-3:1991)

Umweltprüfungen
Teil 3: Leitfaden
Seismische Prüfverfahren für Geräte
(IEC 68-3-3:1991)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Foreword

At the request of CENELEC Reporting Secretariat SR 50A, HD 323.3.3 S1:1991 (IEC 68-3-3:1991) was submitted to the CENELEC voting procedure for conversion into a European Standard.

The text of the International Standard was approved by CENELEC as EN 60068-3-3 on 9 March 1993. The following dates were fixed:

- latest date of publication of
an identical national
standard (dop) 1994-03-01
- latest date of withdrawal of
conflicting national
standards (dow)—

Annexes designated “normative” are part of the body of the standard. In this standard, and Annex ZA is normative.

Section 1. General

Introduction

Guidance is included in each of the three test methods referred to in this standard but it is specific to the test method. The guidance in this standard is directed towards choosing the appropriate test method and applying it to seismic testing.

This standard is to be used in conjunction with IEC Publication 68-1.

1 Object

This guide applies primarily to electrotechnical equipments but its application can be extended to other equipments and to components.

The verification of the performance of an equipment by analysis or by a combination of testing and analysis may be acceptable but is outside the scope of this guide, which is restricted to verification based entirely upon data from dynamic testing.

This guide deals solely with the seismic testing of a full size equipment which can be tested on a vibration table. The seismic testing of an equipment is intended to demonstrate its ability to perform its required function during and/or after the time it is subjected to the stresses and displacements resulting from an earthquake.

The object of this guide is to present a range of methods of testing which, when prescribed by the relevant specification, can be applied to demonstrate the performance of equipments for which seismic testing is required with the main aim of achieving qualification.

NOTE Qualification by so-called "fragility-testing" is not considered to be within the scope of this guide which has been prepared to give generally applicable guidance on seismic testing and specifically on the use of IEC Publication 68-2 test methods.

The choice of the method of testing can be made according to the criteria described in this guide. The methods themselves are closely based on published IEC test methods.

This guide is intended for use by manufacturers to substantiate, or by users to evaluate and verify, the performance of an equipment.

2 General considerations

Two seismic classes have been established: a general seismic class and a specific seismic class. Neither of these classes can be considered to be more demanding than the other. The difference between the two classes lies in the availability of and/or the accuracy in defining the characteristics of the seismic environment. When high reliability safety equipment for a specified environment is required, such as safety related equipment in nuclear power plants, the use of precise data is necessary and, therefore, the specific seismic class is applicable and not the general seismic class. Appendix A contains a flow chart for the selection of the test class (general seismic class or specific seismic class) and four flow charts (A1 to A4) covering the possibilities discussed in this guide. To obtain the maximum advantage from this guide it is strongly recommended that the flow charts be studied very thoroughly.

2.1 General seismic class

This class covers equipments for which the relevant seismic motion does not result from a specific study taking into account the characteristics of the geographic location and of the supporting structure or building.

In the case of equipments in this class, the seismic motion is generally characterized by one datum which is a peak acceleration at the ground level. This acceleration is derived from the seismic data relative to the area of interest.

When an equipment is not mounted at ground level, the transmissibility of the building and/or the supporting structure should be taken into account.

2.2 Specific seismic class

This class covers the equipment for which the relevant seismic motion results from a specific study taking into account the characteristics of the geographic location and of the supporting structure or building.

For equipment in this class, the seismic motion is defined by response spectra (evaluated for different damping ratios) or by a time-history.

3 Definitions

The terms used in this standard are generally defined in ISO Standard 2041 or in IEC Publications 68-1, 68-2-6, 68-2-57 and 68-2-59.

Where, for the convenience of the reader, a definition from one of these sources is included here, the derivation is indicated and departures from the definitions in those sources are also indicated.

The additional terms and definitions that follow are also applicable for the purpose of this standard.

3.1 assembly

two or more devices sharing a common mounting or supporting structure

3.2 bandpass at 3 dB

frequency intervals defined by the points possessing an ordinate larger than or equal to $\sqrt{2}/2$ times the maximum value of the plot (see Figure 1)

3.3 basic response spectrum

unmodified response spectrum defined by the characteristics of the building, its floor level, damping ratio, etc. and obtained from a specific ground motion (see Figure 1)

NOTE The basic response spectrum is generally of the narrow band type at floor level.

3.4 broad-band response spectrum

response spectrum that describes the motion indicating that a number of interacting frequencies exist which must be treated as a whole (see Figure 2c)

NOTE The bandwidth is normally greater than one octave.

3.5 critical frequency (definition technically equivalent to that in Sub-clause 8.1 of IEC Publication 68-2-6)

frequencies at which:

- malfunctioning and/or deterioration of performance of the specimen which are dependent on vibration are exhibited, and/or
- mechanical resonances and/or other response effects occur, for example chatter.

3.6 crossover frequency (definition technically equivalent to that of ISO 2041)

frequency at which the characteristic of a vibration changes from one relationship to another

NOTE For example, a crossover frequency may be that frequency at which the vibration amplitude changes from a constant displacement value versus frequency to a constant acceleration value versus frequency.

3.7 damping (not identical with ISO 2041 definitions)

generic term ascribed to the numerous energy dissipation mechanisms in a system. In practice, damping depends on many parameters, such as the structural system, mode of vibration, strain, applied forces, velocity, materials, joint slippage, etc.

3.7.1 critical damping

minimum viscous damping that will allow a displaced system to return to its initial position without oscillation

3.7.2 damping ratio

ratio of actual damping to critical damping in a system with viscous damping

3.8 direction factor

factor taking account of the difference in magnitude at ground level that normally exists between the horizontal and vertical accelerations resulting from earthquakes

3.9 floor acceleration

acceleration of a particular building floor (or an equipment mounting) resulting from the ground motion of a given earthquake

NOTE In practice the floor acceleration may be resolved into its horizontal and vertical components.

3.10 geometric factor

factor required in single axis testing to take into account the interaction along the different axes of the equipment of simultaneous multi-directional input vibrations

3.11 “ g_n ”

standard acceleration due to the earth's gravity, which itself varies with altitude and geographical latitude

NOTE For the purposes of this standard, the value of g_n is rounded up to the nearest whole number, that is 10 m/s².

3.12 ground acceleration

acceleration of the ground resulting from the motion of a given earthquake

NOTE In practice the ground acceleration may be resolved into its horizontal and vertical components.

3.13 lateral frequencies

two frequencies determined according to the – 3 dB response around the overall resonance frequency (see Figure 1)

3.14 malfunction

loss of capability of the equipment to initiate or sustain a required function, or the initiation of undesired spurious action which may result in adverse consequences for safety

NOTE Malfunction will be defined by the relevant specification.

3.15

narrow-band response spectrum

response spectrum in which single frequency excitation predominates (see Figure 2a)

NOTE 1 The bandwidth is normally 1/3 octave or less.

NOTE 2 When several widely spaced well-defined frequencies exist, if justified, each of their responses may be treated separately as narrow band response spectrum (see Figure 2b).

3.16

natural frequency

frequency of free vibration of a structure depending only on its own physical characteristics (mass, stiffness, and damping)

3.17

overall resonance

resonance frequency at which a complete structure amplifies the exciting motion

NOTE Within the frequency range between 1 Hz and 35 Hz, overall resonance generally corresponds to the first mode of vibration. It is important to take into account the overall resonance frequencies when they are enclosed in the strong part of the required response spectrum (see Sub-clause 3.27).

3.18

pause

interval between consecutive test waves (for example sine beats)

NOTE A pause should be such that it results in no significant superposition of the response motions of an equipment.

3.19

preferred testing axes

three orthogonal axes which correspond to the most vulnerable axes of the equipment

3.20

required response spectrum

response spectrum specified by the user (see Figure 1, Figure 2 and Figure 3)

3.21

resonance frequency

frequency at which, in forced oscillation, a change in the frequency of excitation causes a decrease in the response of the system

NOTE 1 The value of resonance frequency depends upon the measured variable. For a given mode, the values of resonance frequency for displacement, velocity and acceleration are in increasing order of frequency. The differences between these resonance frequency values are small for the usual damping ratios.

NOTE 2 In seismic testing, it is often assumed that a resonance frequency is significant when the transmissibility of the response is greater than 2.

3.22

response spectrum (not identical with ISO 2041 definition)

plot of the maximum response to a defined input motion of a family of single-degree-of-freedom bodies at a specified damping ratio (see Figure 1, Figure 2 and Figure 3)

3.23

s1-earthquake

an earthquake which would be expected to occur during the operating life of the equipment and for which safety related equipments are to be designed to continue to operate without malfunction

NOTE An S1-earthquake corresponds in nuclear applications to the operating base earthquake (OBE).

3.24

s2-earthquake

an earthquake which produces the maximum vibratory ground motion for which certain structures, systems and components are designed to remain functional. These structures, systems and components are those essential to assure proper function, integrity and safety of the total system

NOTE An S2-earthquake corresponds in nuclear applications to the safe shutdown earthquake (SSE).

3.25

sine beat

continuous sinusoidal wave of one frequency which is modulated by a sinusoidal wave of a lower frequency. The duration of one sine beat is half the period of the modulating frequency (see Figure 4)

NOTE In this standard, the sine beat is considered as a single frequency wave.

3.26

strong part of time-history

part of time-history from the time when the plot first reaches 25 % of the maximum value to the time when it falls for the last time to the 25 % level (see Figure 5)

3.27

strong part of the response spectrum

part of the spectrum for which the response acceleration is higher than for the – 3 dB bandpass of the required response spectrum (see Figure 1)

NOTE Generally, the strong part of the response spectrum is located in the first third of the frequency band.

3.28

superelevation factor

factor accounting for the change in the acceleration with respect to the earth due to the transmissibility of buildings and structures

3.29**synthesized time-history**

artificially generated time-history such that its response spectrum envelops the required response spectrum

3.30**test level**

largest peak value within a test wave

NOTE In seismic testing, acceleration is the parameter normally used.

3.31 test frequency

Frequency at which the specimen is to be excited during a test.

A test frequency is one of two types as defined below:

3.31.1**predetermined test frequency**

frequency prescribed by the relevant specification

3.31.2**investigated test frequency**

frequency obtained by a vibration response investigation

3.32**test response spectrum**

response spectrum derived from the real motion of the vibration table either analytically or by using spectrum analysis equipment (see Figure 1, Figure 2c and Figure 2d)

3.33

time-history (not identical with ISO 2041 definition)

recording, as a function of time, of acceleration or velocity or displacement

3.34**zero period acceleration**

high frequency asymptotic value of acceleration of a response spectrum (for an example see Figure 1)

NOTE The zero period acceleration is of practical significance as it represents the largest peak value of acceleration, for example in a time-history. This should not be confused with the peak value of acceleration in the response spectrum.

4 Qualification considerations

The relevant specification should contain information relating to the subjects discussed in Sub-clauses 4.1, 4.2 and 4.3.

4.1 Service conditions

Service conditions should be duplicated as closely as possible when an equipment is tested, particularly those conditions (electrical, mechanical, and thermal pressure, etc.) whose stresses combine with those of the test to affect the operation or integrity of the equipment. When account is not taken of these service conditions in the test, the omission should be justified.

4.2 Malfunction criteria

When the service conditions and function are known or have been selected, the relevant specification will prescribe acceptance and/or malfunction criteria.

NOTE There are cases when the final service conditions or the conditions of use of the equipment which is to be tested are not known but have been selected. In these cases, malfunction criteria cannot be accurately established and are therefore assumed without formal justification; for example, in the absence of better information, the assumption is frequently made that the duration of a malfunction in electrical circuitry is 5 ms.

4.3 Qualification criteria

The following classification is introduced as it allows criteria to be assigned to equipment for a particular application.

- Criterion 0: Equipment subjected to seismic testing which experienced no malfunction either during or after the test.
- Criterion 1: Equipment subjected to seismic testing which suffered a malfunction during the test but reverted to its correct state after the test.
- Criterion 2: Equipment subjected to seismic testing which experienced a malfunction during the test and required resetting or adjustment on completion of the test but required no replacement or repair.

5 Testing procedures

Testing should be in accordance with Section 2 (Clauses 6 to 10) for the general seismic class or Section 3 (Clauses 11 to 15) for the specific seismic class.

5.1 Mounting

The equipment should be mounted in accordance with IEC Publication 68-2-47.

NOTE For more detailed guidance in the case of equipment normally used with vibration isolators see Clause A5 of IEC Publication 68-2-6.

The influence of connections, cables, piping, etc., should be taken into account when mounting the equipment. Also, unless justified, the normal "in service" mounting structure of the equipment should be included in the seismic test.

The orientation and mounting of the equipment during the test should be specified and is then the only condition for which the equipment is considered qualified, unless adequate justification can be made to extend the qualification to an untested condition (for instance, if it is proved that the effects of gravity do not influence the behaviour of the equipment).

5.2 Measurements

Measurements should be carried out in accordance with IEC Publications 68-2-6, 68-2-57 and 68-2-59 as relevant.

5.2.1 *Vibration measurements at the vibration table*

Vibration measurements at the vibration table are to be made to ensure that the correct levels of vibration are applied at the required measuring positions.

Parameters to be permanently recorded (displacement, velocity, acceleration), the equipment used, and the functions of each transducer (reference, measurement) should be specified.

5.2.2 *Vibration measurements on the equipment*

In addition to the measurements at the vibration table, measurements may be made on the equipment to provide further information about its performance during the test. These latter measurements are not a part of the vibration test requirements.

5.2.3 *Functional monitoring on the equipment*

Monitoring should be adequate to evaluate the performance of the equipment before, during and after the test.

The relevant specification for the equipment should prescribe any characteristics to be permanently recorded.

5.3 Frequency range

In earthquakes, the predominant frequencies are generally between 1 Hz and 35 Hz. This range is sufficient to determine the critical frequencies of the equipment and for its testing. In certain cases the test frequency range of 1 Hz to 35 Hz may be extended or reduced dependent on the critical frequencies present, but this should be justified.

Section 2. General seismic class

Section 2 describes the recommended seismic testing methods for equipment covered by the general seismic class for which the seismic environment is either not known or is imprecisely known.

6 Conditioning

6.1 Selection of test type

In order to prove the ability of equipments to withstand seismic forces, several types of test may be considered. These are listed in Table 1.

In the general seismic class, single axis testing with sine beat or sine sweep is preferred for the following reasons:

- a) sine beat, as its form is similar to that of the horizontal earthquake wave at floor levels in simple structures presenting one mode of resonance;
- b) sine sweep, as it is simple to achieve but may be less realistic than the actual earthquake waves appearing at the floor levels.

When there is significant coupling between the three preferred test axes of the equipment or if the use of geometric correction factors is not desirable, multi-axis testing (biaxial or triaxial) can be used, although not normally recommended. If multi-axis testing is used, caution should be taken with the use of single frequency waves — sine-beat, sine sweep or continuous sine — as the peak seismic accelerations for the various axes are not usually in phase. A multifrequency wave such as time-history should therefore then be used.

Table 1 — Selection of test type

Test wave	Test type	
	Single-axis test	Multi-axis test
Sine sweep	a	c
Sine-beat	a	c
Time-history	b	a
Continuous sine	b	c
a = recommended b = suitable c = not normally recommended		

6.2 Selection of the test method

Two methods exist:

- a) standard amplitude conventional test: this is applied where the conditions of use of the equipment are unknown (see Clause 7);
- b) calculated amplitude test: this is applied where the conditions of use of the equipment are sufficiently known to allow the different parameters of the test to be specified (see Clause 8).

7 Standard amplitude conventional test method

7.1 Application

This conventional test has three performance levels, often referred to as qualification levels, (see Table 2) and it is recommended when the conditions of use of the equipment are unknown. The user of the equipment should decide if the qualification level for which the equipment has been tested is suitable for the considered application. After achieving a specified qualification level, the equipment may then claim qualification up to and including that level, provided that all other requirements have been satisfied.

Table 2 — Performance level

Performance level ^a	Floor acceleration a_f	
	Horizontal	Vertical
	m/s ²	m/s ²
I	6	3
II	9	4.5
III	15	7.5

^a These levels can be used above a crossover frequency of 1.6 Hz. Below this frequency, the amplitude of velocity is used down to 0.8 Hz. Below 0.8 Hz the amplitude of displacement is used (see Figure 7a).

7.2 Conditions of testing

The standard amplitude conventional test method is a single-axis test only. The different axes are excited one after another. The test acceleration is determined from the performance level (see Sub-clause 7.2.1), the wave factor (see Sub-clause 9.2.1) and the geometric factor (see Sub-clause 9.2.2).

7.2.1 Performance level (standard amplitude conventional test)

In the standard amplitude conventional test method the floor acceleration (a_f) is selected directly from the levels given in Table 2.

7.2.2 Test wave

The recommended test wave is the five-cycle sine beat or the sine sweep. However, other waves, if justification is given, are permissible. The maximum value of acceleration of the excitation for the selected level should be corrected by the wave factor (see Sub-clause 9.2.1) and the geometric factor (see Sub-clause 9.2.2).

8 Calculated amplitude test method

8.1 Application

The calculated amplitude test method is recommended when sufficient information is available on the characteristics and on the location of the equipment to allow a more accurate estimation of test level than is possible with the standard amplitude conventional test method (see Clause 7).

8.2 Conditions of testing

In principle this is a single-axis test, where the different axes are excited one after the other. This is appropriate where, for example, there is little interaction between the different axes or the interaction can be accounted for by applying a geometric factor.

8.2.1 Performance level

The severity of the test is determined by the values ascribed to the following parameters, which the relevant specification for the equipment should prescribe:

- a) test wave (see Sub-clause 8.2.2),
- b) damping of the equipment (see Sub-clause 8.2.3),
- c) superelevation factor (see Sub-clause 8.2.5),
- d) direction factor (see Sub-clause 8.2.6),
- e) duration of the test (see Sub-clause 9.1),
- f) amplitude of the test wave (see Sub-clause 9.2).

8.2.2 Test wave selection

The test wave selected will have a noticeable influence on the response of the equipment when its damping value is significantly different from 5 % (see Figure 6) even with the use of a wave factor.

8.2.3 Damping ratio

A damping ratio of 5 % is recommended when the critical damping of the equipment lies between 2 % and 10 %. If the damping ratio is outside this range, it is recommended that a value representative of the actual vibrational behaviour of the equipment is used to determine the applicable wave factor. For further details, see Sub-clause 9.2.1 and Figure 6.