INTERNATIONAL STANDARD

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Vibration generating machines — Guidance for selection —

Part 1
Equipment for environmental testing

Générateurs de vibrations — Lignes directrices pour la sélection —

Partie 1: Moyens pour les essais environnementaux

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10813-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 6, *Vibration and shock generating systems*.

ISO 10813 consists of the following parts, under the general title *Vibration generating machines — Guidance for selection*:

— *Part 1: Equipment for environmental testing*

Further parts are under preparation.

Introduction

To select a suitable vibration generating system is an urgent problem if it is necessary for a certain test to purchase new test equipment or to update the equipment already available, or to choose between equipment proposed by a test laboratory or even a laboratory itself which offers its service to carry out such a test. A problem like this can be resolved quite easily if a number of factors are considered simultaneously, as follows:

— the type of the test to be carried out (environmental testing, normal and/or accelerated, dynamic structural testing, diagnosis, calibration, etc.);

— the requirements to be followed;

— the test conditions (one mode of vibration or combined vibration, single vibration test or combined test, for example, dynamic plus climatic);

— the objects to be tested.

This part of ISO 10813 deals only with equipment to be used during environmental testing, and those selection procedures that are predominantly to meet the requirements of this test. However, the user should keep in mind that a specific test condition and a specific object to be tested can significantly influence the selection. Thus, to excite a specimen inside a climatic chamber imposes limitations on the vibration generator interface, and a specimen of a large size and/or of a complex shape, having numerous resonances in all directions, demands larger equipment than that specified for the procedures of this part of ISO 10813, assuming that excitation is to be applied to the rigid body of the same mass. Unfortunately, such aspects cannot easily be formalized and, thus, are not covered by this part of ISO 10813.

If the equipment is expected to be used for tests of different types, all possible applications should be considered when selecting. Later parts of ISO 10813 will address the problem of the case where the vibration generator is acquired to be applied during both environmental and dynamic structural testing. It is presumed in this part of ISO 10813 that the system selected will be able to drive the object under test up to a specified level. In order to generate an excitation without undesired motion, a suitable control system should be used. The selection of a control system will be considered in a further International Standard.

It should be emphasized that vibration generating systems are complex machines, so the correct selection always demands a certain degree of engineering judgement. As a consequence, the purchaser, when selecting the vibration test equipment, can resort to the help of a third party. In such a case, this part of ISO 10813 can help the purchaser to ascertain if the solution proposed by the third party is acceptable or not. Designers and manufacturers can also use this part of ISO 10813 to assess the market environment.

Vibration generating machines — Guidance for selection —

Part 1:
Equipment for environmental testing

1 Scope

This part of ISO 10813 gives guidance for the selection of vibration generating equipment used for vibration environmental testing, depending on the test requirements.

This guidance covers such aspects of selection as

— the equipment type,

— the model, and

— some main components, excluding the control system.

NOTE Some examples are given in Annex A.

2 Normative references

The following referenced documents are indispensable for the application 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.

ISO 2041, *Vibration and shock — Vocabulary*

ISO 5344, *Electrodynamic vibration generating systems — Performance characteristics*

ISO 8626, *Servo-hydraulic test equipment for generating vibration — Methods of describing characteristics*

ISO 15261, *Vibration and shock generating systems — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 5344, ISO 8626 and ISO 15261 apply.

4 Requirements for vibration tests

4.1 Vibration test purposes

The purpose of vibration tests is to estimate the capability of an object to maintain its operational characteristics and to stay intact under vibration loading of defined severity. The tests are subdivided, in accordance with their tasks, into functional, strength and endurance tests.

Strength tests are carried out to estimate the capability of an object to withstand vibration of defined severity and to stay in working order when the excitation is removed. In these tests, vibration might cause mechanical damage (fatigue) and may be used to predict the lifetime of the object under vibration.

Endurance tests are carried out to estimate the capability of an object to function and maintain the operational parameters within the acceptable limits under vibration. Usually during those tests the object is working for a defined period in its normal condition and is being exposed to vibration not causing mechanical damage to it. Faults and malfunctions in the operation of the object should be registered.

4.2 Test methods

4.2.1 General

Laboratory test methods may use both sinusoidal and multifrequency excitation in various forms, such as sinusoidal at a fixed frequency, swept sinusoidal, random (narrow-band or wide-band), as well as in a mixed mode. The excitation may be multidirectional and/or multipoint.

Test specifications usually deal with the following waveforms:

- sinusoidal at a fixed frequency;
- swept sinusoidal;
- wide-band random;
- time history;
- sine-beat.

The above waveforms are briefly described in 4.2.2 to 4.2.5 primarily in aspects as standardized by the IEC (see [1] to [4]), however the user should be aware that other variants of a waveform may be used for specific applications.

Requirements for the test excitation (and, hence, for the test equipment) for test methods standardized by the IEC are given for information in Annex B.

4.2.2 Sinusoidal vibration

4.2.2.1 Sinusoidal vibration at fixed frequencies

This excitation consists of a set of discrete-frequency sinusoidal processes of defined amplitude, applied sequentially to the test object within the frequency range of interest. Frequency and amplitude are adjusted manually. A control system maintains the displacement or acceleration amplitude. The test conditions to be set include the frequency range (bands) and individual fixed frequencies, test duration and displacement, velocity or acceleration amplitude.

4.2.2.2 Swept sinusoidal vibration

This excitation is a sinusoidal signal of a constant amplitude, commonly defined in displacement terms at low frequencies and in acceleration terms at high frequencies. The frequency is continuously swept from the lower to the upper limit of the frequency range of interest and vice versa. Cross-over frequency usually lies in the range of 10 Hz to 500 Hz. A control system maintains the displacement or acceleration amplitude. During the frequency sweep, the mechanical resonances and undesirable mechanical and functional behaviour of the test object can be observed and identified. The test conditions to be set include the frequency range of interest, displacement and acceleration amplitudes, cross-over frequency, sweep rate and test duration.

4.2.3 Wide-band random vibration

The wide-band random excitation, specified by the shape of spectral density of acceleration to be close to real operational conditions in the frequency range of interest, is generated at the control point of the table or the object. The test conditions to be set include the acceleration spectral density levels for the frequency bands in which tests are carried out.

4.2.4 Time-history method

This test consists of subjecting the specimen to a time-history specified by a response spectrum with characteristics simulating the effects of short-duration random-type forces. A time-history may be obtained from a natural event (natural time-history), or from a random sample, or as a synthesized signal (artificial time-history). The use of a time-history allows a single test wave to envelop a broad-band response spectrum, simultaneously exciting all modes of the specimen on account of the combined effects of the coupled modes.

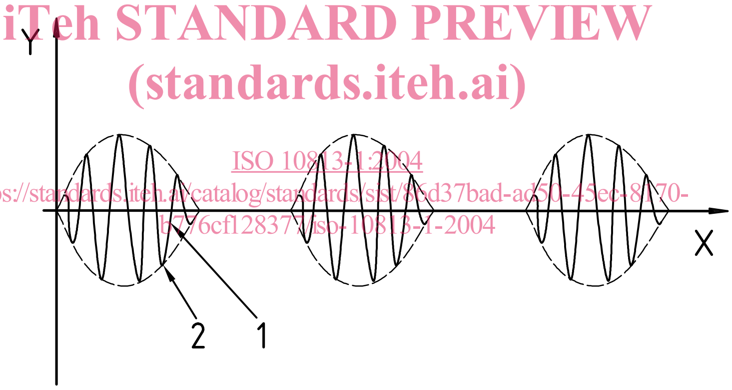
This test is applied to specimens which in service can be subjected to short-duration random-type dynamic forces induced, for example, by earthquakes, explosions or transportation.

The test conditions to be set include the frequency range of interest, required response spectrum, number and duration of time-histories, number of high peaks of the response.

4.2.5 Sine-beat method

In this test the specimen is excited at fixed frequencies (to be experienced in the practical application or to be changed with a step of not greater than one-half octave) with a preset number of sine beats (see Figure 1). These fixed frequencies may be critical frequencies identified by means of vibration response investigation.

The test conditions to be set include the frequency range, test level, number of cycles in the sine beat, number of sine beats. A control system maintains the displacement amplitude below the cross-over frequency and the acceleration amplitude above the cross-over frequency.



Key

X time

Y vibration aplitude

1 carrier wave (test frequency)

2 envelope curve (modulating frequency)

Figure 1 — Typical sequence of sine beats

5 Types and characteristics of vibration generators

5.1 Main types of vibration generators

5.1.1 General

A vibration generator is the final control element of a vibration generating system, providing generation of the desired vibration and transmission of it to the object being tested. The type and performance of a vibration generator determine the main system characteristics, such as force generation capabilities, permissible loads, displacement/velocity/acceleration amplitudes, frequency ranges and accuracy characteristics (tolerances, distortions, transverse motions, etc.). Depending on their design, vibration generators are subdivided into electrodynamic, servohydraulic, mechanical, electromagnetic, piezoelectric, magnetostrictive, etc. The most common types of vibration generators being used for environmental testing are electrodynamic, servohydraulic and mechanical.

5.1.2 Electrodynamic vibration generators

This type of vibration generator produces a vibration force by interaction of a static magnetic field and an alternating magnetic field. The alternating magnetic field is produced by an alternating current in the moving coil, which is an actuator.

A vibration generating system including an electrodynamic vibration generator is called an electrodynamic system. It consists of a power amplifier, input signal source and control system, measuring instrumentation, field power supply and auxiliaries. The system may also include an auxiliary table.

5.1.3 Servohydraulic vibration generators

This type of vibration generator produces a vibration force by application of a liquid pressure being changed in a predetermined manner. In servohydraulic vibration generators, force and motion are transmitted to the object by a hydraulic actuator (piston pushed by fluid) controlled by servovalves.

A vibration generating system including a servohydraulic vibration generator is called a servohydraulic system. It consists of a hydraulic power supply system, signal source, close-loop control system, and measurement and auxiliary equipment.

5.1.4 Mechanical vibration generators

This type of vibration generator produces a vibration force by transformation of mechanical rotation energy.

Mechanical vibration generators are classified into kinematic and reaction-type vibrators.

In kinematic vibrators, the test object is moved by some control unit directly, for example by a crank, a rocker or a cam.

In reaction-type vibrators, the centrifugal force is generated by rotational movement (sometimes by reciprocal movement) of unbalanced masses.

A vibration generating system including a mechanical vibration generator is called a mechanical system.

5.2 Major parameters

ISO 5344 and ISO 8626 deal with characteristics of electrodynamic and servohydraulic vibration generators respectively. They cover the following main characteristics:

— rated force;

— permissible static load;

— frequency range;

— limits for displacement, velocity and acceleration;

— distortion;

— transverse motion ratio;

— non-uniformity of table motion;

— resonance frequencies.

5.3 Features

5.3.1 Electrodynamic vibration generators

Typical parameters for electrodynamic vibration generators are given in the Table 1. Manufacturers offer various series or steps of force ratings for the vibration generating system. When a system is being purchased from a manufacturer, or being selected for usage from several systems of purchaser's own, it is recommended to use actual specification sheets.

Table 1 — Typical parameters for electrodynamic vibration generators

Rated force N	Output of the power amplifier VA	Frequency range Hz	Maximum displacement mm	Maximum velocity m/s	Maximum acceleration without load m/s^2	Maximum load kg	Mass of moving system kg
31,5	6,3	5 to 13 000	2,5	0,4	200	1,0	0,16
63	19	5 to 10 000	2,5	0,4	300	1,5	0,2
125	62,5	5 to 8 000	5,0	0,8	500	2,0	0,25
250	165	5 to 8 000	8,0	1,3	650	4,0	0,38
500	400	5 to 7 000	8,0	1,3	800	10,0	0,62
1 000	1 000	5 to 5 000	12,5	2,0	1 000	25,0	1,0
2 000	2 000	5 to 5 000	12,5	2,0	1 000	75,0	2,0
4 000	4 000	5 to 4 000	12,5	2,0	1 000	200,0	4,0
8 000	8 000	5 to 3 500	12,5	2,0	1 000	300,0	8,0
16 000	16 000	5 to 3 000	12,5	2,0	1 000	400,0	16,0
32 000	32 000	5 to 2 500	12,5	2,0	1 000	500,0	32,0
64 000	64 000	5 to 2 000	12,5	2,0	1 000	1 000,0	64,0
128 000	128 000	5 to 1 800	12,5	2,0	1 000	2 000,0	128,0
200 000	200 000	5 to 1 600	12,5	2,0	1 000	3 125,0	200,0

NOTE Upper limits for different vibration parameters cannot be achieved simultaneously.

The main features of electrodynamic vibration generators are the following:

— any type of excitation is possible: sinusoidal (at fixed frequencies and swept), random (broad-band and narrow-band), etc.;

— ease of control (manual and automatic);

— wide frequency range: 0,5 Hz up to 15 000 Hz (typically 5 to 5 000 Hz); in general, the lower the rated force the higher the upper limit of the frequency range;

— high displacement: up to ± 25 mm (typically up to ± 12,5 mm), and acceleration: up to 1 500 m/s^2 (typically up to 1 000 m/s^2);

— high force: up to 400 kN (typically up to 200 kN);

— relatively large permissible load: up to 4 000 kg (typically up to 1 000 kg);

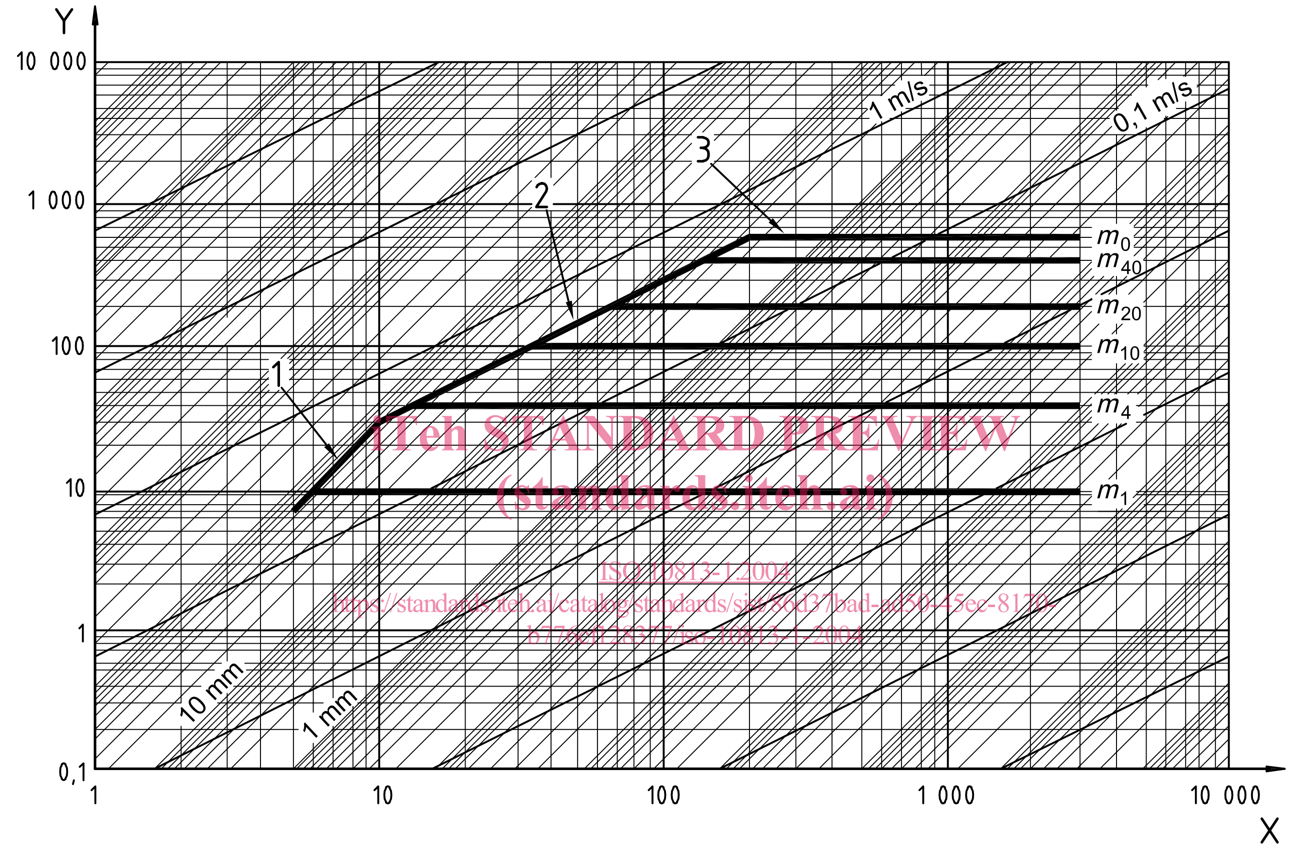
— low harmonic distortion: about 5 %, excluding frequency bands where distortion increases because of resonances between the vibration generator and the load;

— acceptable transverse motion and uniformity of table motion: about 10 %, excluding frequency bands where an undesired motion arises due to moving system resonances or off-set test loads.

One disadvantage of electrodynamic generators is caused by the presence of a magnetic field in the area of the vibration table. This, however, may be reduced to the order of 0,001 T by means of special compensation devices.

Also rated force cannot be generated over the whole frequency range. It is limited by the rated travel at low frequencies, by the rated velocity at middle frequencies and by the resonances of the moving system at high frequencies. Achievable acceleration depends on the load mass. ISO 5344 states six test loads m_0, m_1, m_4, m_{10}, m_{20}, m_{40}, where the first load is zero and the following are those permitting maximal accelerations of 10 m/s^2, 40 m/s^2, 100 m/s^2, 200 m/s^2 and 400 m/s^2 respectively.

Figure 2 shows typical curves of acceleration (displacement, velocity) against frequency for various loads.



Key

X frequency, Hz
Y acceleration, m/s^2

1 displacement limit
2 velocity limit
3 maximum acceleration

Figure 2 — Typical curves for electrodynamic vibration generators

In the case of random vibration, the rated force is defined in terms of the acceleration spectral power density $\Phi_a(f)$, in (m/s^2)^2/Hz (see ISO 5344):

$$\Phi_a(f) = 0 \qquad f < 20\ \text{Hz}$$

$$\Phi_a(f) = (f/100)^2\ \Phi_0 \qquad 20\ \text{Hz} < f < 100\ \text{Hz}$$

$$\Phi_a(f) = \Phi_0 \qquad 100\ \text{Hz} < f < 2\,000\ \text{Hz}$$

$$\Phi_a(f) < \Phi_0 (2\,000/f)^4 \quad \text{or} \quad 10^{-4}\Phi_0 \qquad f > 2\,000\ \text{Hz}$$