International Standard 5344

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Electrodynamic test equipment for generating vibration — Methods of describing equipment characteristics

Moyens d'essais électrodynamiques utilisés pour la génération des vibrations — Méthodes de description des caractéristiques

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5344 was developed by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, and was circulated to the member bodies in March 1978.

It has been approved by the member bodies of the following countries :

Australia	France	Sweden
Austria	Germany, F.R.	Turkey
Belgium	Italy	United Kingdom
Brazil	Japan	USA
Bulgaria	Mexico	USSR
Chile	Netherlands	Yugoslavia
Czechoslovakia	South Africa, Rep. of	
Denmark	Spain	

No member body expressed disapproval of the document.

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Electrodynamic test equipment for generating vibration — Methods of describing equipment characteristics

0 Introduction

This International Standard concerns the characteristics to be standardized for test equipment used to generate vibration by electrodynamic means and serves as a guide to the selection of such equipment.

In the context of this International Standard, the term "electrodynamic" means that the vibratory force created by the generator results from the interaction of a constant magnetic field and an alternating current in a built-in coil.

This International Standard applies to the following :

a) electrodynamic vibration generators (see clauses 3 to 7, and annexes);

b) power amplifiers (see clauses 3, 4, 5, 6 and 8, and annexes);

c) vibration generator and associated power amplifiers (see clauses 3 to 9, and annexes).

A test equipment system comprises : vibration generators and amplifiers combined as in this International Standard, and control consoles, auxiliary tables (see ISO 6070) and other test equipment to be standardized later.

The division into separate classes, a), b) and c) above, has been made to permit the performance of vibration generators and their associated amplifiers to be predicted from the characteristics of separate portions of the test equipment. Classes a) and b) are provided primarily to permit a prospective user to calculate the performance of a vibration generator from one manufacturer with a power amplifier from another manufacturer. Class c) may be all that a prospective user requires if both the vibration generator and the power amplifier are from the same manufacturer.

1 Scope and field of application

The test equipment used for the electrodynamic generation of vibration possesses many characteristics which can be evaluated in many very different ways.

To permit comparison of test equipment from different sources, this International Standard establishes the following :

a) a list of the characteristics;

b) the standard method of obtaining certain characteristics.

This International Standard provides three levels of description to be used in describing test equipment, as follows :

a) minimum level of description;

b) medium level of description;

c) high level of description.

This International Standard gives, for each level of description, a list of the characteristics to be specified by the manufacturer in his tender and in his literature.

2 References

ISO/R 468, *Surface roughness.*

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources — Engineering method for free-field conditions over a reflecting plane.*

IEC Publication 268-3, *Sound system equipment — Part 3 : Sound system amplifiers.*

3 Symbols

a Acceleration

a_b rms acceleration in random mode

b Damping coefficient of the moving element suspension

d Total harmonic distortion (see 5.9)

F Maximum sinusoidal force (see 5.2)

F_b Maximum random force, broad band

F_o Rated sinusoidal force (see 5.3)

F_{ob} Rated random force, broad band (see 5.4)

F_{omt} Rated sinusoidal force (see 7.2.3) (subscript t represents the various loads)

f Frequency

f_{max} Maximum frequency for which the value of a specified parameter is never less than a specified or rated value of this parameter

f_{min} Minimum frequency for which the value of a specified parameter is never less than a specified or rated value of this parameter

f_{mt} First mechanical resonance frequency of the moving element (subscript t represents the various loads) (see 5.7)

f_{st} Resonance frequency of the moving element suspension (subscript t represents the various loads) (f_{s0} is the particular case for no load) (see 5.5)

$H_i\,(f)$ Acceleration per unit current in the moving element coil

$H_v\,(f)$ Acceleration per unit voltage across the moving element coil terminals

I Current

I_b Available effective current under random conditions

I_o Complex output current

I_{so} Rated effective current under sinusoidal conditions

K Dynamic stiffness of the moving element suspension

m_e Effective mass of the moving element

m_t Masses of test loads ($t = 0$, $t = 1$, $t = 2$, $t = 3$, $t = 4$)

P Maximum apparent sinusoidal power

P_b Apparent random power, broad band

P_{so} Rated apparent sinusoidal power (see 5.8)

P_{ob} Rated apparent random power

P_{obc} Rated apparent peak random power

R_{so} Resistive test load

U_E Complex input voltage

U_o Complex output voltage

V_g Overall output noise voltage

V_o Rated output signal voltage

V_{so} Rated sinusoidal voltage

v_s Velocity of moving element

Z_b Generator impedance in the random vibration mode

Z_{so} Inductive test load

γ_i Acceleration/current response

Δf Frequency bandwidth

Φ_a Acceleration power spectral density

Φ_F Maximum force power spectral density

Φ_{Fo} Rated force power spectral density

Φ_P Power spectral density for maximum random power

Φ_{Po} Power spectral density for rated random power

Ψ Force or acceleration crest factor

φ Phase shift (phase angle)

4 Units and quantities

When the manufacturer or the user gives the values for the parameters required by this International Standard, he should clearly define the units that have been used, and state whether the quantities are given as rms, peak or peak-to-peak values.

5 Definitions

This clause defines only some of the terms used in this International Standard. See ISO 2041 for definitions of a general nature.

5.1 force : In this International Standard, force is the force developed by an electrodynamic vibration generator which can be delivered to a load mounted on the test table or connected to the force take-off. This force differs from the force generated by currents flowing in the moving element primarily due to the effects of moving element mass, moving element resonances, suspension stiffness, suspension damping, and the limits of vibration travel.

5.2 maximum force under sinusoidal conditions, F : The upper limit of the force which the vibration generator is capable of delivering at a given frequency and for a specified test load.

5.3 rated force under sinusoidal conditions, F_o : The minimum value of all the values of F_{omt} which the vibration generator is capable of delivering; expressed in another way, it is the minimum value of the function F for test loads m_t.

5.4 rated random force, broad band, F_{ob} : The minimum value, for any test load, of the random force, broad band. This force corresponds to a spectral power density of uniform acceleration between lower and upper frequency limits.

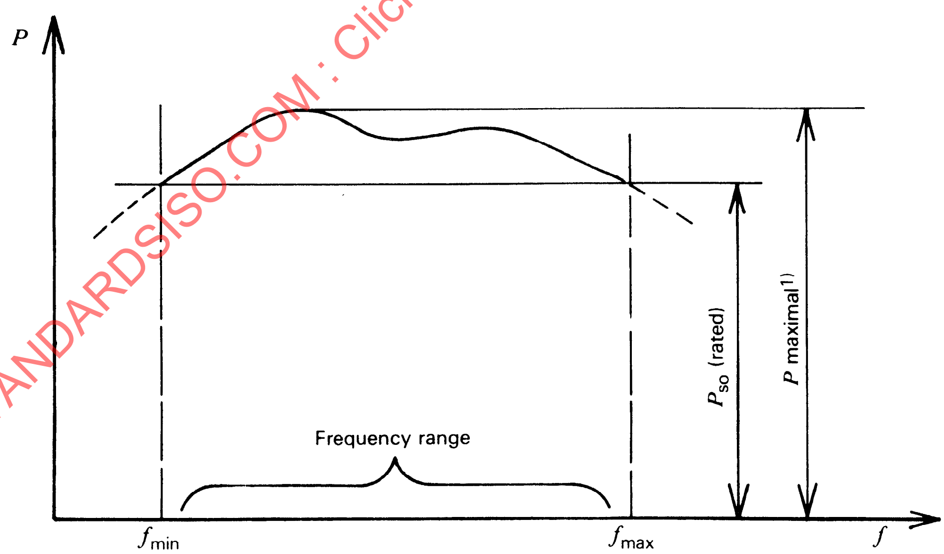
5.5 mechanical resonance frequency of the moving element suspension, f_{st} : This frequency is determined by the effective mass of the moving element and test load and the dynamic stiffness of the moving element suspension.

5.6 electrical resonance frequency of the moving element : The frequency at which the current in the moving coil is in phase with the voltage, and the electrical impedance is a minimum.

5.7 mechanical resonance frequency of the moving element, f_{mt} : This frequency is the first mechanical resonance frequency of the moving element found above the mechanical resonance frequency of the moving element suspension.

5.8 rated apparent power under sinusoidal conditions, P_{so} : The minimum value of curve P (see figure 1). This curve results from the product of the current and voltage which the amplifier can deliver within the frequency range.

NOTE — The quantity "rated apparent power" shall be used with either a resistive, or an inductive, or a mixed load. The power factor must be stated.



1) See ISO 2041, sub-clause 2.043.

Figure 1 — Curve of maximum apparent power versus frequency

5.9 total harmonic distortion, d : Referred to the output signal, it is expressed as a percentage by the following equation :

$$d = \frac{\sqrt{X_2^2 + X_3^2 + \ldots + X_n^2}}{\sqrt{X_1^2 + X_2^2 + \ldots + X_n^2}} \times 100$$

where X_1 is the value of the fundamental term and X_2, $X_3, \ldots, X_n$ represent the harmonic components of the nth order of the signal.

NOTES

1 Some instruments measure the total harmonic distortion d by suppressing the fundamental acceleration, and noise is then present; in this case the ratio of the total harmonic distortion to the background noise, expressed as a percentage of the rms value of the total harmonic distortion, must be at least 10 dB.

2 The total harmonic distortion d can also be calculated by summing the values of the harmonic distortion of nth order according to the "square law" (see IEC Publication 268-3).

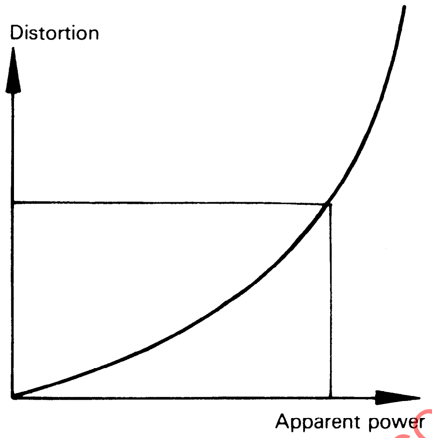


Figure 2 — Total harmonic distortion as a function of apparent power at a given frequency

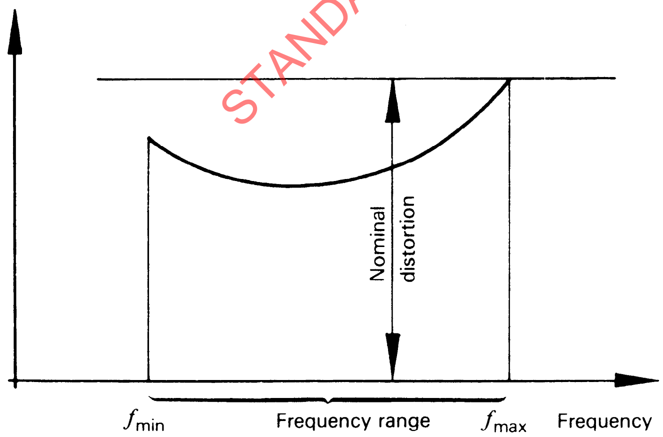


Figure 3 — Total harmonic distortion as a function of frequency at the rated apparent power

5.10 transverse acceleration ratio : The ratio of the transverse acceleration to the axial acceleration.

5.11 effective mass of the moving element, m_e : The moving element, its suspension system, connectors and other devices attached to the moving element constitute a vibration system which is both discrete and continuous. It exhibits the vibratory characteristics attributable to an equivalent discrete system with one degree of freedom, where the parameters of mass and stiffness are functions of the frequency.

It is arbitrarily assumed that the stiffness does not vary and that any variation in the dynamic characteristics is therefore attributable to a variation in mass. In the frequency band

$$3 f_{st} \leqslant f \leqslant \frac{f_{mt}}{3},$$

which excludes resonances, the maximum value of the mass, determined by the method of clause B.1 of annex B, defines the effective mass m_e of the moving element.

5.12 rated travel : The limits between which the moving element of the generator normally operates and beyond which performance is no longer guaranteed by the manufacturer.

6 Characteristics to be supplied by the manufacturer

Attention is drawn to the fact that the three levels of description as adopted in this International Standard are not related to the quality or size of the equipment.

A higher level of description may, for example, be required for a vibration generator of small size and medium quality, whereas under certain circumstances a medium level of description can be sufficient for a large size, high quality equipment.

The level of description required will normally depend on the use to which the equipment is to be put by the customer.

This International Standard also gives characteristics useful in matching an electrodynamic vibration generator acquired from one source or at one time to a power amplifier acquired from another source or at another time.

The characteristics shown by a cross in tables 1 to 3 shall be supplied where demanded by the particular level of description.

Those characteristics which are not required for the particular level of description (those not shown by a cross) can however be supplied by agreement between manufacturer and user.

NOTE — Attention is drawn to the necessity of specifying such particular characteristics at the time of enquiry and ordering because their cost, which can be high, has to be taken into consideration.

Clauses 7, 8 and 9 describe the characteristics listed in tables 1 to 3 without specifying their level of description. Methods of measurement of some of these characteristics are given in annex B.

Table 1 — Vibration generator

Characteristic	Reference to corresponding sub-clause	Level of description		
		minimum	medium	high
Rated frequency ranges	7.2.1		x	x
Frequency range limitation	7.2.2		x	x
Rated sinusoidal force, F_{omt}	7.2.3	x	x	x
Rated random force, broad band, F_{ob}	7.2.4		x	x
Uniformity of the test table motion at the load fixing surface	7.2.5			x
Transverse motion of the test table	7.2.6			x
Total acceleration distortion	7.2.7			x
Response characteristics	7.2.8			
Impedance in random vibration mode	7.2.9			
Response characteristics in random vibration mode	7.2.10			
Stray magnetic field	7.2.11		x	x
Background noise	7.2.12		x	x
Effective mass of the moving element, m_e	7.3.1	x	x	x
Rated travel	7.3.2	x	x	x
Static stiffness of the moving element suspension	7.3.3		x	x
Dynamic stiffness of the moving element suspension	7.3.4			
Mechanical resonance frequency of the moving element suspension	7.3.5		x	x
Mechanical resonance frequencies of the moving element	7.3.6		x	x
Damping coefficient of the moving element suspension	7.3.7			
Permissible static load on the moving element, with the axis vertical and central test load	7.3.8		x	x
Permissible static load on the moving element, with the axis vertical and offset test load	7.3.9			
Permissible static load on the moving element, with the axis horizontal	7.3.10			x
Means of attaching the loads	7.3.11	x	x	x
Maximum torque on each threaded insert or fixing element	7.3.12		x	x
Maximum permissible axial force per threaded insert	7.3.13		x	x
Flatness of the test table	7.3.14		x	x
Perpendicularity of the threaded inserts with respect to the plane of the test table	7.3.15			x
Perpendicularity of the motion with respect to the test table plane	7.3.16			
Coincidence of axes (exciter free take-off)	7.3.17			
Test table dimensions	7.3.18	x	x	x
Tolerances on the coupling of an auxiliary table	7.3.19			
General layout	7.4.1	x	x	x
Masses composing the vibration generator and auxiliary services	7.4.2	x	x	x
Vibration generator pedestal	7.4.3.1	x	x	x
	7.4.3.2		x	x
	7.4.3.3		x	x
	7.4.3.4			x
	7.4.3.5	x	x	x
Sound power level of the emitted noise	7.4.4	x	x	x
Heat dissipation	7.4.5		x	x
Temperature of test table	7.4.6		x	x
Built-in pickup	7.5.1		x	x
Cooling system	7.5.2	x	x	x
Field supply system	7.5.3	x	x	x
Demagnetizing system	7.5.4		x	x
Protective and safety system	7.5.5	x	x	x
Permissible working site environment	7.6.1	x	x	x
Combined tests	7.6.2			
Technical specifications and operating instructions	7.6.3	x	x	x

Table 2 — Power amplifier

Characteristic	Reference to corresponding sub-clause	Level of description		
		minimum	medium	high
Frequency range for a given rated power	8.2.1	x	x	x
Rated apparent sinusoidal power, P_{so}	8.2.2	x	x	x
Total rated harmonic distortion	8.2.3		x	x
Rated apparent random power, P_{ob}	8.2.4			x
Input characteristics	8.3.1	x	x	x
Output characteristics	8.3.2	x	x	x
Frequency response curves	8.3.3			x
Signal-to-noise ratio	8.3.4		x	x
Output voltage stability	8.3.5			x
Gain stability	8.3.6			
Installation requirements	8.4	x	x	x
Miscellaneous characteristics	8.5.1	x	x	x
	8.5.2.1		x	x
	8.5.2.2		x	x
	8.5.2.3		x	x
	8.5.3			
Technical specifications and operating instructions	8.5.4	x	x	x

Table 3 — Generator/amplifier system

Characteristic	Reference to corresponding sub-clause	Level of description		
		minimum	medium	high
Rated frequency range	9.2.1	x	x	x
Frequency range limitations	9.2.2		x	x
Rated sinusoidal force, F_{oml}	9.2.3	x	x	x
Rated random force, broad band, F_{ob}	9.2.4		x	x
Uniformity of table motion at the load fixing surface	9.2.5			x
Transverse motion of the test table	9.2.6			x
Total acceleration distortion	9.2.7		x	x
Stray magnetic field	9.2.8			x
Background noise acceleration	9.2.9		x	x
Background noise output voltage of the power amplifier	9.2.10		x	x
Input characteristics of generator/amplifier system	9.2.11	x	x	x
Signal-to-noise ratio	9.2.12		x	x
Output force stability	9.2.13			x
Erratic movements of the moving element	9.2.14		x	x
Response characteristics	9.4			
General layout	9.5.1	x	x	x
Masses composing the principal parts of the generator/amplifier system	9.5.2	x	x	x
Pedestal of the generator/amplifier system	9.5.3.1	x	x	x
	9.5.3.2		x	x
	9.5.3.3		x	x
	9.5.3.4			x
	9.5.3.5	x	x	x
Generated sound power level	9.5.4	x	x	x
Heat dissipation	9.5.5		x	x
Test table temperature	9.5.6		x	x
Auxiliary equipment required by the installation	9.5.7	x	x	x
Built-in control transducer	9.6.1		x	x
Cooling system	9.6.2	x	x	x
Field supply system	9.6.3	x	x	x
Demagnetizing system	9.6.4		x	x
Protective and safety system	9.6.5	x	x	x
Miscellaneous	9.7.1	x	x	x
	9.7.2.1		x	x
	9.7.2.2		x	x
	9.7.2.3			x
	9.7.3			
Combined tests	9.7.4			
Technical specifications and operating instructions	9.7.5	x	x	x

7 Electrodynamic vibration generators

Diagrams showing the principles of electrodynamic vibration generators with vibrating tables and force take-off (exciter) are given in annex A (figures 7, 8 and 9).

7.1 Test loads, m_t

Electrodynamic vibration generators shall be tested using the mechanical test loads defined below.

The test shall be carried out in a frequency band including the frequency for which the rated force has been specified.

The test loads shall meet the following requirements :

— Fixing screws shall be used in all available mounting locations.

— The length of fixing screws between the head and the thread engagement part shall be such that the resonance frequency of the fixing is outside the frequency range of the test.

— The torque to be applied to fixing screws shall be such that the test load remains in contact with the test table at the fixing points but shall not exceed the limiting value given by the manufacturer (see 7.3.11).

— The surface texture of the contact area of the test load shall be as follows :

$R_a \leqslant 1,6$ µm[1)]

(ground finish).

— The flatness tolerance for the contact area shall be 0,1 mm per metre.

— The test load used on test tables shall consist of a right cylinder with a diameter equal to the largest fixing diameter increased by six times the screw diameter.

— The use of a thin test load shall be avoided in order to maintain adequate rigidity. The recommended ratio of thickness to diameter shall be greater than 0,4 and shall be achieved by changing the nature of the material used for the manufacture of the test load.

Furthermore, in the case of vibration generators with force take-offs (exciters), the coupling arrangements and shape of test load shall be described by the manufacturer.

NOTES

1 Some test loads may require the use of a load compensating system.

2 By agreement between the manufacturer and the user, eccentric test loads may be used; in this case, the loads and fixing means shall be described.

7.1.1 test load m_0 : The particular case where the test load is zero and where the moving element alone is driven.

7.1.2 test load m_1 : A load permitting an acceleration of approximately 40 g_n amplitude under sinusoidal conditions.

7.1.3 test load m_2 : A load permitting an acceleration of approximately 10 g_n amplitude under sinusoidal conditions.

7.1.4 test load m_3 : A load permitting an acceleration of approximately 4 g_n amplitude under sinusoidal conditions.

NOTE — This test load m_3 shall be used only when required, and by agreement between the manufacturer and the user.

7.1.5 test load m_4 : A load permitting an acceleration of approximately 1 g_n amplitude under sinusoidal conditions.

NOTE — This test load m_4 is used only for generators with force take-offs (exciters), and by agreement between the manufacturer and the user.

7.1.6 test load m_5 : A load permitting an acceleration of approximately 20 g_n under sinusoidal conditions.

NOTE — This test load m_5 shall be used only when test load m_1 cannot be used because an acceleration of 40 g_n exceeds the capability of the vibration generator. At the option of the manufacturer, data with this load m_5 may be provided wherever this document calls for data with the test load m_1; however, such substitution shall be called to the attention of the user by adding the subscript 5 to the symbols for all such data and adding to each page of data the note : test load m_5 replaces test load m_1.

1) See the definition of R_a in ISO/R 468.

7.2 General characteristics

7.2.1 Rated frequency ranges

The manufacturer shall state the rated frequency ranges corresponding to the rated force for each test load m_0, m_1 and m_2 (see 7.1).

7.2.2 Frequency range limitation

The manufacturer shall state the frequency ranges corresponding to the displacement, velocity and acceleration of the vibration generator moving element. He shall also state the factors affecting the operation of the test equipment within these ranges.

NOTE — The use of the test equipment may be limited towards the lower frequencies by the following :

a) the harmonic distortion of the test table acceleration;

b) the signal-to-noise ratio;

c) the conditions of installation of the vibration generator or the conditions of suspension of the vibration generator with force take-off (exciter).

The use of the test equipment may be limited towards the upper frequencies by the following :

a) the mechanical resonance frequency of the moving element;

b) the following factors :

1) for a vibration generator with a test table :

— the uniformity of the acceleration over the surface of the test table;

— the transverse motions of the test table;

— the harmonic distortion of the test table acceleration;

2) for a vibration generator with a force take-off (exciter) :

— the apparent compliance of the force take-off;

— the transverse motions of the force take-off;

— the harmonic distortion of the force take-off acceleration.

7.2.3 Rated force under sinusoidal conditions, F_{omt}

The manufacturer shall state the rated force available with test loads m_0, m_1 and m_2 (see 7.1) for the given frequency ranges (see 7.2.1).

If continuous operation is not possible under certain conditions such as certain ranges of loads or frequency bands (for example those of the suspension spring resonances), these limitations shall be clearly stated.

It shall be clearly specified that the rated force applies only to the vibration generator alone and not to the combination of the vibration generator and the power amplifier.

The rated sinusoidal force, F_{omt}, is calculated for the specified test load m_t by :

$$F_{omt} = (m_e + m_t)\,a$$

NOTE — Newton's law is then applicable over the whole frequency range to the system, which is assumed to be rigid (pure mass, see the definition in ISO 2041) and without taking the stiffness and damping of the suspension into account.

7.2.4 Rated random force, broad band, F_{ob}

The manufacturer shall state the rated force available with test loads m_0, m_1 and m_2 (see 7.1).

The manufacturer shall state the load range (pure masses) under which the rated force for the vibration generator in continuous operation can be obtained for the specified acceleration power spectral density.

For generators operating at frequencies between 20 and 2 000 Hz, the shape of the acceleration power spectral density, $\Phi_a(f)$ expressed in g^2/Hz or $\mathrm{m^2/s^3}$, shall be :

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

$$\Phi_a(f) = \left(\frac{f}{100}\right)^2 \Phi_0 \qquad \text{for } 20\ \mathrm{Hz} < f < 100\ \mathrm{Hz}\ \text{(20 dB/decade)}$$

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

$$\Phi_a(f) = 0 \qquad \text{for } f > 2\,000\ \mathrm{Hz}$$

NOTE — $\Phi_0(f)$ is a function of the frequency defined as the limiting value of $\dfrac{a_b^2}{\Delta f}$ when Δf tends towards 0, and where a_b is the rms value of the random acceleration and Δf a frequency band centred about frequency f.

The rated random force, broad band, F_{ob}, is calculated for the specified test load m_t by :

$$F_{ob} = (m_e + m_t)\,a_b$$

If continuous operation is not possible under certain conditions such as certain ranges of load or certain frequency bands (for example those of the natural resonances of the suspension springs), these limitations shall be clearly stated.

It shall also be clearly indicated that the rated force applies to the vibration generator alone and not to the combination of the vibration generator and the power amplifier.

NOTES

1 The available force delivered by the vibration generator is a function both of the shape of the acceleration power spectral density and of the load dynamic response (which does not correspond to the case of a pure mass). Since most real loads are totally coupled to the vibration generator only in the lower part of the frequency range, the available rms acceleration may be greater than the acceleration as calculated for pure mass loads. Under such conditions, if the actual shape of the acceleration spectral density is different from the specified spectrum shape, the rms current limit or random rms acceleration limit may reduce the available acceleration to a lower level than the calculated level.

2 The crest factor of the force shall be at least 3.

7.2.5 Uniformity of the test table motion at the load fixing surface

The manufacturer shall indicate the uniformity of the acceleration field of the unloaded test table as a function of frequency in a set of curves representing the acceleration of the worst fixing point on each bolt circle relative to a given reference point, preferably the centre of the table. In the case of a slotted test table, at least two measuring points shall be selected on the radius.

- the best possible (as close to the centre as possible);
- the worst possible.

Example : 20 to 1 500 Hz : $\pm x$ dB, 1 500 to 1 900 Hz : $\pm y$ dB, 1 900 to 2 000 Hz : $\pm z$ dB.

7.2.6 Transverse motion of the test table

The manufacturer shall show the transverse motion of the test table as a function of frequency by two curves showing the ratio of the transverse motions to the axial motion at the central fixing point. The two orthogonal directions shall be parallel and perpendicular respectively to the trunnion axis. If the central point is not accessible, the position of the reference point shall be stated.

Measurements shall be made with the table unloaded and with test load m_2, at the rated force if possible, and the manufacturer shall specify the method used.

Supplementary measurements of the transverse motion such as measurements with other test loads m_t, or measurements away from the central point, may be carried out by agreement between the manufacturer and the purchaser.

7.2.7 Total acceleration distortion

The manufacturer shall indicate the acceleration distortion of the unloaded generator test table or of the unloaded exciter force take-off.

The acceleration distortion shall be shown by a curve as a function of the frequency at constant force equal if possible to the rated force. The limits of this curve are defined by the rated frequency ranges (see 7.2.1 and 7.2.2).

Supplementary measurements of the total acceleration distortion, such as measurement with test loads m_t, may be made by agreement between the manufacturer and the user.

7.2.8 Response characteristics

The manufacturer shall state the acceleration response per unit current in the moving element coil $H_i(f)$ and the acceleration response per unit voltage across the moving coil terminals $H_v(f)$ as a function of the frequency.

They shall be presented as curves in the rated frequency range within the limits indicated in 7.2.2, taking rated conditions and test loads (m_0, m_1 and m_2) into account.

See the curves represented on figures 4 and 5.

NOTES

1 The point selected for measurement shall be the centre of the test table or the centre of the top part of the load unless another point is specified by the manufacturer.

2 The data from which $H_i(f)$ and $H_v(f)$ are calculated are taken from slow sweeps over the rated frequency range at the maximum limits of the vibration generator, displacement, velocity, or force, measuring acceleration, current, and voltage.

7.2.9 Impedance in the random vibration mode

The manufacturer shall indicate the impedance of the generator in the random vibration mode for test loads m_0, m_1 and m_2 (see 7.1) and for a particular shape of acceleration power spectral density. For generators operating at frequencies between 20 and 2 000 Hz, the shape of the acceleration power spectral density shall be as specified in 7.2.4.

NOTES

1 The impedance Z_b in the random mode can be used to calculate the random acceleration of a vibration generator fitted with any amplifier for which the random output voltage and current characteristics are specified.

2 The calculation of Z_b carried out by the manufacturer involves the acceleration per unit current in the moving element coil $H_i(f)$ and the acceleration per unit voltage across the moving element coil terminals $H_v(f)$ in accordance with the following equations :

$$Z_b = \frac{K_v}{K_i}$$

with

$$K_v = \left\{ \int_{f_1}^{f_2} \Phi_a(f) \, [H_v(f)]^{-2} \, df \right\}^{1/2}$$

$$K_i = \left\{ \int_{f_1}^{f_2} \Phi_a(f) \, [H_i(f)]^{-2} \, df \right\}^{1/2}$$

3 Z_b is not a function of the overall spectral level but only of the desired spectral shape and of the ratio of the two response functions K_v and K_i.

7.2.10 Response characteristics in the random vibration mode

The manufacturer shall indicate the acceleration/current response, γ_i, for test loads m_0, m_1 and m_2 (see 7.1) and for the same shape of acceleration power spectral density as in 7.2.9.

The calculation of γ_i requires the computation of the rms acceleration a_b for the specified shape of the acceleration power spectral density.

$$a_b = \left[\int_{f_1}^{f_2} \Phi_a(f) \, df \right]^{1/2}$$

The acceleration/current response γ_i is given by :

$$\gamma_i = \frac{a_b}{K_i}$$

where K_i is as defined by the equation given in 7.2.9.

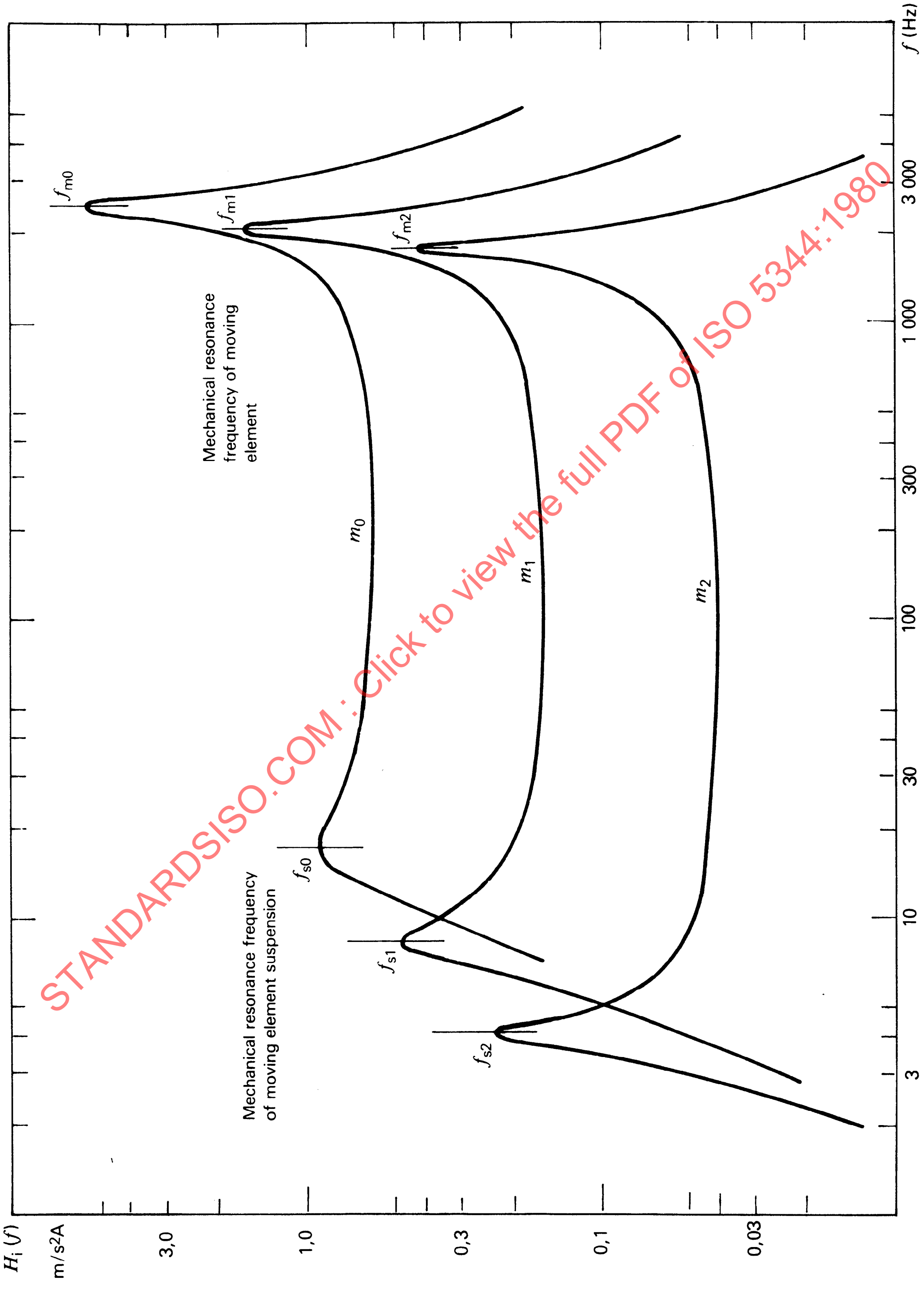


Figure 4 — Acceleration per unit current in the moving element coil

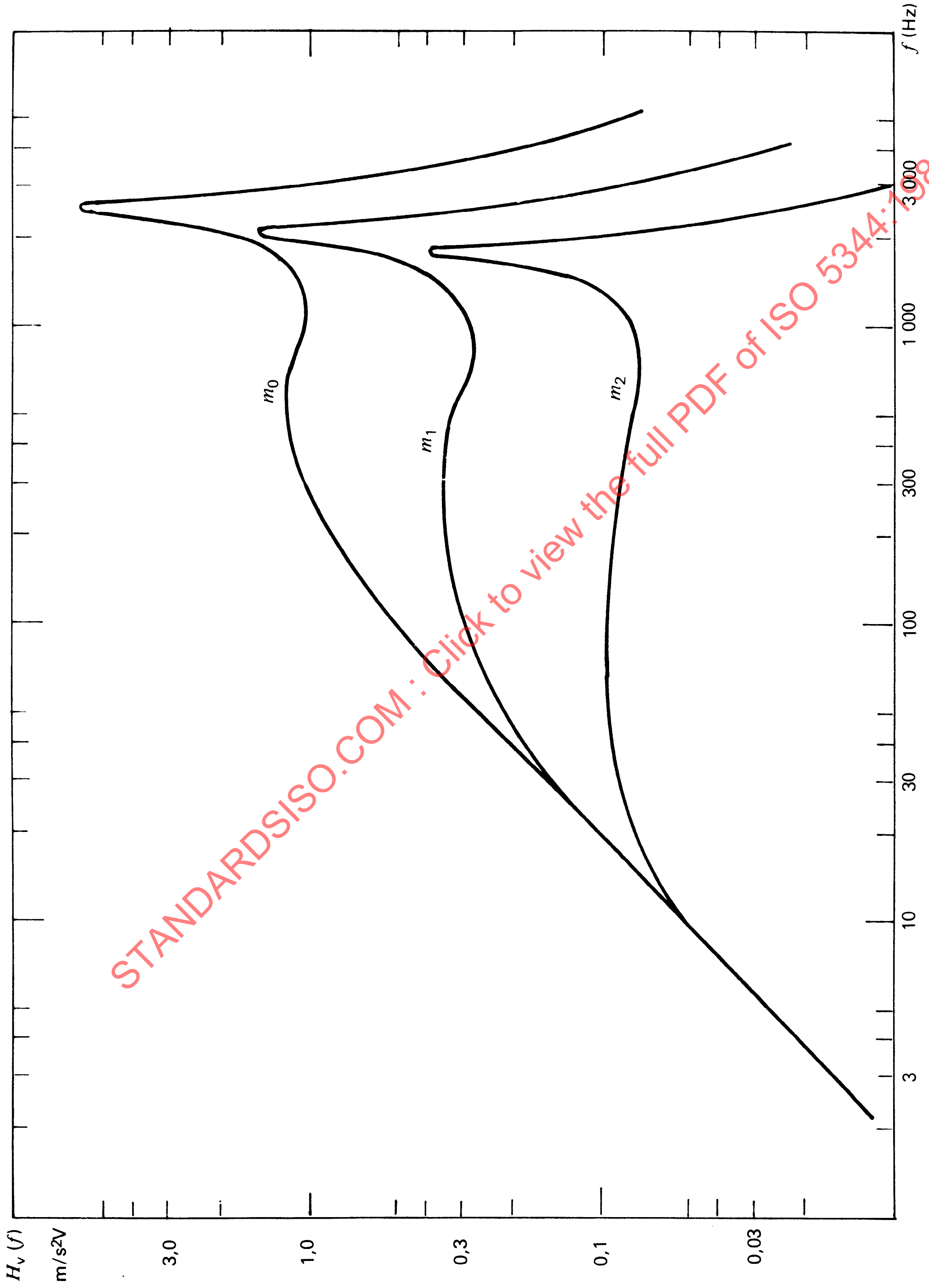


Figure 5 — Acceleration per unit voltage across the moving element coil terminals

7.2.11 Stray magnetic field

The manufacturer shall state the stray magnetic field with the test table or the force take-off in the unloaded condition and under thermally stable conditions. Along the axis, it shall be specified as a function of the distance from the centre. Over the surface, it shall be specified in a plane parallel to the surface at a distance from the surface of one quarter of the largest bolt circle diameter at points in the plane directly above each of the threaded inserts. The value given shall be the maximum value of the magnetic field in the area of the point under consideration.

If the use of a demagnetizing device is optional, measurements shall be carried out with and without this device.

In the case of slotted vibrating tables, measurements shall be made at the centre and at two points on each radius, one of which must be at the edge of the table.

7.2.12 Background noise

The manufacturer shall state the level of the rms background noise of the acceleration of the unloaded test table (or of the force take-off).

7.3 Moving element

The moving element of an electrodynamic vibration generator consists of the following :

- a test table (2 in figure 7) or a force take-off (20 in figure 8);
- a moving element structure (1 in figures 7 and 8);
- a moving coil (3 in figures 7 and 8);
- a suspension connecting the moving element structure to the fixed part of the vibration generator (5 in figure 7);
- various auxiliary devices such as flexible supports, electrical connections and cooling connections.

7.3.1 Effective mass of the moving element, m_e

The manufacturer shall indicate the effective mass, m_e, for the moving element as mounted in the electrodynamic vibration generator. It shall be determined within the frequency band between $3 f_{st}$ and $\frac{f_{ml}}{3}$ (see also 5.11). The maximum mass thus derived from measurements at the level of the test table or force take-off includes the influence of the suspension of the connectors and other auxiliary devices attached to the moving element. (See method of measurement in clause B.1 of annex B.)

7.3.2 Rated travel

The manufacturer shall indicate the rated travel of the moving element (see 5.12). This can be checked by applying the method of measuring the deflection curve described in clause B.6 of annex B.

The travel between the electrical safety devices and between the mechanical stops shall also be stated.

7.3.3 Static stiffness of the moving element suspension

The manufacturer shall indicate the static stiffness of the moving element suspension as an average value.

Additionally, a curve of deflection as a function of the load at ambient temperature shall be supplied at the customer's request. The ambient temperature at which the measurements are made shall be given. (See method of measurement in clause B.6 of annex B.)

NOTES

1 The curve of static stiffness as a function of deflection may be deduced from the curve of deflection as a function of load.

2 If the vibration generator is fitted with a load compensating device, the operation and characteristics of the latter shall be described. The limitations imposed on the vibration generator characteristics shall be stated (see 7.3.8).

3 Many moving element suspension systems contain elastomeric elements which exhibit both creep and hysteresis effects that vary with time, temperature, frequency and velocity. If these effects are important to a given application, the user shall request adequate data from the manufacturer.

7.3.4 Dynamic stiffness of the moving element suspension

The manufacturer shall state the dynamic stiffness of the moving element suspension.

This stiffness is calculated from quantities f_{st} and m_e (see the method of calculation in clause B.2 of annex B).

7.3.5 Mechanical resonance frequency of the moving element suspension

The manufacturer shall state the mechanical resonance frequency of the moving element suspension. (It usually lies between 1 and 100 Hz) (see figure 4 and the method of determination in B.4.1 of annex B).

7.3.6 Mechanical resonance frequencies of the moving element

The manufacturer shall state the mechanical resonance frequencies of the moving element (see figure 4 and the method of determination in B.4.2 of annex B).

7.3.7 Damping coefficient of the moving element suspension

The manufacturer shall state the dynamic damping of the moving element suspension.

This damping shall be measured at the mechanical resonance frequency of the moving element suspension and deduced from either of the two methods of measurement described in clause B.3 of annex B as selected by the manufacturer. Attention is drawn to the fact that the deduced damping includes dry and viscous friction.

7.3.8 Permissible static load on the moving element, with the axis vertical and with a central test load

The manufacturer shall state the permissible static load, with the axis vertical and the centre of gravity of the test load on the vertical axis of the moving system. He shall state the period for which it may be applied.

7.3.9 Permissible static load on the moving element, with the axis vertical and with an offset test load

The manufacturer shall state the permissible static load on the moving element, with the axis vertical and with an offset test load.

He shall state the maximum offset of the test load from the centre of the table, together with the period for which it may be applied.

7.3.10 Permissible static load on the moving element, with the axis horizontal

The manufacturer shall state the maximum permissible load on the moving element with the axis horizontal. The curve for the permissible load can be plotted as a function of the distance of the centre of gravity of the load to the plane of the test table.

7.3.11 Means of attaching the loads

The manufacturer shall indicate the means of attaching the loads and the limits of torque to be applied to the fixing screws.

In the case of test tables, he shall state whether or not they are fitted with replaceable threaded inserts and whether they are recessed or raised.

A diagram shall be provided giving the dimensions of the table, the dimensions and positional tolerances of the inserts and the material from which they are made.

7.3.12 Maximum torque on each threaded insert or fixing element

The manufacturer shall state the value of the maximum permissible torque to be applied to each threaded insert or to each fixing element.

7.3.13 Maximum permissible axial force per threaded insert

The manufacturer shall state the value of the maximum permissible axial force per threaded insert.

7.3.14 Flatness of the test table

The manufacturer shall indicate the overall and local tolerances for the flatness of the test table under ambient conditions and with thermally stable conditions according to 7.4.5.

If the table is fitted with recessed inserts, the flatness of the whole surface of the table shall be indicated.

If the table is provided with replaceable raised inserts, the manufacturer shall state both the flatness of the mounting surfaces for these inserts and the tolerance on the thickness of the mounting flanges of the inserts.

7.3.15 Perpendicularity of the threaded inserts with respect to the plane of the test table

The manufacturer shall state the tolerance of perpendicularity of the threaded inserts with respect to the plane of the test table.

7.3.16 Perpendicularity of the motion with respect to the test table plane

The manufacturer shall state the tolerance of perpendicularity of the vibratory motion with respect to the plane of the test table.

7.3.17 Coincidence of axes (Exciter force take-off)

The manufacturer shall state the tolerances on parallelism for the vibratory motion with respect to the axis of the exciter force take-off.

7.3.18 Test table dimensions

The manufacturer shall state the dimensions of the test table and supply a dimensioned drawing of the fastenings and their tolerances.

He shall further state the requirements for attaching and mounting to the test table.

7.3.19 Tolerances on the coupling of an auxiliary table

The manufacturer shall state the tolerances on the coupling between the auxiliary table and the vibration generator.

7.4 Installation requirements

7.4.1 General layout

The manufacturer shall supply dimensioned drawings with tolerances for the vibration generator and any auxiliary devices (cooling, fluid and electricity supply systems, cables, etc.). If special tools are required, this shall be stated.

7.4.2 Masses composing the vibration generator and auxiliary services

The manufacturer shall state :

— the total mass of the vibration generator;

— the mass of the pedestal, if any;

— the heaviest mass to be handled during dismantling of the vibration generator;

— the mass of auxiliary devices (cooling systems, etc.).

7.4.3 Vibration generator pedestal

The manufacturer shall give the following data on :

7.4.3.1 The device for orienting the vibration generator : its positioning stops and locking device, as well as the principle of its operation.

7.4.3.2 The generator body suspension system : its stiffness and method of locking.

7.4.3.3 The natural frequencies of the vibration generator pedestal in the vertical and horizontal orientations, when the suspension (see figure 7, part 16) is not locked.

7.4.3.4 The curve of acceleration as a function of frequency at the level of the vibration generator bearing trunnion (see figure 7, part 15) with the suspension in the free position (see figure 7, part 16), in order to determine the effectiveness of the isolation.

7.4.3.5 The requirements for installing the generator pedestal on its foundations, with drawings if necessary (see figure 7, part 19).

7.4.4 Sound power level of the emitted noise

The manufacturer shall state the maximum sound power level in each octave band emitted by the vibration generator and by the hydraulic and cooling systems under the following operating conditions :

— with the moving element unloaded but with full field and the field coil cooling system operating;

— at rated sinusoidal force without load (load m_0) with excitation frequency adjusted to the centre of each octave band.

The manufacturer shall use one of the methods of measurement described in ISO 3744. If this cannot be used, he shall then clearly explain the method employed.

NOTES

1 If the vibration generator is equipped with an independent cooling system, the manufacturer shall state the sound power levels corresponding to the vibration generator, the cooling system, and the auxiliary devices respectively.

2 If the vibration generator is fitted with suspension springs, the acoustic values shall correspond to the values obtained under normal test conditions (with the suspension in free position). If, however, the sound power level in an octave band increases by more than 3 dB when the springs are locked, this information shall also be given.

7.4.5 Heat dissipation

The manufacturer shall state the heat dissipation of the vibration generator together with the thermal stabilization time under rated conditions.

If auxiliary devices are used, the heat dissipation by them shall be stated separately.

7.4.6 Temperature of test table

The manufacturer shall state the temperature of the test table for stabilized conditions corresponding to the maximum heating of the moving element.

7.5 Auxiliary equipment

7.5.1 Built-in pickup

When a pickup is incorporated in the vibration generator, the manufacturer shall give the following data :

— calibration;

— linearity characteristics;

— frequency response curve;

— transverse response;

— thermal stability (transient and permanent conditions).

When the built-in pickup is an accelerometer, its natural frequency shall be stated.

The ratio of the maximum operational frequency of the vibration generator to the natural frequency of the pickup shall not exceed 0,2.

The possible effect of the test load on the accuracy of the calibration of the pickup shall be stated.

NOTE — The pickup shall not be used to measure the performance of the generator.

7.5.2 Cooling system

The manufacturer shall state the requirements for connecting the cooling system to the vibration generators, as well as the following characteristics :

— flow rate;

— pressure;

— input and output temperatures;

— maximum permissible temperature;

— electrical power required;

— description of the thermostat, if any;

— physio-chemical characteristics of the cooling fluid(s) (for example mineral salt content of water, humidity of air, etc.);

— closed circuit operation (if applicable).

7.5.3 Field supply system

The manufacturer shall state whether the field supply system is included or whether it is produced by a permanent magnet.

The following electrical characteristics shall be stated :

— power required;

— voltage;

— current;

— resistance of the field coils at 20 °C;

— insulation resistance with respect to the yoke of the vibration generator.

7.5.4 Demagnetizing system

The manufacturer shall state the following information concerning the demagnetizing system :

— power required;

— voltage;

— current;

— range of adjustment of the demagnetizing device (see 7.2.11).

7.5.5 Protective and safety system

The manufacturer shall state the characteristics relating to the following items :

— mechanical stops for upper and lower ends of the travel (position and method of operation);

— electric displacement limit stops;

— electrical and electronic protective systems for the vibration generator (usually incorporated in the amplifier);

— thermal protection for the following components :

  — field coils;

  — moving coil;

  — cooling system.

The description shall state the method of operation of these protective and safety systems and their response time.

7.6 Environmental and operating conditions for vibration generator use

7.6.1 Permissible working site environment

The manufacturer shall state the permissible conditions of use for the generator, under rated conditions and without damage :

— maximum and minimum temperatures;

— relative humidity.

7.6.2 Combined tests

When the vibration generator is used in combined tests (vibration tests carried out in conjunction with heat, pressure, climatic or centrifugal acceleration tests), the manufacturer shall give the following information :

7.6.2.1 Climatic conditions

— maximum and minimum operating temperatures;

— permissible relative humidity;

— permissible absolute pressure, stating, where necessary, operation

  — with heat barrier;

  — in a climatic chamber.

7.6.2.2 Mechanical conditions

Centrifugal acceleration

— for the vibration generator, the maximum permissible continuous acceleration for the three directions;

— the acceleration compensation system. If such a system is provided, details shall be specified.

7.6.3 Technical specifications and operating instructions

The manufacturer shall supply instructions for the operation, maintenance and adjustment of the vibration generator.

They shall include the following :

— principles;

— description of the vibration generator;

— method of operation;

— mounting plan;

— diagram of the service connections;

— cable diagram;

— installation requirements;

— assembling and dismantling instructions;

— list of special tools, if required;

— nomenclature;

— preferred list of spare parts recommended by the manufacturer;

— miscellaneous.

8 Power amplifiers

8.1 Test loads

Power amplifiers shall be tested using the electrical test loads as defined below.

8.1.1 Inductive test load, Z_{so}

The inductive test load of power factor 0,5 shall have the following characteristics[1) :

a) the magnitude of the inductive test load Z_{so} shall be equal to $\frac{V_{so}}{I_{so}}$ to within 5 %.

b) the inductive and resistive components of Z_{so} shall be such that the current lags the voltage by $60^\circ {}^{+5^\circ}_{0}$.

c) Z_{so} may be an electrodynamic vibration generator, whose impedance is adjusted by varying the mechanical load and the test frequency.

8.1.2 Resistive test load, R_{so}

The resistive test load R_{so} shall exhibit the following characteristics :

a) The magnitude of the resistive test load R_{so} shall be equal to $\frac{V_{so}}{I_{so}}$ to within 5 %.

b) The reactive component of the load impedance shall be such that the current is in phase with the voltage to within 20° in the frequency range from f_{min} to 3 f_{max} (see 8.2.1).

8.2 General characteristics

8.2.1 Frequency range for a given rated power

The manufacturer shall indicate the frequency range for the rated power defined in 8.2.2 using the resistive test load R_{so} (see 8.1.2).

This frequency range is defined by frequencies f_{max} and f_{min} between which the power is never less than the specified rated power.

NOTE — If the amplifier may be used below f_{min} (with direct current, for example), the manufacturer shall supplement the preceding result by supplying plotted curves of the rms sinusoidal current and voltage as a function of frequency. The manufacturer shall also specify the limits, if any, of the load to which these current and voltage values might be applied.

8.2.2 Rated apparent sinusoidal power, P_{so}

The manufacturer shall state the rated apparent sinusoidal power P_{so} using the inductive test load Z_{so} (see 8.1.1).

The rated apparent sinusoidal power P_{so} is the product of :

a) the rated rms sinusoidal output current I_{so} which the manufacturer guarantees the amplifier to be capable of delivering at any and all frequencies in the rated frequency range under continuous operation at the load specified in 8.1, and

b) the rated rms sinusoidal output voltage V_{so} which the manufacturer guarantees the amplifier to be capable of delivering at any and all frequencies in the rated frequency range under continuous operation at the load specified in 8.1.

These currents and voltages shall be available throughout the full range of rated mains voltages and cooling system and coolant temperatures without causing distortion or dissipation greater than the guaranteed values.

NOTE — If the amplifier has several output connections which can be connected to the same load impedance, P_{so}, I_{so}, V_{so} and the corresponding load shall be specified separately for each of them.

8.2.3 Total rated harmonic distortion

The manufacturer shall state the total rated harmonic distortion using the resistive test load (see 8.1.2).

The total harmonic distortion of the output signal varies with the sinusoidal output power at a fixed frequency according to figure 2. The total rated harmonic distortion is the highest value in the range between f_{min} and f_{max} (figure 3).

8.2.4 Rated apparent random power, P_{ob}

The manufacturer shall state the rated apparent random power, P_{ob}, which is the maximum value of P_b.

A curve of the apparent random power P_b as a function of the impedance Z_b of the vibration generator shall be supplied. This curve of apparent random power has the general form shown in figure 6. (See note 1.)

1) It is generally enough to carry out the test at a frequency between 300 and 1 000 Hz. The selected test frequency shall be that frequency at which the available test load best corresponds to the particular conditions as defined in a) and b).

The manufacturer shall also state the apparent random power using the inductive test load Z_{so}. (See 8.1.1 and note 2.)

The spectrum of output current power spectral density, A^2/Hz, shall have the same shape as the shape of the acceleration power spectral density defined in 7.2.4.

For vibration generators operating in the random mode with an impedance Z_b, the available random power P_b is limited to an area below the limiting lines of figure 6.

Operation above the clipping limit may result in excessive clipping of voltage or current or both, and random acceleration peaks will no longer be able to reach 3 times the rms value of acceleration.

During operation above the current limit or the dissipation limit (see note 1), some components of the power amplifier may break down, or the protective circuits of the power amplifier may interrupt the operation to prevent such failure.

The manufacturer shall guarantee that available peak currents and voltages shall each exceed 2,3 times the rms values of current and voltage for the clipping limit curve of figure 6. (Experience has shown that peak factors of 2,3 provide adequate reproduction of acceleration peaks corresponding to 3 times the rms acceleration because of filtering by the vibration generator.)

NOTES

1 In some power amplifiers, the dissipation limit may lie above the current limit and other limits may occur below the limit lines illustrated, for example, the instantaneous dissipation limit and the secondary breakdown limit of output power transistors.

2 The value of apparent random power using the inductive test load, Z_{so}, will be significantly lower than P_{ob} since Z_{so} of 8.1.1 is typically about twice the magnitude of Z_b of 7.2.9. A test using Z_{ob} gives only one point of the curve of P_b as a function of Z_b, significantly to the right of the peak value of P_b.

By agreement between the manufacturer and the user, additional test loads may be used to establish other points on the curve. These additional test loads may take the form of an autotransformer with the same basic test load Z_{so}.

3 Figure 6 may be used by the prospective purchaser of an amplifier to estimate the rms random acceleration he can expect to obtain from any combination of vibration generator and amplifier.

a) The first step in calculating the rms random acceleration is to determine the apparent random power output of the amplifier. This output is a function of the electrical load connected to the amplifier output terminals, which in this case is the electrical impedance Z_b of the vibration generator. The electrical impedance, Z_b, of the vibration generator is a function not only of the vibration generator design, but also of the mechanical load on the vibration generator and of the shape of the spectrum of acceleration to be applied to that mechanical load [see d) below]. The apparent random power output of the amplifier is obtained from figure 6 by drawing a line of constant impedance Z_b parallel with the ordinate axis and noting the values of P_b obtained at each intersection with one or more of the limit lines : "clipping limit", "dissipation limit", and "current limit". The smallest value of P_b thus obtained is the apparent random power output of the amplifier with the electrical load Z_b.

b) The available rms random current I_b is a function of the load impedance Z_b and is given by :

$$I_b = \left(\frac{P_b}{Z_b}\right)^{1/2}$$

c) The rms random acceleration a_b to be expected from the vibration generator-amplifier combinations is :

$$a_b = \gamma_i \times I_b$$

d) The impedance Z_b in the random mode and the acceleration/current response γ_i of the generator may be obtained from the vibration generator manufacturer or may be calculated by procedures given in 7.2.9 and 7.2.10.

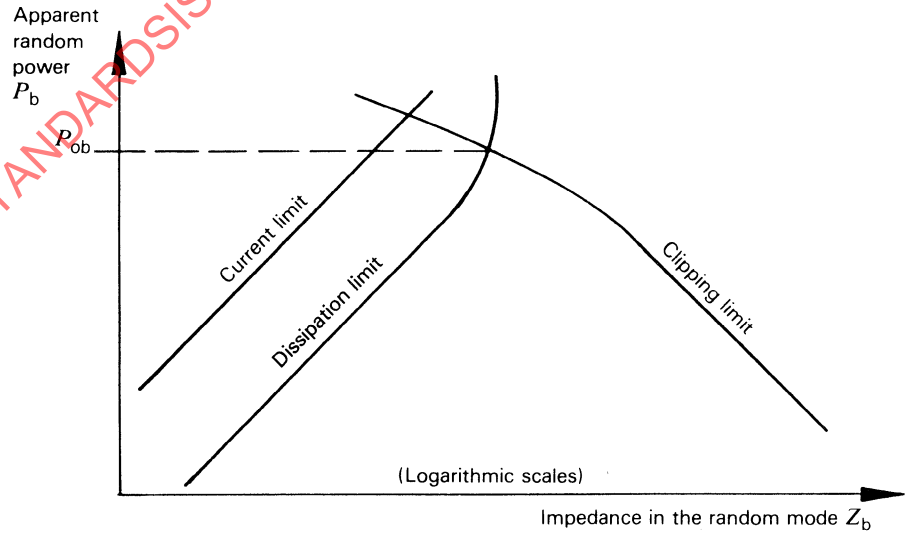


Figure 6 — Apparent random power, P_b

8.3 Response characteristics

8.3.1 Input characteristics

The manufacturer shall state the input characteristics of the power amplifier, including the required input voltage and the minimum input impedance over the frequency range f_{min} to f_{max}.

8.3.2 Ouput characteristics

With the power amplifier operating into the resistive test load R_{so} (see 8.1.2), the manufacturer shall state the output characteristics of the power amplifier in the rated frequency range (modulus and phase of voltage and current and ouput impedance).

NOTE — These response characteristics shall be stated for the method(s) of operation of the amplifier, for example :

- without control;
- with voltage, current, control, etc.

8.3.3 Frequency response curves

The manufacturer shall furnish the frequency response curves using the resistive test load R_{so} (see 8.1.2).

The frequency response curves for the amplifier shall be measured at constant input voltage in the frequency range of the amplifier concerned making sure that it is not overloaded.

Preferably, the response curves should extend at least an octave above and below the frequency range.

The input voltage at which the frequency response curves are measured shall be stated.

In particular, the following curves shall be given as a function of frequency :

8.3.3.1 For amplifiers with low output impedance

8.3.3.1.1 Modulus of the ratio of the output voltage to the input voltage :

$$\left| \frac{U_O(f)}{U_E(f)} \right|$$

8.3.3.1.2 Phase shift between the ouput voltage and the input voltage :

$$\arg \frac{U_O(f)}{U_E(f)}$$

8.3.3.2 For amplifiers with high output impedance

8.3.3.2.1 Modulus of the ratio of the output current to the input voltage :

$$\left| \frac{I_o(f)}{U_E(f)} \right|$$

8.3.3.2.2 Phase shift between the output current and the input voltage

$$\arg \frac{I_o(f)}{U_E(f)}$$

8.3.4 Signal-to-noise ratio

The signal-to-noise ratio, expressed in decibels (dB), is given by the following expression :

$$20 \lg \frac{V_{so}}{V_g}$$

The voltages V_{so} and V_g, expressed in rms value, are measured at the terminals of the resistive test load R_{so}; V_{so} represents the useful rated sinusoidal voltage and V_g the overall voltage of the output noise with the input to the power amplifier without control signal being loaded with an impedance equivalent to the impedance of the source used for the determination of frequency response curves (see 8.3.3).

This procedure does not take into consideration the noise generated by the source.

The measurement of V_g shall be taken for several gain adjustments, and the greatest value of V_g so measured shall be introduced in the expression for the signal-to-noise ratio.

8.3.5 Output voltage stability

The manufacturer shall state the maximum values for all undesired power amplifier output voltages that exceed 1 % of V_{so}, including oscillatory bursts and low-frequency variations caused by :

a) a 10 % step change in the supply voltage (a.c. power mains voltage);

b) a step change in the load from 0,95 R_{so} to 1,05 R_{so};

c) a step change in the voltage applied to the input terminals from zero to the level required to produce V_{so}.

8.3.6 Gain stability

The manufacturer shall state gain variations as a function of time, load, and supply voltage, for the entire frequency range.

8.4 Installation requirements

The manufacturer shall state the facilities required for the power amplifier installation, i.e. :

8.4.1 The required electricity supply (voltage, current, frequency, power, with the permissible variations for each, as well as the number of phases and the number of conductors.

8.4.2 Fluid supply (compressed air, water, etc.).

8.4.3 Space required.

8.4.4 Foundations required.

8.4.5 Means of controlling the environmental influences (see also 8.5.2).

8.4.6 Environmental conditions meeting the requirements of 8.5.2.

8.5 Miscellaneous characteristics

8.5.1 The manufacturer shall state the following characteristics of the power amplifier :

8.5.1.1 A description of the amplifier, including, if required, remote controls, control panel, installation diagram, etc.

8.5.1.2 A description of the safety devices.

8.5.1.3 The requirements for connecting the cooling system to the power amplifier and the following characteristics :

- flow rate;
- pressure;
- input and output temperatures;
- maximum permissible temperature;
- electric power required;
- description of the thermostat, if any;
- physio-chemical characteristics of the cooling fluid(s) (for example mineral salt content of water, air humidity, etc.);
- closed circuit operation (if applicable).

8.5.1.4 The temperature range in which the amplifier can operate under rated conditions.

8.5.1.5 The dimensions and mass of the amplifier.

8.5.2 The manufacturer shall state the following characteristics of the power amplifier :

8.5.2.1 Generated sound power level.

8.5.2.2 Heat discharged into the surrounding area.

8.5.2.3 Electromagnetic disturbances generated by the power amplifier.

8.5.3 The manufacturer shall state the characteristics that the power amplifier can withstand, namely :

8.5.3.1 The relative humidity range in which the amplifier may operate under rated conditions.

8.5.3.2 Vibration, generated sound power level, electromagnetic disturbances, etc.

8.5.4 Technical specifications and operating instructions

The manufacturer shall supply instruction for operation, maintenance and adjustment of the power amplifier.

They shall include the following :

- principles;
- description of the power amplifier;
- method of operation;
- mounting plan;
- diagram of the service connection;
- cable diagram;
- installation requirements;
- assembling and dismantling instructions;
- list of special tools, if required;
- nomenclature;
- preferred list of spare parts recommended by the manufacturer;
- miscellaneous.

9 Electrodynamic vibration generator and amplifier system

An electrodynamic vibration generator and amplifier system is composed of an electrodynamic vibration generator and an associated power amplifier with auxiliary equipment.

The characteristics defined in this clause apply to the system and are not to be applied separately to each of its components.

9.1 Test loads

The electrodynamic vibration generator and amplifier systems shall be tested using the mechanical test loads defined in 7.1.

9.2 General characteristics

9.2.1 Frequency ranges to be stated

The manufacturer shall state the frequency ranges corresponding to the rated force for each of the test loads m_0, m_1 and m_2 (see 7.1).

NOTE — The frequency range may be limited by the generator-amplifier system; it constitutes the envelope of the limits of velocity, displacement, etc. The limiting frequencies of the frequency range are designated f_{min} and f_{max}.

9.2.2 Limitation of frequency ranges

The manufacturer shall state the frequency ranges corresponding to the displacement, velocity and acceleration of the moving element of the vibration generator. He shall also state the factors affecting the operation of the test equipment within these ranges.

NOTE — The use of the test equipment may be limited towards the lower frequencies by the following :

a) the harmonic distortion of the test table acceleration;

b) the value of signal-to-noise ratio;

c) the conditions of installation of the vibration generator and amplifier system or the conditions of suspension of the vibration generator and amplifier system with force take-off (exciter).

The use of the test equipment may be limited towards the upper frequencies by the following :

a) the mechanical resonance frequency of the moving element;

b) the following factors :

1) for a vibration generator and amplifier system with a test table :

— the uniformity of the acceleration over the surface of the test table;

— the transverse motions of the test table;

— the harmonic distortion of the test table acceleration.

2) for a vibration generator and amplifier system with a force take-off (exciter) :

— the apparent compliance of the force take-off;

— the transverse motions of the force take-off;

— the harmonic distortion of the force take-off acceleration.

9.2.3 Rated force under sinusoidal conditions, F_{omt}

The manufacturer shall state the rated force available with test loads m_0, m_1 and m_2 (see 7.1) for the rated frequency ranges (see 7.2.1).

If continuous operation is not possible under certain conditions such as certain ranges of loads or frequency bands (for example those of the suspension spring natural resonances), these limitations shall be clearly stated.

It shall be clearly specified that the rated force applies only to the generator-amplifier system.

The rated sinusoidal force, F_{omt}, is calculated for the specified test load m_t by :

$$F_{omt} = (m_e + m_t)\, a$$

The effective mass m_e is deduced from a test (see method of measurement in clause B.1 of annex B).

NOTE — Newton's law is applicable over the whole frequency range to the system, which is assumed to be rigid (pure mass, see the definition in ISO 2041), and without taking the stiffness and damping of the suspension into account.

9.2.4 Rated random force, broad band, F_{ob}

The manufacturer shall state the rated force available with test loads m_0, m_1 and m_2 (see 7.1).

The manufacturer shall state the range of pure mass loads to which the generator-amplifier system can deliver this rated force in continuous operation with the specified acceleration power spectral density.

For generator-amplifier systems operating at frequencies between 20 and 2 000 Hz, the shape of the acceleration power spectral density, $\Phi_a(f)$, expressed in g^2/Hz or m^2/s^3, shall be :

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

$$\Phi_a(f) = \left(\frac{f}{100}\right)^2 \Phi_0 \text{ for } 20 \text{ Hz} < f < 100 \text{ Hz (20 dB/decade)}$$

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

$$\Phi_a(f) = 0 \text{ for } f > 2\,000 \text{ Hz}$$

NOTE — $\Phi_0(f)$ is a function of the frequency defined as the limiting value of $\frac{a_b^2}{\Delta f}$ when Δf tends towards 0, and where a_b is the rms value of the random acceleration and Δf a frequency band centred about frequency f.

The rated random force broad band F_{ob} is calculated for the specified test load m_t by :

$$F_{ob} = (m_e + m_t)\, a_b$$

If continuous operation is not possible under certain conditions such as certain ranges of load or certain frequency bands (for example those of the natural resonances of the suspension springs), these limitations shall be clearly stated.

It shall also be clearly indicated that the rated force applies to the generator-amplifier system.

NOTES

1 The available force delivered by the generator-amplifier system is a function of both the shape of the acceleration power spectral density and of the load dynamic response (which does not correspond to the case of a pure mass). Since most real loads are totally coupled to the generator-amplifier system only in the lower part of the frequency range, the available rms acceleration may be greater than the acceleration as calculated for pure mass loads. Under such conditions, if the actual shape of the acceleration spectral density is different from the specified spectrum shape, the rms current limit or random rms acceleration limit may reduce the available acceleration to a lower level than the calculated level.

2 The crest factor of the force shall be at least 3.

9.2.5 Uniformity of the table motion at the load fixing surface

The manufacturer shall state the uniformity of the acceleration field of the unloaded test table as a function of frequency in a set of curves representing the acceleration of the worst fixing point on each bolt circle relative to a given reference point, preferably the centre of the table. In the case of slotted test tables, at least two measuring points shall be selected on the radius :

- the best possible (as close to the centre as possible);
- the worst possible.

9.2.6 Transverse motion of the test table

The manufacturer shall show the transverse motion of the test table as a function of the frequency by two curves showing the ratio of the transverse motions to the axial motion at the central fixing point. The two orthogonal directions should be parallel and perpendicular respectively to the trunnion axis. If the central point is not accessible, the position of the reference point shall be stated.

Measurements shall be made if possible with the table unloaded at the rated force and the manufacturer shall specify the method used.

Supplementary measurements of the transverse motion such as measurements with test loads m_t, or measurements away from the central point may be carried out by agreement between the manufacturer and the purchaser.

9.2.7 Total acceleration distortion

The manufacturer shall indicate the total acceleration distortion of the generator-amplifier system at the unloaded test table or at the exciter force take-off.

The acceleration distortion shall be shown by a curve as a function of the frequency at constant force equal if possible to the rated force. The limits of this curve are defined by the rated frequency ranges (see 7.2.1 and 7.2.2).

Supplementary measurements of the total acceleration distortion, for example test loads m_t, may be carried out by agreement between the manufacturer and the user.

9.2.8 Stray magnetic field

The manufacturer shall indicate the stray magnetic field with the test table or the force take-off in the unloaded condition and under thermally stable conditions. Along the axis, it shall be specified as a function of the distance from the centre. Over the surface, it shall be specified in a plane parallel to the surface at a distance from the surface of one quarter of the largest bolt circle diameter at points in the plane directly above each of the threaded inserts. The value given shall be the maximum value of the magnetic field in the area of the point under consideration.

If the use of a demagnetizing device is optional, measurements shall be carried out with and without this device alternately.

In the case of slotted vibrating tables, measurements shall be made at the centre and at two points on each radius, one of which must be at the edge of the table.

9.2.9 Acceleration background noise

The manufacturer shall indicate the level of the rms background noise acceleration of the unloaded test table (or of the force take-off) with the input to the power amplifier loaded by an impedance equivalent to the impedance of the source used for the determination of the response characteristics (see 9.4).

This procedure does not take into consideration the noise generated by the source.

9.2.10 Background noise output voltage of the power amplifier

The manufacturer shall state the rms value (and possibly the peak factor) of the background noise voltage measured at the output of the amplifier loaded by the vibration generator, with the input to the amplifier loaded by an impedance equivalent to the impedance of the source used for the determination of the response characteristics (see 9.4).

This procedure does not take into consideration the noise generated by the source.

9.2.11 Input characteristics of the generator-amplifier system

The manufacturer shall indicate the input characteristics of the generator-amplifier system.

The required input voltage and minimum input impedance for the range of frequencies between f_{min} and f_{max} shall be indicated.

9.2.12 Signal-to-noise ratio

The signal-to-noise ratio, in mechanical terms and expressed in decibels (dB), is given by the following expression :

$$20 \lg \frac{a}{a_g}$$

where

a is the maximum permitted acceleration under sinusoidal conditions (F_{om0}) with the moving element unloaded;

a_g is the background noise acceleration when the input to the amplifier without control signal loaded by an impedance equivalent to the signal source impedance.

9.2.13 Stability of the output force

The manufacturer shall indicate the stability of the output force for a 10 % variation of the mains voltage applied to the system.

9.2.14 Erratic movements of the moving element

The manufacturer shall state the maximum values and characteristics of erratic movements of the moving element under the following conditions :

- normal starting-up conditions;
- normal switching conditions during operation;
- normal shutting-down conditions;
- operation of safety systems, if any;
- in the case of sudden switching off of the supply to all or part of the generator-amplifier system.

The measurements shall be carried out with no input signal to the power amplifier.

9.3 Moving element

The data to be supplied for the generator-amplifier system at the various levels of description are the same as those to be supplied for the generator alone.

NOTE — For all characteristics of the moving element of the vibration generator and amplifier system, refer to 7.3 and 7.3.1 to 7.3.19.

9.4 Response characteristics

The manufacturer shall indicate the response curves of the generator/amplifier system using test loads m_0, m_1 and m_2 (see 7.1).

9.4.1 Modulus of the ratio of the forces F_{omi} to the amplifier input voltage

$$\left| \frac{F_{om0}(f)}{U_{E0}(f)} \right| \quad \left| \frac{F_{om1}(f)}{U_{E1}(f)} \right| \quad \left| \frac{F_{om2}(f)}{U_{E2}(f)} \right|$$

9.4.2 Phase shift between the forces F_{omi} and the amplifier input voltage

$$\arg \frac{F_{om0}(f)}{U_{E0}(f)} \quad \arg \frac{F_{om1}(f)}{U_{E1}(f)} \quad \arg \frac{F_{om2}(f)}{U_{E2}(f)}$$

9.5 Installation requirements

9.5.1 General layout

The manufacturer shall supply dimensioned and toleranced drawings for the vibration generator, the power amplifier and the auxiliary devices (cooling, fluid and electricity supply systems, cables, etc.), and state the use of special tools, if any.

Additionally, the manufacturer shall state the installation requirements for the connection between the various parts of the system (insulation, cable ducts, etc.).

9.5.2 Masses composing the principal parts of the generator-amplifier system

The following shall be stated by the manufacturer :

- the total mass;
- the mass of the principal parts of the generator-amplifier system;
- the heaviest mass to be handled during dismantling of the generator-amplifier system.

9.5.3 Pedestal of the generator-amplifier system

The manufacturer shall give the following data on :

9.5.3.1 The device for orienting the generator-amplifier system : its positioning stops and locking device, as well as the principle of its operation.

9.5.3.2 The generator-amplifier body suspension system : its stiffness and method of locking.

9.5.3.3 The natural frequencies of the pedestal of the generator-amplifier system, with the suspension in the free condition, in the vertical and horizontal directions (see figure 7, part 16) .

9.5.3.4 The curve of acceleration as a function of frequency at the level of the generator-amplifier system bearing trunnion (see figure 7, part 15) with the suspension in the free position (see figure 7, part 16), in order to determine the effectiveness of the isolation.

9.5.3.5 The conditions for installing the generator pedestal on its foundations, with drawings if necessary (see figure 7, part 19).

9.5.4 Sound power level of emitted noise

The manufacturer shall state the maximum sound power level in each octave band emitted by the generator-amplifier system and by the hydraulic and cooling systems under the following operating conditions :

— with the moving element unloaded but with full field and the field coil cooling system operating;

— at rated sinusoidal force without load (load m_0), with the excitation frequency adjusted to the centre of each octave band.

The manufacturer shall use one of the methods of measurement described in ISO 3744. If this cannot be used, he shall then clearly explain the method employed.

NOTES

1 If the generator-amplifier system is equipped with an independent cooling system, the manufacturer shall state the sound power levels corresponding to the vibration generator, the power amplifier, the cooling system and the auxiliary devices respectively.

2 If the generator-amplifier system is fitted with suspension springs, the acoustic values shall correspond to the values obtained under normal test conditions with the suspension free. If, however, the sound power level in an octave band increases by more than 3 dB when the springs are locked, this information shall also be given.

9.5.5 Heat dissipation

The manufacturer shall state the heat dissipation of the generator-amplifier system, together with the thermal stabilization time under rated conditions.

If an independent cooling system is used, the heat dissipation of this system shall be stated separately.

9.5.6 Temperature of the test table

The manufacturer shall state the test table temperature for stabilized conditions corresponding to maximum heating of the moving element.

9.5.7 Auxiliary equipment required by the installation

The manufacturer shall indicate the auxiliary equipment required by the generator-amplifier system, i.e. :

— the required electricity supply (voltage, current, frequency, power, with the permissible variations for each, as well as the number of phases and conductors);

— fluid supply (compressed air, water, etc.);

— space required;

— foundations required;

— means of controlling the environmental influences (see also 8.5.2);

— environmental conditions meeting the requirements of 8.5.2.

9.6 Auxiliary equipment

9.6.1 Built-in control transducer

When a pickup is incorporated in the generator-amplifier system, the manufacturer shall give the following data :

— calibration;

— linearity characteristics;

— frequency response curve;

— transverse response;

— thermal stability (transient and permanent conditions).

When the built-in pickup is an accelerometer, its natural frequency shall be stated.

The ratio of the maximum operational frequency of the generator-amplifier system to the natural frequency of the pickup shall not exceed 0,2.

The possible effect of the test table on the accuracy of the calibration of the pickup shall be stated.

NOTE — The pickup shall not be used to measure the performance of the generator-amplifier system.

9.6.2 Cooling system

The manufacturer shall state the requirements for connecting the cooling system to the generator-amplifier system, as well as the following characteristics :

— flow rate;

— pressure;

— input and output temperatures;

— maximum permissible temperature;

— electric power required;

— description of the thermostat, if any;

— physio-chemical characteristics of the cooling fluid(s) : (for example mineral salt content of water, temperature of air, etc.);

— closed circuit operation (if applicable).

9.6.3 Field supply system

The manufacturer shall state whether the field supply system is included or whether it is produced by a permanent magnet. The following electrical characteristics shall be stated :

— power required;

— voltage;

— current;

— resistance of the field coils at 20 °C;

— insulation resistance with respect to the yoke of the vibration generator.

9.6.4 Demagnetizing system

The manufacturer shall state the following information concerning the demagnetizing system :

— power required;

— voltage;

— current;

— range of adjustment of the demagnetizing device (see 9.2.9).

9.6.5 Protective and safety system

The manufacturer shall state the characteristics relating to the following items :

— mechanical stops for upper and lower ends of the travel (position and method of operation);

— electrical displacement limit stops;

— electrical and electronic protective systems for the generator-amplifier system;

— thermal protection for the following components :

  — field coils;

  — moving coils;

  — cooling system.

The description shall specify the method of operation of these protective and safety systems and their response time.

9.7 Miscellaneous characteristics

9.7.1 The manufacturer shall state the following characteristics of the vibration generator-amplifier system :

9.7.1.1 A description of the generator-amplifier system, including, if required, remote controls, control panel, installation diagram, etc.

9.7.1.2 A description of the safety devices.

9.7.1.3 The requirements for connecting the cooling system to the power generator-amplifier system and the following characteristics :

— flow rate;

— pressure;

— input and output temperature;

— maximum permissible temperature;

— electric power required;

— description of the thermostat, if any;

— physio-chemical characteristics of the cooling fluid(s) (for example mineral salt content of water, air humidity, etc.);

— closed circuit operation (if applicable).

9.7.1.4 The temperature range in which the generator-amplifier system can operate under rated conditions.

9.7.1.5 The dimensions and mass of the generator-amplifier system.

9.7.2 The manufacturer shall state the following characteristics of the power generator-amplifier system :

9.7.2.1 Generated sound power level.

9.7.2.2 Range of relative humidity in which the generator-amplifier system can operate under rated conditions.

9.7.2.3 Heat discharged into the surrounding area.

9.7.3 The manufacturer shall indicate the following characteristics relating to the generator-amplifier system :

9.7.3.1 Electromagnetic disturbances generated by the system.

9.7.3.2 Vibration, generated sound power level, electromagnetic disturbances, etc., which the generator-amplifier system can withstand.

9.7.4 Combined tests

When the generator-amplifier system is used in combined tests (vibration tests carried out in conjunction with heat, pressure, climatic or centrifugal acceleration tests), the manufacturer shall give the following information :

9.7.4.1 Climatic conditions

— maximum and minimum operating temperatures;

— permissible relative humidity;

— permissible absolute pressure, stating, where necessary, operation

  — with heat barrier;

  — in a climatic chamber.

9.7.4.2 Mechanical conditions

Centrifugal acceleration

- for the vibration generator, the maximum permissible continuous acceleration for the three directions;
- the acceleration compensation system. If such a system is provided, details should be specified.

9.7.5 Technical specifications and operating instructions

The manufacturer shall supply instructions for the operation, maintenance and adjustment of the system.

They shall include the following :

- principles;
- description of the vibration generator;
- method of operation;
- mounting plan;
- diagram of the service connections;
- cable diagram;
- installation requirements;
- assembling and dismantling instructions;
- list of special tools, if required;
- nomenclature;
- preferred list of spare parts recommended by the manufacturer.