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Servo-hydraulic test equipment for generating vibration — Method of describing characteristics

Moyens d'essais servo-hydrauliques utilisés pour la génération de vibrations — Méthodes de description des caractéristiques

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Foreword

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International Standard ISO 8626 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Servo-hydraulic test equipment for generating vibration — Method of describing characteristics

0 Introduction

This International Standard covers the characteristics of servo-hydraulic test equipment used for generating linear vibrations and serves as a guide for the selection of such equipment.

NOTE — For the purposes of this International Standard, servo-hydraulic test equipment is more simply referred to as "hydraulic test equipment".

The term "hydraulic" means that the vibratory movement produced results from the variable flow of a liquid which is generally ensured by means of an electrohydraulic control device fed by a hydraulic power system and acting on an actuator, using one or several control loops.

The hydraulic test equipment for generating vibration, a schematic diagram of which is shown in figures 6 and 7, comprises

- the complete hydraulic vibration generator system [hydraulic vibration generator(s), servovalve control device(s), hydraulic power system],
- control desks,
- auxiliary tables,
- other peripherals.

NOTE — Control desks will be dealt with in a future International Standards. Auxiliary tables are covered by ISO 6070.

Clauses 6, 7, 8 and 9 enable the user to specify separately individual components of a servo-hydraulic vibration test system if he chooses to assemble the system from components obtained from more than one source.

If the user chooses to acquire the complete servo-hydraulic vibration test system from a single source, he shall refer to clauses 6, 9 and 10.

1 Scope and field of application

The hydraulic test equipment used for generating vibration has a wide range of characteristics which can be evaluated in many different ways.

In order to enable the possibilities afforded by test equipment from different sources to be compared, this International Standard establishes

a) a list of the characteristics;

b) the standard method of obtaining certain of these characteristics.

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

a) level 1 description;

b) level 2 description.

It gives, for each level of description, chosen by agreement between the user and the manufacturer, a list of the characteristics to be described by the manufacturer in his tender as well as a list of technical documents to be supplied with the equipment. Furthermore, the manufacturer's literature shall contain at least the characteristics corresponding to a level 1 description.

This International Standard applies to the following equipment:

- hydraulic vibration generators [actuators, servovalves, all or part of the position control device and, if fitted, the static force compensating device (see clauses 5, 6 and 7)];
- the servovalve control devices (see clauses 5, 6, and 8);
- the hydraulic power systems (see clauses 5, 6 and 9);
- the complete hydraulic vibration generator systems (see clauses 5, 6 and 10).

2 References

ISO 2041, *Vibrations and shock — Vocabulary.*

ISO 3746, *Acoustics — Determination of sound power levels of noise sources — Survey method.*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding level of contamination by solid particles.*

ISO 4413, *Hydraulic fluid power — General rules for the application of equipment to transmission and control systems.*

ISO 6070, *Auxiliary tables for vibration generators — Methods of describing equipment characteristics.*

3 Symbols

A	Useful cross-section
a	Acceleration
a_b	Maximum r.m.s acceleration under random conditions
a_g	Noise acceleration with the amplifier input in the absence of a control signal — being loaded with an impedance equivalent to the impedance of the signal source.
a_o	Maximum no-load acceleration
a_{max}	Maximum acceleration (see 5.5.7.2.1.1)
b	Viscous damping
c	Longitudinal velocity (see annex C)
d	Total distortion (see 5.5.10.1)
d_o	Rated total distortion (see 5.5.10.2)
D	Diameter of the test load
E	Longitudinal elasticity (Young's modulus)
f	Fundamental frequency
f_{min}	Minimum frequency used
f_{max}	Maximum frequency used
f_o	Smallest modal frequency of the load test (see annex C)
f_{oh}	Normal hydraulic mode frequency (see 5.5.6)
F_o	Rated force under sinusoidal conditions (see 5.5.7.2.1.2)
F_{ob}	Rated random force, broad-band (see 5.5.7.2.2)
F_{om_t}	Rated force under sinusoidal conditions for a test mass m_t (see 5.5.7.2.1.1) (the index t represents the various masses)
F_{st}	Static force (see 5.5.7.1)
g_n	Standard acceleration of free fall (due to gravity)
$H_h(s)$	Hydraulic transfer function
$H_I(f)$	Acceleration transfer characteristic at constant current (see clause B.1)
I_d	Servovalve input current
I_{so}	Rated r.m.s. current under sinusoidal conditions at the input of the servovalve
k_h	Linear hydraulic stiffness
L	Height of the test mass (see annex C)
m_e	Mass of the moving element (see 5.5.5)
m_t	Test masses (t = 0, 1, 2, 3, 4, 5) (see 5.4)
p_s	Supply pressure
$p_{s,max}$	Maximum supply pressure
q_V	Flow rate generated by the servovalve
q_{V_n}	Flow rate of the hydraulic power system
s	Laplacian operator
S	Dynamic amplification factor
U	Control voltage at the position loop amplifier input
U_{so}	Rated r.m.s. voltage under sinusoidal conditions at the input of the servovalve
v	Velocity
x	Displacement
x_b	R.M.S. value of displacement under random conditions
ε	Reduced damping factor
μ	Tranverse contraction coefficient (Poisson ratio) (see also annex C)
ν	Modal frequency
ϱ	Density
φ	Operational noise
$\Phi(f)$	Acceleration power spectral density (acceleration PSD)
$\theta(f)$	Displacement power spectral density (displacement PSD)

4 Units

When the manufacturer or the user gives values for the parameters required by this International Standard, he shall clearly define the units and state, where necessary, whether the values are r.m.s., peak or peak-to-peak values.

5 Definitions

For the purposes of this International Standard, the general definitions given in ISO 2041 and the following definitions apply.

5.1 hydraulic vibration generator: A test device in which the vibratory linear movement of the test table or power take-off[1] is produced by the action of a fluid on a piston.

A schematic diagram of the test table power take-off vibration generator is shown in figure 7.

1) Throughout the text, where for simplicity's sake "test table" has been used, read "test table or power take-off".

The hydraulic vibration comprises the constituent parts defined in 5.1.1 to 5.1.3.

5.1.1 moving element: Constituent part comprising the piston rod, the piston and, if fitted,

- the moving table,
- the connecting element between the piston rod and the power take-off, if it is other than part of the rod,
- the moving part of the position transducer,
- the moving parts of the anti-rotation system.

5.1.2 pedestal: Constituent part that connects the body of the actuator to the foundation, the reaction mass or baseplate, if fitted.

5.1.3 gravity compensation device: Constituent part fitted, in certain cases, to the hydraulic vibration generators in order to resist the static forces caused by the material under test.

5.2 servovalve control device: Device the function of which is to ensure

- the conditioning of the control signals under static and dynamic conditions,
- that the mean position of the moving element is maintained (see note 1), and
- that the harmonic distortion factors are minimized (see note 2).

NOTES

1 In certain cases or for certain servovalves, the valve may not include the hydromechanical position transducer; this should then be a function of the control system.

2 In order to minimize the harmonic distortion factors, this device may be fed with acceleration, velocity or pressure data in addition to the vibration signal and its slide valve position data.

5.3 hydraulic power supply: The complete hydraulic installation necessary for feeding the hydraulic vibration generators.

A schematic diagram is given in figure 8.

The hydraulic power supply designed for feeding the hydraulic vibration generator is generally made up of the elements defined in 5.3.1 to 5.3.8

5.3.1 hydraulic fluid: The power transfer agent between the hydraulic power supply and the vibration generator.

5.3.2 reservoir: Container for storing the hydraulic fluid and the capacity of which generally depends on the maximum flow rate of the hydraulic pump.

5.3.3 hydraulic pump: Equipment which produces the flow rate and pressure necessary for feeding the hydraulic vibration generator; it can have a constant or variable flow rate.

5.3.4 pressure regulator: Equipment which keeps the pressure between certain limits fixed by the vibration generator manufacturer; it may have a proportional or on-off action.

5.3.5 filtration system: Series of filters in the reservoir discharge and return circuits which keep the hydraulic circuits clean, as required for servovalve applications.

5.3.6 heat exchangers: Devices which maintain the temperature of the hydraulic fluid in the reservoir within the temperature range set by the manufacturer.

5.3.7 accumulator: Pressurized fluid reservoir which compensates for pressure surges in the hydraulic (discharge and return) circuits and attenuates hammering in the installation.

5.3.8 auxiliary equipment: Equipment comprising the accessories used, the device providing information, and the alarm and safety systems (see 10.3.2).

5.4 test masses, m_t**:** Mechanical masses selected by the manufacturer and used for the testing of hydraulic vibration generators.

NOTE — For requirements on shape, dimensions, flatness, surface roughness and fixing of the test mass, see annex C.

5.4.1 test mass m_0**:** The special case where the test mass is zero and only the moving table is driven.

5.4.2 test mass m_1**:** A load permitting a peak acceleration of approximately 1*g* under sinusoidal conditions.

5.4.3 test mass m_2**:** A load permitting a peak acceleration of approximately 4*g* under sinusoidal conditions.

5.4.4 test mass m_3**:** A load permitting a peak acceleration of approximately 10*g* under sinusoidal conditions.

5.4.5 test mass m_4**:** A load permitting a peak acceleration of approximately 20*g* under sinusoidal conditions.

5.4.6 test mass m_5**:** A load permitting a peak acceleration of approximately 40*g* under sinusoidal conditions.

5.5 Quantities

5.5.1 supply pressure, p_s**:** The pressure produced by the hydraulic power system at the flow rate q_{V_n}. The supply pressure is measured at the pressure regulator outlet in bars or pascals.

5.5.2 flow rate of the hydraulic system, q_{V_n}: The maximum flow rate which can be delivered by the power system at the supply pressure, p_s, measured at the pressure regulator output in litres per minute or cubic centimetres per second.

5.5.3 Travel

5.5.3.1 rated travel: The limits, in millimetres, within which the moving element of the vibration generator normally operates and beyond which the performance is no longer guaranteed by the manufacturer.

5.5.3.2 travel between stops: The rated travel plus the safety margins at each limit which are to be used for braking.

5.5.4 rated velocity, X_n: Maximum velocity amplitude of the moving element which can be obtained under sinusoidal conditions with test mass m_0 without the use of any resonance effect. The rated velocity is given in millimetres per second or metres per second.

5.5.5 mass of the moving element, m_e: The mass, in kilograms, of the moving element, as described in 5.1.1.

NOTE — This mass does not include the mass of the moving hydraulic fluid.

5.5.6 frequency of the normal hydraulic model, f_{oh}: The frequency given by the following formula:

$$f_{oh} = \frac{1}{2\pi}\sqrt{\frac{k_h}{m_e + m_t}}$$

Indeed the hydraulic generator has a behaviour similar to that of a single degree-of-movement system which has the following parameters:

— a total moving mass $m_e + m_t$

— a hydraulic stiffness k_h

NOTE — The viscous damping b may be disregarded.

5.5.7 force: For the purposes of this International Standard, the force in newtons or kilonewtons, developed by a hydraulic vibration generator which can be delivered to a load mounted on the test table or connected to the power take-off, i.e. output force.

5.5.7.1 static force, F_{st} (at zero velocity): The force of the moving element at zero velocity and supply pressure p_s; this is the product of the supply pressure p_s and the useful cross-section A:

$$F_{st} = p_s A$$

NOTE — If fitted, the gravity compensation device does not affect this definition (see 5.1.3 and 7.2.7).

5.5.7.2 dynamic forces: These are generally a function of the following two main variables:

a) the frequency;

b) the type of load on the moving element.

Practical loads may include spring forces and/or damper forces which will influence the performance of the generator. Characteristics of vibration generators are normally specified for mass loading which is the basis of this International Standard. A manufacturer should, however, be expected to give actuator performance with pure spring loading or pure damper loading, if required.

5.5.7.2.1 Dynamic forces under sinusoidal conditions

5.5.7.2.1.1 rated test force, F_{om_t}, for a specific test mass, m_t: This is the maximum force which can be introduced in a test mass, m_t, without use of any resonant effect.

$$F_{om_t} = F_o - m_e a_{max} = m_t a_{max}$$

The maximum acceleration a_{max} is defined in connection with the test loads (see 5.4). The frequency range in which a_{max} can be obtained is the rated frequency range for the test load m_t.

5.5.7.2.1.2 rated force, F_o: The rated dynamic force F_o that the vibration generator can supply for all the test masses m_t (see 5.4).

$$F_o = (m_e + m_t)\, a_{max}$$

NOTE — The rated dynamic force, F_o, may be different from the static load force, F_{st}, and should not cause any fatigue damage of the actuator.

5.5.7.2.2 rated random force, broad-band, F_{ob}: Minimum value of the force under random conditions in a broad band with test mass m_t. This force corresponds to a power spectral density (PSD) of uniform acceleration a_b within the frequency band f_3 to f_4 (see 5.5.8, 5.5.9 and figure 5).

$$F_{ob} = m_t a_b$$

5.5.8 Random displacement/acceleration power spectral density (PSD)

For test applications using servo-hydraulic vibration test equipment, both the acceleration power spectral density, $\Phi(f)$, and the related displacement power spectral density, $\theta(f)$, are significant.

5.5.8.1 acceleration power spectral density, $\Phi(f)$: The limiting value of $\frac{a_b^2}{\Delta f}$ when Δf tends towards zero, where a_b is the r.m.s. value of an acceleration waveform with Gaussian amplitude distribution and Δf is a frequency band centred about frequency f.

5.5.8.2 displacement power spectral density, $\theta(f)$: The limiting value of $\frac{x_b^2}{\Delta f}$ when Δf tends towards zero, where x_b is the r.m.s. value of a displacement waveform with Gaussian amplitude distribution and Δf is a frequency band centred about frequency f.

The graph of the acceleration and displacement power spectral density functions may be specified in terms of the lowest operating frequency f_1, a displacement-velocity transition frequency f_2, a velocity-acceleration transition frequency f_3, a cut-off frequency f_4, a second cut-off frequency f_5, if required, and the highest operating frequency, f_6. Between f_1 and f_2 the displacement power spectral density is constant, between f_3 and f_4 the acceleration power spectral density is constant.

The values for the displacement and acceleration PSDs for the various frequency ranges are listed in table 1.

Table 1 — Values for displacement and acceleration PSDs

Frequency band	Displacement PSD	Acceleration PSD
$f < f_1$	$\theta(f) = 0$	$\Phi(f) = 0$
$f_1 \leqslant f \leqslant f_2$	$\theta(f) = \theta_0$	$\Phi(f) = \dfrac{f^4}{(f_2 f_3)^2} \Phi_1$
$f_2 \leqslant f \leqslant f_3$	$\theta(f) = \dfrac{f_2^2}{f^2} \theta_0$	$\Phi(f) = \dfrac{f^2}{f_3^2} \Phi_1$
$f_3 \leqslant f \leqslant f_4$	$\theta(f) = \dfrac{(f_3 f_2)^2}{f^4} \theta_0$	$\Phi(f) = \Phi_1$
$f_4 \leqslant f \leqslant f_5$	$\theta(f) = \dfrac{(f_4 f_3 f_2)^2}{f^6} \theta_0$	$\Phi(f) = \dfrac{f_4^2}{f^2} \Phi_1$
$f_5 \leqslant f \leqslant f_6$	$\theta(f) = \dfrac{(f_5 f_4 f_3 f_2)^2}{f^8} \theta_0$	$\Phi(f) = \dfrac{(f_4 f_5)^2}{f^4} \Phi_1$
$f > f_6$	$\theta(f) = 0$	$\Phi(f) = 0$

In table 1

$$\theta_0 = \frac{1}{(2\pi f_2)^4} \Phi_0$$

5.5.9 R.M.S. values of displacement and acceleration

5.5.9.1 r.m.s. value of displacement, x_b: Value given by the following formula:

$$x_b = \theta_0^{1/2} \left[(f_2 - f_1) + f_2^2 \left(\frac{1}{f_2} - \frac{1}{f_3} \right) + \frac{1}{3} (f_3 f_2)^2 \left(\frac{1}{f_3^3} - \frac{1}{f_4^3} \right) + \frac{1}{5} (f_4 f_3 f_2)^2 \left(\frac{1}{f_4^5} - \frac{1}{f_5^5} \right) + \frac{1}{7} (f_5 f_4 f_3 f_2)^2 \left(\frac{1}{f_5^7} - \frac{1}{f_6^7} \right) \right]^{1/2}$$

5.5.9.2 r.m.s. value of acceleration, a_b: Value given by the following formula:

$$a_b = \Phi_1^{1/2} \left[\frac{1}{5 (f_2 f_3)^2} (f_2^5 - f_1^5) + \frac{1}{3 f_3^2} (f_3^3 - f_2^3) + (f_4 - f_3) + f_4^2 \left(\frac{1}{f_4} - \frac{1}{f_5} \right) + \frac{(f_4 f_5)^2}{3} \left(\frac{1}{f_5^3} - \frac{1}{f_6^3} \right) \right]^{1/2}$$

5.5.9.3 The formulae given in 5.5.9.1 and 5.5.9.2 are simplified where particular frequency bands are omitted. For example in the case where the highest operating frequency, f_6, is lower than the first cut-off frequency, f_4, the formulae become:

$$x_b = \theta_0^{1/2} \left[(f_2 - f_1) + f_2^2 \left(\frac{1}{f_2} - \frac{1}{f_3} \right) + \frac{1}{3} (f_3 f_2)^2 \left(\frac{1}{f_3^3} - \frac{1}{f_6^3} \right) \right]^{1/2}$$

$$a_b = \Phi_1^{1/2} \left[\frac{1}{5 (f_2 f_3)^2} (f_2^5 - f_1^5) + \frac{1}{3 f_3^2} (f_3^3 - f_2^3) + (f_6 - f_3) \right]^{1/2}$$

The crest factor shall be at least 3.

The rated travel (see 5.5.3.1) shall be at least twice the r.m.s. value of the displacement, x_b, multiplied by the crest factor to avoid contacting the mechanical stops.

5.5.10 Distortion

There are two definitions with respect to distortion with different values for d, determined using the following formulae:

$$d = \frac{\sqrt{a^2 - a_1^2}}{a_1}$$

$$d = \frac{\sqrt{a^2 - a_1^2}}{a}$$

where a and a_1 are as defined in 5.5.10.1.

With respect to the operational noise φ, the distortion is often determined by the formula

$$d = \sqrt{\frac{\int_{f_{min}}^{f_1 - \Delta f/2} G_{XX}(f)\mathrm{d}f + \int_{f_1 + \Delta f/2}^{f_{max}} G_{XX}(f)\mathrm{d}f}{\int_{f_{min}}^{f_{max}} G_{XX}(f)\mathrm{d}f}}$$

where

$G_{XX}(f)$ is the PSD of the signal;

f is the frequency of the basic signal.

5.5.10.1 Total distortion, d (see figure 1)

5.5.10.1.1 acceleration distortion: An acceleration signal a may be considered as made up of components as given by the following formula:

$$a = \sqrt{\varphi^2 + a_1^2 + a_2^2 + a_3^2 + \ldots + a_n^2} = \sqrt{\varphi^2 + \sum_{i=1}^{n} a_i^2}$$

where

a is the r.m.s. value of the acceleration;

a_1 is the r.m.s. value of the component of acceleration at the fundamental frequency f, which is usually the only component desired;

$a_2, a_3, \ldots a_n$ are the r.m.s. values of the harmonic components at frequencies $2f$, $3f$, ... nf, where n includes all components of significant value;

φ is the operational noise (see 5.5.11.2).

The total distortion, d, is the ratio between all of the undesired acceleration components and the desired acceleration, a_1:

$$d = \frac{\sqrt{\varphi^2 + a_2^2 + a_3^2 + \ldots + a_n^2}}{a_1} = \frac{\sqrt{\varphi^2 + \sum_{i=2}^{n} a_i^2}}{a_1} = \frac{\sqrt{a^2 - a_1^2}}{a_1}$$

5.5.10.1.2 velocity distortion: When the acceleration signal is integrated to obtain a velocity signal, each component is divided by its own frequency and the ratio between the harmonic components and the fundamental is deduced. If the harmonic components are much larger than the noise, as is usually the case, the velocity distortion will be much lower than the acceleration distortion. If velocity rather than acceleration distortion is intended, the words "velocity distortion" shall be clearly stated.

The velocity distortion is expressed by the following formula:

$$d_v = \frac{\sqrt{\left(\int_0^t \varphi_a \mathrm{d}t\right)^2 + \sum_{i=2}^{n}\left(\frac{a_i}{i\,2\pi f}\right)^2}}{\frac{a_1}{2\pi f}} = \frac{\sqrt{v^2 - v_1^2}}{v_1}$$

5.5.10.1.3 displacement distortion: When the velocity signal is integrated again to obtain a displacement signal, if the harmonic components of displacement are larger than the displacement noise, which may be the case, the displacement distortion will be less than the velocity distortion. If displacement distortion rather than acceleration distortion d is intended, the words "displacement distortion" shall be clearly stated.

The displacement distortion is expressed by the following formula:

$$d_x = \frac{\sqrt{\left(\int_0^t\int_0^t \varphi_a \mathrm{d}t\,\mathrm{d}t\right)^2 + \sum_{i=2}^{n}\left(\frac{a_i}{i^2\, 4\pi^2 f^2}\right)^2}}{\frac{a_1}{4\pi^2 f^2}} = \frac{\sqrt{x^2 - x_1^2}}{x_1}$$

5.5.10.2 rated total distortion, d_o: The maximum value of the total distortion, d, determined at maximum acceleration in the rated frequency range, for a given test mass. See figure 2.

5.5.11 noise: Noise is caused by the measuring system as well as by the control loop.

5.5.11.1 background noise: The r.m.s. or peak-to-peak value of the vibratory motion, in a given frequency band, with the input signal of the system at zero.

NOTE — The background noise acceleration, a_g, is defined with the servovalve control device input loaded with an impedance equivalent to the signal source impedance and the control device adjusted for optimum control performances.

5.5.11.2 operational noise, φ: The residual value of the vibratory motion, in a given frequency band, with a control signal present.

φ is the r.m.s. value of the "noise", or non-harmonically related acceleration components, caused usually by:

— line frequency pick-up into the servovalve control,

— start-stop friction in the servovalve and/or the actuator (jack),

— impacting of loose parts in the specimen being tested,

— turbulence flow effect at controlling edges of servovalves.

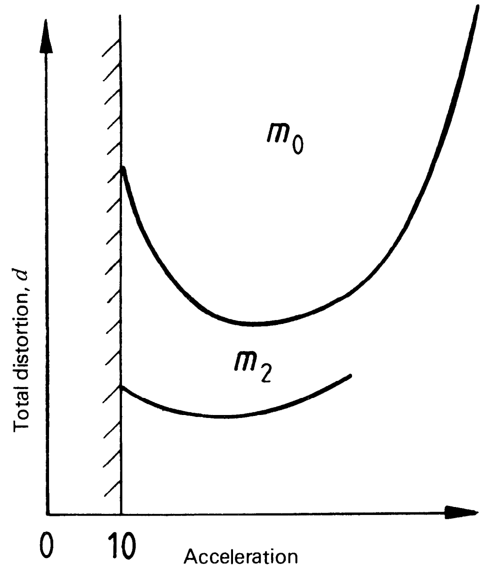

Figure 1 — Total distortion at a fixed frequency as a function of the acceleration

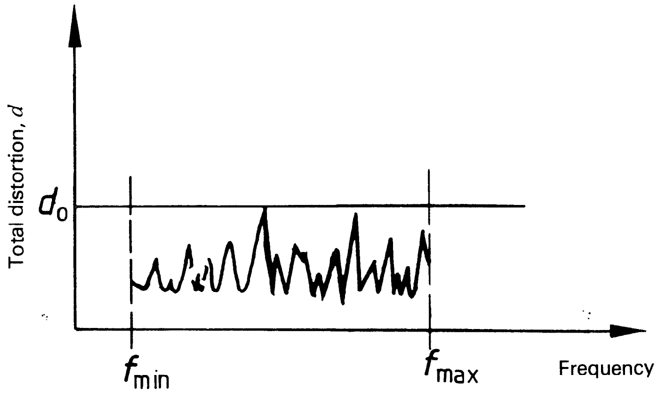

Figure 2 — Total distortion as a function of the frequency at maximum acceleration for a given test mass

5.5.11.3 signal-to-noise ratio: Value derived from technical causes, expressed in decibels, and given by the following formula:

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

where

a is the maximum permissible acceleration under sinusoidal conditions at rated force F_{om_t} and test mass m_0;

a_g is the background noise acceleration (see 5.5.11.1).

5.5.12 dither: High frequency signal introduced into the signal in the servovalve control device to linearize the servovalve zero crossing region, and also to decrease the friction in order to improve the resolution of the valve and actuator.

5.5.13 transverse acceleration ratio: The ratio between the transverse acceleration and the axial acceleration; this may be related to test loads and frequency.

5.5.14 mean position deflection under load: Applying a load results in the first mean position being displaced, which is a function of the characteristics of the position control loop. The differential pressure on each side of the piston resulting from opening the servovalve statically balances the external forces. The opening of the servovalve therefore depends on the loads to be balanced, the leakage flow rate and the mean position error of the piston. It is controlled by the mean position control loop.

6 Characteristics to be supplied by the manufacturer for each level of description

Attention is drawn to the fact that the two levels of description adopted in this International Standard do not relate to the quality or size of the test equipment.

A level 1 description may be adequate for a large, high-quality test apparatus whereas, under certain circumstances, a level 2 description would be, for example, required for a small, medium-quality test apparatus.

The level of description required shall usually depend on the use to which the equipment is to be put.

This International Standard also gives the relevant characteristics for matching different components of the vibration generator system.

The characteristics indicated by an "X" in tables 2 to 5 shall be supplied when demanded by the particular level of description. The characteristics which are not required for a particular level of description, i.e. those which are not marked with an "X", may, however, be supplied if agreed between the manufacturer and the user.

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

Tables 2, 3, 4 and 5 give a list of the characteristics to be described by the manufacturer as a function of the chosen level of description. Explanations of the listed characteristics are given in clauses 7, 8 and 9. Explanations of methods for measuring certain of these characteristics are given in annex B.

Table 2 — Vibration generator

Characteristic	Reference to corresponding clause	Level of description	
		1	2
General characteristics			
Hydraulic supply conditions	7.1.1	X	X
Characteristics of the servovalve	7.1.2	X	X
Static force	7.1.3	X	X
Rated velocity	7.1.4	X	X
Rated frequency ranges	7.1.5	X	X
Limitations of characteristics under sinusoidal conditions	7.1.6	X	X
Limitation of characteristics under random conditions	7.1.7		
Rated force under sinusoidal conditions, F_{om_t}	7.1.8	X	X
Rated random force, broad-band, F_{ob}	7.1.9		
Uniformity of the acceleration field of the test table	7.1.10		
Transverse motion of the test table	7.1.11		
Limitation of characteristics	7.1.12		X
Moving element			
Mass	7.2.1	X	X
Rated travel	7.2.2	X	X
Travel between electrical safety devices	7.2.3		X
Travel between stops	7.2.4	X	X
Normal hydraulic mode frequency	7.2.5		X
Hydraulic stiffness	7.2.6		X
Gravity compensation device	7.2.7	X	X
Maximum transverse load	7.2.8.1		X
Rated static transverse load	7.2.8.2		X
Transverse static stiffness	7.2.9		X
Static friction of moving element	7.2.10		
Dimensions of the test table	7.2.11	X	X
Means of attaching the loads or the materials under test	7.2.12	X	X
Recommended torque on the threaded inserts or fixing elements in the table	7.2.13	X	X
Maximum permissible axial force on the threaded inserts or other fixing element	7.2.14		X
Flatness of the test table	7.2.15		X
Perpendicularity of the threaded inserts with respect to the plane of the test table	7.2.16		X
Perpendicularity of the plane of the test table with respect to the axis of the rod	7.2.17		X
Concentricity of axes (exciter power take-off)	7.2.18	X	X
Coupling tolerances of an auxiliary table	7.2.19	X	X
Auxiliary equipment			
Generator shaft position transducer	7.3.1.1	X	X
Pressure, force, velocity or acceleration transducer	7.3.1.2		X
Cooling system	7.3.2	X	X
Safety systems, alarm and cut-out devices	7.3.3	X	X
End of travel	7.3.3.1	X	X
Actuator force	7.3.3.2	X	X
Bearing temperatures	7.3.3.3	X	X
Oil flow rate	7.3.3.4	X	X
Clogging of the filter	7.3.3.5	X	X
Hoses and cables	7.3.4	X	X
Installation conditions			
General	7.4.1	X	X
Masses of the vibration generator	7.4.2	X	X
Vibration generator pedestal			
Orientation device	7.4.3 a)	X	X
Dynamic characteristics	7.4.3 b)		X
Fixing conditions	7.4.3 c)	X	X
Generated sound power level	7.4.4		
Heat dissipation	7.4.5		
Test table temperature	7.4.6		
Environmental and operating conditions			
Site	7.5.1	X	X
Combined tests	7.5.2		
Documents	7.6	X	X

Table 3 — Control system

Characteristic	Reference to corresponding clause	Level of description 1	Level of description 2
Servovalve control device			
Unmodulated input characteristics	8.1.1	X	X
Modulated input characteristics	8.1.2	X	X
A.C. source output characteristics	8.1.3	X	X
D.C. source output characteristics	8.1.4	X	X
Dither characteristics	8.1.5		X
Characteristics of output to servovalve	8.1.6	X	X
Characteristics of primary input (from signal sources)	8.1.7	X	X
Maximum input voltage	8.1.8	X	X
Transfer functions	8.1.9		
Total distortion, d	8.1.10		
Signal-to-noise ratio	8.1.11		
Stability of the output quantity for a zero input	8.1.12		X
Gain stability	8.1.13		
Limitation of characteristics	8.1.14		X
Control and protection panel	8.2	X	X
Auxiliary equipment	8.3	X	X
Installation conditions	8.4	X	X
Environmental and operating conditions	8.5		X
Documents	8.6	X	X

Table 4 — Hydraulic power system

Characteristic	Reference to corresponding clause	Level of description 1	Level of description 2
General characteristics			
Drive motor characteristics	9.1.1	X	X
Flow rate/pressure characteristics of the power system	9.1.2.1 9.1.2.2	X	X
Hydraulic fluid	9.2.1	X	X
Reservoir	9.2.2	X	X
Hydraulic pump	9.2.3	X	X
Pressure regulator	9.2.4		X
Filter system	9.2.5	X	X
Heat exchanger	9.2.6	X	X
Accumulators	9.2.7	X	X
Auxiliary equipment			
Accessories	9.3.1	X	X
Indicating equipment	9.3.2	X	X
Safety systems, alarms and cut-out devices	9.3.3	X	X
Installation conditions			
General	9.4.1	X	X
Masses of the main part of the hydraulic fluid power system	9.4.2	X	X
Power consumption	9.4.3	X	X
Connections	9.4.4	X	X
Start-up and maintenance	9.4.5	X	X
Generated sound power level	9.4.6		
Heat dissipation	9.4.7		
Cooling medium requirements	5.4.8	X	X
Environmental and operating conditions	9.5	X	X
Documents	9.6	X	X