IEC 60068-2-86

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Environmental testing –
Part 2-86: Tests –Test Fx: Vibration – Multi-exciter and multi-axis method

Essais d'environnement –
Partie 2-86: Essais – Essai Fx: Vibrations – Méthode par excitateurs multiples et axes multiples

IEC 60068-2-86:2024-02(en-fr)

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CONTENTS

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ENVIRONMENTAL TESTING –

Part 2-86: Tests – Test Fx: Vibration –
Multi-exciter and multi-axis method

FOREWORD

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IEC 60068-2-86 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
104/1035/FDIS	104/1043/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60068 series, published under the general title *Environmental testing*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

ENVIRONMENTAL TESTING –

Part 2-86: Tests – Test Fx: Vibration – Multi-exciter and multi-axis method

1 Scope

This document provides a test procedure for use with multi-exciter and multi-axis vibration test systems. The vibration test is intended for general application to components, equipment, and other products, hereinafter referred to as "specimens", subjected to dynamic environments that could arise during an equipment life cycle. Although this document is mainly intended for vibration testing, the procedure is also applied to certain types of shock and transient tests.

The test procedure set out in this document is applicable where a specimen is required to demonstrate its adequacy to resist specified vibration, shock and transient conditions, without unacceptable degradation of functional or structural performance. The test procedure has significant similarity to test procedures of other IEC 60068-2 documents and encompasses the same range of vibration and shock excitation types.

This document is applicable to specimens subjected to vibration, shock and transient conditions resulting from transportation and/or operational environments, for example in aircraft, space vehicles and land vehicles. It is primarily intended for unpackaged specimens. It is applicable to specimens in their transportation container when the latter are considered as part of the specimen itself.

The test method and associated techniques addressed within this document are primarily intended for use with multiple electrodynamic or servo-hydraulic vibration generators along with an associated computer-based digital control system to control of the specimen excitations.

This document encompasses two testing approaches, commonly referred to as multi-exciter single-axis (MESA), and multi-exciter multi-axis (MEMA). These are:

a) Utilising fixed base shakers either in a single axis or a selected combination of fixed X, Y, Z configurations, also allowing for rotations dependent upon fixture coupling design.

b) Utilising multiple shakers attached directly to the specimen via flexible couplings or similar methods. Here the shakers are attached at any point and in any direction on the specimen. This approach is quite similar to that used for modal testing, but using environmental test severities.

It is emphasised that MESA and MEMA testing currently requires a high degree of engineering judgement and relevant experience, and both test specifier and tester are fully aware of this fact. Generally, MESA and MEMA testing requires greater resources to set up an appropriate test, but potentially provides a more accurate outcome.

For the purpose of this document, the creator of the relevant testing specification, the test specifier, is expected to select the procedure and the values of severity appropriate to the specimen and its use. Precursor testing is included within the procedure of this document, as an option, to permit the test specifier to establish the practicality of the test specification and severities with the specimen. A separate specimen is usually provisioned for such precursor testing.

The existing single axis, single vibrator test procedures within the IEC 60068-2 series can be used with a wide range of different excitations, such as broad band random, random on random, sine on random, swept sine, shock, and long-time history replication. Theoretically these different forms of excitations, can also be applied using multi-axis and multi-exciter methods. However, suitable techniques and commercially available test control software, for some of these types of testing, are not necessarily currently commonly available. For this reason, the procedure of this document is currently primarily intended for broad band random and time history replication as facilities to undertake these types of tests are commonly available. With that said, the procedure of this document may be adapted, by the user, for other forms of excitation and advice is provided.

Traditionally, vibration, shock and transient test severities are specified using acceleration as the control parameter. However, this is not an essential pre-requisite of the procedure within this document. For the purpose of this document, vibration, shock and transient test severities are specified by the user and may be in the form of acceleration, velocity, displacement, or force. The need to include different control parameters within this document arises because there is a greater likelihood when using multi-exciter testing to specify mixed parameters for control purposes. In which case the vibration, shock and transient waveforms applied to the specimen will be controlled based upon the feedback from transducers measuring the appropriate parameter.

Although primarily intended for electrotechnical specimens, this document is not restricted to them and may be used in other fields where desired.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests –Test Fc: Vibration, (Sinusoidal)*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-57, *Environmental testing - Part 2-57: Tests – Test Ff: Vibration – Time-history and sine-beat method*

IEC 60068-2-64, *Environmental testing – Part 2-64: Tests –Test Fh: Vibration, broadband random and guidance*

IEC 60068-2-80, *Environmental testing – Part 2-80: Tests –Test Fi: Vibration – Mixed mode*

IEC 60068-2-85, *Environmental testing – Part 2-85: Tests –Test Fj: Vibration – Long time history replication*

ISO 2041, *Mechanical vibration, shock and condition monitoring – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, IEC 60068-1, IEC 60068-2-6, IEC 60068-2-27, IEC 60068-2-57, IEC 60068-2-64, IEC 60068-2-80 and IEC 60068-2-85 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
multi-exciter single-axis
MESA
method of applying vibration test waveforms using multiple vibration exciters, but all applying the vibrations in a single specimen axis

3.2
multi-exciter multi-axis
MEMA
method of applying vibration test waveforms using multiple vibration exciters in two or more specimen axis

Note 1 to entry: The applied excitations may be in the translation axes, rotational axes or both translation and rotational axes.

3.3
single-input single-output
SISO
method of applying vibration test waveforms using input of a single drive signal to an exciter system in a single-degree of freedom configuration and a single measured output from the test specimen or its fixing points in a single-degree of freedom configuration

Note 1 to entry: This is essentially a conventional single axis/exciter test arrangement using a single measured response for control purposes.

3.4
single-input multiple-output
SIMO
method of applying vibration test waveforms using input of a single drive signal to an exciter system in a single degree of freedom configuration, and multiple measured outputs from the test specimen or its fixing points in a multi-degree of freedom configuration

Note 1 to entry: This is essentially an extension of a conventional single axis/exciter test arrangement, but manipulating multiple measured responses for control purposes.

3.5
multiple-input single-output
MISO
method of applying vibration test waveforms using input of multiple drive signals that are applied to the multiple exciters, to produce a single measured output from the test specimen or its fixing points

Note 1 to entry: Unless the multiple inputs are applying the identical waveform, this arrangement is often not possible as multi-exciter test control systems often require the number of outputs to match the number of inputs.

3.6
multiple-input multiple-output
MIMO
method of applying vibration test waveforms using input of multiple drive signals that are applied to the exciters, to produce multiple measured outputs from the test specimen or its fixing points

Note 1 to entry: Commonly, as a minimum, the number of inputs and outputs should be the same, but many systems used for multi-exciter control, allow the number of outputs to exceed the number of inputs. Commonly, multi-exciter and multi-axis test control systems operate as multiple-input multiple-output systems.

4 Background

4.1 General

The capability to undertake multi-exciter testing has been available for some time for seismic as well as durability / fatigue testing. Generally, such tests utilise excitations which occur at relatively low frequencies. It is only comparatively recently that capabilities have become commonly available to undertake multi-axis and/or multi-exciter tests, at frequencies necessary for general purpose vibration, shock and transient testing.

The use of multi-axis and/or multi-exciter testing equipment [1][1] for certain types of vibration, shock and transient testing is currently perceived as having advantage in a number of applications, some of which are set out below. This list should not be considered as exhaustive as applications for multi-axis and/or multi-exciter testing are still being identified. Broadly the advantages of multi-axis and/or multi-exciter testing include better loading distribution, more realistic excitations, and the potential for test time reduction.

4.2 Multi-axis and/or multi-exciter testing to achieve an improved distribution of dynamic responses

Multi-axis and/or multi-exciter testing is in regular use for large and/or dynamically complex specimens, where there is a need to ensure that the dynamic response motions of the specimen are correctly achieved. In such cases multi-exciter testing can achieve a far more accurate distribution of dynamic responses than the traditional vibration, shock and transient testing methods. This is particularly the case when the specimen would experience, in-service, dynamic excitations from multiple excitation sources. An example of this would be a road vehicle were somewhat different dynamic excitations arise from each wheel.

Using multi-axis and/or multi-exciter testing to achieve an improved distribution of dynamic responses within a specimen, usually requires test severities which are derived from vibration, shock or transient data, measured during actual life cycle conditions. The applied dynamic excitations are commonly controlled from measurements at multiple response locations. This is essentially a "controlled response" test control strategy. This is a fundamentally different control strategy, to that used for the majority of the single axis vibration, shock and transient tests within IEC 60068-2. Those single axis tests are basically "controlled excitation" tests both applying and controlling the excitations to the specimen’s fixing points. Such a control strategy is not profoundly influenced by the dynamic responses of the specimen. Consequently, the test severities for such "controlled excitation" tests can readily adopt "generic" severities as the severities are independent of the dynamic responses of the specimen.

For some applications "generic" severities have advantage in that they may represent a wide range of life cycles conditions. For example, the generic test severities for transportation encompass a range of usage conditions and a variety of transportation platforms. The use of simple generic test severities with multi-axis and/or multi-exciter testing may limit the ability to achieve an accurate distribution of dynamic responses.

1 Numbers in square brackets refer to the Bibliography.

4.3 Multi-exciter testing for large equipment

Multi-exciter testing is sometimes used as a testing convenience, permitting the use of several smaller exciters rather than a single much larger (and more expensive) exciter. In this case the use of multi-exciter testing can permit the testing of equipment which otherwise would not be practicable. As an example, four vibrators could be (electrically and mechanically) coupled together to provide a facility to test very large specimens such as entire vehicles. If the waveforms applied to each exciter are correlated, then such a setup is essentially that of a conventional single axis test procedure and comparable test severities could be adopted. If the waveforms are not correlated, then the procedure of this document would be more applicable. In such cases the test severities may be defined either as applied excitations to the specimen fixing points or as specimen responses. In either case, the testing arrangement means that the test will need to be controlled using a "controlled response" strategy.

Although the use of generic test severities is a possibility when using this type of test approach, the phase and amplitude relationship between the excitations will still need to be derived with some knowledge of actual relationships. This is necessary as, without such knowledge, the dynamic conditions experienced by the specimen may well be significantly increased and/or decreased in an indeterminate way from that of a single axis test.

4.4 Multi-axis testing for reliability growth

Multi-axis testing has been perceived as having advantage for reliability growth testing of certain types of electro-technical equipment. This is because the multi-axis dynamic responses produced within the specimen are different, in many ways, to those produced during single axis testing. The multi-axis dynamic responses produced are considered to exercise a greater number of potential failure and degradations modes of the specimen than the conventional single axis testing.

The test severities used for reliability growth testing are generally exaggerated (viz. greater than those likely to be experienced in-service) and applied at the fixing points of the specimen. For this specific purpose, the use of generic test severities may be appropriate. Nevertheless, the dynamic responses within the specimen may not necessarily represent conditions which actually occur during the specimen life cycle. For this reason, failures identified by such test are commonly the subject of a reliability failure assessment, to ensure they could realistically occur during the equipment’s life cycle.

4.5 Multi-axis testing to reduce test durations

Multi-axis testing has sometimes been proposed as a testing convenience for reducing the duration of applied excitation. Simplistically, by applying excitations in all three-axis simultaneously, the test duration can be reduced by a third from that of single axis tests undertaken in three axes separately. It may also achieve savings in that only one test set up is required. However, these savings may not necessarily be fully achieved as the multi-axis test set up may be more complicated to achieve. When coupled with the purpose of achieving an improved distribution of dynamic responses, such a saving may not always possible, as the use of more realistic severities may also require them to be applied for longer durations.

There can also be a concern when multi-axis testing is used with generic severities to achieve a test duration reduction. This is because the phase and amplitude relationship utilised between the different excitation axes, will produce indeterminately increased and/or decreased dynamic conditions with the specimen from those of three separate single axis tests. Commonly generic severities are based upon long historic experience with the existing single axis test. As such it may not be realistic to compare the outcome of multi-axis testing, undertaken with generic severities, with the outcome of historic single axis tests.

5 Test apparatus and control strategy

The use of any multi-exciter or multi-axis test system, capable of satisfying the test requirements, is acceptable [1]. The capability of the excitation equipment and control facility to conduct the test, as specified in the relevant specification, shall be verified prior to undertaking the test.

Guidance information on multi-exciter / multi-axis test control systems is provided in Annex A. Guidance on the application of different control strategies is provided in Annex B. Guidance on the use of different multi-exciter / multi-axis test configuration is provided in Annex C. Further general guidance on multi-exciter and multi-axis testing can be found in [2], [3], [4] and [5].

6 Test severities and tolerances

6.1 Test severities

The test severities utilised shall be those specified in the relevant specification. Unless specified otherwise, the severities and other parameters necessary to undertake this test should be based on the purpose for which it is being conducted and on the conditions the specimen is likely to experience during its life cycle.

Guidance information on establishing severities for multi-exciter / multi-axis testing is provided in Annex D.

6.2 Tolerances

The measured control responses shall not deviate from the specified requirements by more than the test tolerances quoted in the relevant specification.

Unless specified otherwise the tolerance on:

a) Power spectral density values, of a Gaussian random vibration test, shall be within ±3 dB of the specified values.
b) Time history amplitudes, of a time history replication test, shall be within ±20 % of the highest amplitude of the specified waveform for at 90 % of the specified waveform duration.

The test tolerances shall not be used to modify the specified requirements.

Any deviation from the specified tolerances shall be agreed with the relevant test specifier and the actual tolerances achieved, and reason for the deviation, stated in the test report. In order to achieve such an agreement, it is recommended that the verification measurements set out in Annex B should be made available to the relevant test specifier.

Guidance information on the selection of suitable tolerances for multi-exciter / multi-axis testing is provided in Annex E.

6.3 Excitations outside the specified test frequency range

Excitations outside the specified test frequency range shall be minimised and if required quantified. The approach to be used to quantify excitations outside the specified test frequency range, if required, shall be specified in the relevant specification. Guidance information on establishing severities for multi-exciter / multi-axis testing is provided in Annex B.

Unless specified otherwise the out of test frequency range excitations shall be established as set out below.

a) Random vibration: For random vibration tests, including all the vibration tests, which have broad band and narrowband random components, the out of test frequency range responses shall be established up to 5 000 Hz or 5 times the driving frequency, whichever is the lesser. The out of test frequency range responses shall be established in accordance with the procedure of IEC 60068-2-64, although it should be noted that the procedure of IEC 60068-2-64 is specifically related to the use of acceleration as a control parameter.

b) Time history replication: For time signal replication tests the out of test frequency range responses shall be established up to 10 000 Hz or 10 times the driving frequency, whichever is the lesser. The out of test frequency range responses shall be established in accordance with the procedure of IEC 60068-2-85.

c) Sinusoidal tests: For sinusoidal vibration tests (fixed, swept and stepped) the signal tolerance shall be established up to 5 000 Hz or 5 times the driving frequency, whichever is the lesser. This parameter applies whether the signal is acceleration, velocity, or displacement. The signal tolerance shall be established in accordance with the procedure of IEC 60068-2-6.

6.4 Cross-axis motions

The relevant specification shall specify whether cross-axis motions are to be controlled. If there is a requirement to control cross-axis motions, then the relevant specification shall also specify the approach to be used to quantify the cross-axis motions and the appropriate tolerance.

If cross-axis motions are of concern and no requirements are provided in the relevant specification, then the following are recommended.

a) Random vibration: should not exceed -3 dB of the highest specified spectral acceleration for each control axis for each frequency up to 500 Hz or 0 dB for higher frequencies in accordance with IEC 60068-2-64.

b) Sine vibration: should not exceed 50 % of the highest specified acceleration for each control axis for each frequency up to 500 Hz or 0 dB for higher frequencies in accordance with IEC 60068-2-6.

c) Time history replication: should not exceed 50 % of the highest specified acceleration for each control axis at each time step in accordance with IEC 60068-2-85.

Any deviation from the specified cross-axis requirements shall be agreed with the relevant test specifier and the actual cross axes motions achieved, and reason for the deviation, stated in the test report. In order to achieve such an agreement, it is recommended that the verification measurements set out in Annex B should be made available to the relevant test specifier.

Further guidance information on cross-axis motions for multi-exciter/multi-axis testing is provided in Clause B.3.

7 Mounting of specimen and installation of measurement systems

The specimen shall be mechanically connected to the multi-exciters and fixtures, in the required orientation and state, as specified in the relevant specification. Unless specified otherwise, the specimen shall be held by its normal means of attachment. The specimen installation shall include, as required, any connections necessary for power supplies, test signals, performance monitoring and any monitoring instrumentation, to establish the responses from the test specimen.

General guidance on the mounting of specimens for vibration testing is provided in IEC 60068-2-47 [6]. However, the guidance and normative requirements of IEC 60068-2-47 are intended for single axis testing, they are not necessarily fully applicable to multi-exciter testing. Additional guidance on test fixtures and the mounting of specimens, applicable to different types of multi-axis or multi-exciter testing, is provided in [1] as well as in Annex C.

Thermal, vibration, shock and transient measurement instrumentation shall be installed on to the test specimen and test fixture, as specified by the relevant specification.