INTERNATIONAL STANDARD

ISO 7096

Second edition
1994-10-01

Earth-moving machinery — Laboratory evaluation of operator seat vibration

Engins de terrassement — Évaluation en laboratoire des vibrations du siège de l'opérateur

Reference number
ISO 7096:1994(E)

Foreword

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

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

International Standard ISO 7096 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

This second edition cancels and replaces the first edition (ISO 7096:1982), of which it constitutes a technical revision.

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Earth-moving machinery — Laboratory evaluation of operator seat vibration

1 Scope

This International Standard specifies a laboratory method for vibration testing of operator seats for earth-moving machinery at frequencies between 1 Hz and 20 Hz.

It is based on ISO 10326-1 which is a general method applicable to seats for different types of vehicles; this International Standard lays down the specifications which relate particularly to earth-moving machinery.

It applies to operator seats of the following earth-moving machines as defined in ISO 6165:

— wheel-loaders and crawler-loaders;

— tractor-scrapers;

— wheel-tractors and crawler-tractors.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6165:1987, *Earth-moving machinery — Basic types — Vocabulary.*

ISO 8041:1990, *Human response to vibration — Measuring instrumentation.*

ISO 10326-1:1992, *Mechanical vibration — Laboratory method for evaluating vehicle seat vibration — Part 1: Basic requirements.*

3 Symbols and indices

For the purposes of this International Standard, the following symbols and indices apply.

3.1 Symbols

a Instantaneous acceleration, in metres per second squared.

a_w Frequency-weighted acceleration signal, in metres per second squared.

f Frequency, in hertz.

f_c Filter cut-off frequency.

f_r Resonance frequency.

$G_P^*(f)/G_o$ Power spectral density.

G_o Standard spectral power, in square metres per second cubed $\left[(m/s^2)^2/Hz\right]$.

j Assumed unit ($j^2 = -1$).

$T(f_r)$ Resonance transmission factor.

3.2 Indices

P Platform

S Seat

4 Criteria for evaluation of seats

Two criteria are used for the evaluation of seats:

— the vibration magnitude measured between the seat pan and the test person (see ISO 10326-1:1992, subclause 9.1);

— transmissibility at resonance (see ISO 10326-1:1992, subclause 9.2).

Users of this International Standard are reminded that the quantities referred to shall be calculated from the acceleration values measured simultaneously on the vibration table and between the seat pan and the test person or the inert mass.

The specifications for instrumentation shall be as given in ISO 8041. Measurements during testing shall be made with type 1 instruments according to ISO 8041. The frequency filter shall have a 12 dB/octave slope at the relevant cut-off frequencies.

5 Vibration testing of operator seats

5.1 Seat mounting

A platform, the dimensions of which correspond approximately to those of the operator's position on an earth-moving machine, shall be mounted on a vibrator which is capable of generating vibrations along the (vertical) z-axis (see figure 1).

The vibrator shall, when loaded, be capable of simulating sinusoidal vibrations having a displacement amplitude equivalent to at least 7,5 cm, at a frequency of 2 Hz.

5.2 Seat adjustment

The seat shall be adjusted to the mass of the test person in accordance with the manufacturer's instructions.

With seats where the stroke available is unaffected by the adjustment for seat height or test person mass, testing shall be performed with the seat adjusted to the centre of the stroke.

With seats where the stroke available is affected by the adjustment of the seat height or by test person mass, testing shall be performed in the position which gives the minimum available stroke.

The manufacturer shall specify what influence different combinations of mass and seat height adjustments will have on the stroke available during testing.

When the inclination of the backrest is adjustable, the angle shall be approximately 10° ± 5° behind the vertical.

5.3 Test person and posture

The simulated input vibration test shall be performed with two persons with masses of 55 kg $^{0}_{-3}$ kg and 98 kg $^{+5}_{0}$ kg. To meet the required mass of the test persons, added weights may be used, e.g. a belt weight of 5 kg for the light and 8 kg for the heavy person.

Each person shall adopt a natural position on the seat and maintain this position throughout the test (see figure 1). Differences in the posture of the test person can cause a 10 % difference between test results. Provision shall therefore be made for adjustment of angles of knees and ankles as specified in figure 1.

5.4 Test procedure

Suspension seats require a run-in period that is long enough for the seat performance to stabilize before testing. Carry out the run-in procedure specified in ISO 10326-1:1992, subclause 7.1.2.

5.4.1 Simulated input vibration test

Three tests shall be performed for each subject in accordance with ISO 10326-1:1992, subclause 9.1. The effective duration of each test shall be at least 300 s.

The results of measurements made on the seat a_{wS} and on the platform a_{wP} may be corrected, as indicated in ISO 10326-1:1992, subclause 9.1, last paragraph, in order to bring them into line with the reference conditions for the input vibrations.

This International Standard defines the input vibration in four spectral classes: I, II, III and IV. Each class is defined by a normalized power spectral density, $G_P^*(f)/G_o$ and the weighted rms acceleration measured on the platform (see tables 1 and 2, and figure 2).

The seats for all machines except wheel-loaders are tested according to one spectral class. Wheel-loaders generally perform two specific tasks (load and carry corresponding to driving, and short cycle corresponding to loading). Therefore, testing according to two spectral classes, II and III, shall be performed. See tables 2 and 3.

5.4.2 Damping test

The seat shall be loaded with an inert mass of 75 kg and then be excited by a sinusoidal vibration in the range from 0,5 Hz to 3 Hz. The inert mass shall if necessary be secured to the seat to prevent it from moving on the seat or falling off.

The frequency range shall be investigated with either a constant frequency sweep from 0,5 Hz to 3 Hz and back again to 0,5 Hz or in steps of maximum 0,05 Hz. The frequency sweeping shall be made during at least 80 s.

The damping test and the calculation of the transmissibility at resonance shall be performed according to ISO 10326-1:1992, subclause 9.2.

The frequency weighted root-mean-square (rms) acceleration, $a_{wP}(f)$ for a vertical input excitation corresponding to a constant displacement amplitude is defined as follows:

for classes I, II and III:

$$a_{wP}(f) = 25 \frac{f^2}{\sqrt{2}}$$

for class IV and for longitudinal excitation:

$$a_{wP}(f) = 15 \frac{0{,}6\, f^2}{\sqrt{2}}$$

5.5 Tolerances on input vibration

The input excitations applied to the seat, as defined in 5.4, can be produced on a simulator only with a certain degree of approximation. The test shall satisfy the conditions in 5.5.1 to 5.5.3 in order to be acceptable.

5.5.1 Distribution function

Use should be made of procedures having a Gaussian cumulative probability density, truncated at 3,5 times the standard deviation.

5.5.2 Normalized power spectral density

The power spectral density of the acceleration measured on the platform is considered to be representative of $G_P^*(f)$ if, and only if:

a) for $f_1 \leqslant f \leqslant f_2$:

$$\frac{G_P^*(f)}{G_o} - 0{,}2 \left| \frac{G_P^*(f)}{G_o} \right|^{1/2} \leqslant \frac{G_P(f)}{G_o}$$

$$\leqslant \frac{G_P^*(f)}{G_o} + 0{,}2 \left| \frac{G_P^*(f)}{G_o} \right|^{1/2}$$

b) for $f < f_1$ and $f > f_2$:

$$0 \leqslant \frac{G_P(f)}{G_o} \leqslant 0{,}08 \text{ for } \frac{G_P^*(f)}{G_o} \leqslant 0{,}04$$

c)

$$(1 - 0{,}2) \int_{f_1}^{f_2} \frac{G_P^*(f)}{G_o}\, df \leqslant \int_{f_1}^{f_2} \frac{G_P(f)}{G_o}\, df$$

$$\leqslant (1 + 0{,}2) \int_{f_1}^{f_2} \frac{G_P^*(f)}{G_o}\, df$$

These tolerances are illustrated in figure 3. The numerical values of f_1 and f_2 are:

f_1 = 1 Hz for classes I, II and III

f_1 = 3 Hz for class IV

f_2 = 4 Hz for classes I and II

f_2 = 16 Hz for class III

f_2 = 18 Hz class IV

5.5.3 rms value

The rms value of the acceleration obtained in the course of all testing shall lie within a relative range of ± 10 % in relation to the reference value:

$$\begin{cases} 0{,}9 a_{wP}^* \leqslant a_{wP} \leqslant 1{,}1 a_{wP}^* \\ 0{,}9 a_P^* \leqslant a_P \leqslant 1{,}1 a_P^* \\ 0{,}9 a_P^*(f) \leqslant a_P(f) \leqslant 1{,}1 a_P^*(f) \end{cases}$$

NOTE 1 For the damping test the platform vibration may be measured by a displacement pick-up. In this case the tolerance of ± 10 % applies to the displacement amplitude.

6 Conditions for acceptance of seat

The conditions for acceptance of the seat are the following:

— the transmissibility $T(f_r)$ at resonance in the z-axis shall not exceed

1,5 for classes I and II, and

2 for classes III and IV;

— the magnitude of vibration in the z-axis transmitted to the heavy and to the light operator shall not exceed (in acceleration terms) 1,25 m/s^2.

7 Test report

The test report shall give the following information:

a) name and address of the seat manufacturer;

b) model of seat, product and serial number;

c) date of test;

d) time duration of run-in period, in hours;

e) type of measuring disc used: semi-rigid, rigid;

f) characteristics of the simulated input vibration test;

g) vibration transmission to the persons at the simulated input vibration test:

— test person's mass in kilograms,

— Seat Effective Amplitude Transmissibility (SEAT-factor),

— corrected magnitude on the seat surface;

h) transmissibility at the resonance during the damping test and the resonance frequency, or alternatively the transfer function with sinusoidal vibration input;

i) the name of the person responsible for the test;

j) identification of test laboratory.

Table 1 — Definition of spectral classes of input vibrations

Spectral class of input vibration	$G^{*}_{P}(f)/G_o$	Filter cut-off frequency, f_c				
		LP_6	LP_{12}	HP_{12}	LP_{24}	HP_{24}
I	1,275 5 $(HP_{24})^2$ $(LP_{24})^2$	—	—	—	2,5 Hz	1,5 Hz
II	1,128 5 $(HP_{24})^2$ $(LP_{24})^2$	—	—	—	3 Hz	1,5 Hz
III	1,451 7 $(HP_{24})^2$ $(LP_6)^2$	3,5 Hz	—	—	—	1,5 Hz
IV	2,314 $(HP_{12})^2$ $(LP_{12})^2$	—	9 Hz	6,5 Hz	—	—

$$LP_6 = \frac{1}{1 + S}$$

$$LP_{12} = \frac{1}{1 + 1{,}414S + S^2}$$

$$HP_{12} = \frac{S^2}{1 + 1{,}414S + S^2}$$

$$LP_{24} = \frac{1}{1 + 2{,}613S + 3{,}414S^2 + 2{,}613S^3 + S^4}$$

$$HP_{24} = \frac{S^4}{1 + 2{,}613S + 3{,}414S^2 + 2{,}613S^3 + S^4}$$

where

$$S = \frac{\mathrm{j}f}{f_c}$$

NOTE — HP and LP designate high-pass and low-pass filters of the Butterworth type. The subscripts state the filter slope in decibels per octave. This table defines band-pass filters completely in terms of cut-off frequencies and slopes.

Table 2 — Characteristics of simulated input vibration on z-axis for different types of machines

Type of machine		Input vibration: Class	Input vibration: G_o $(m/s^2)^2/Hz$	rms acceleration on platform a_P^* m/s^2	Weighted rms acceleration on platform a_{wP}^* m/s^2	Frequency range to calculate a_{wP}^*: Frequency range	Frequency range to calculate a_{wP}^*: Octave band Hz
Tractor-scraper	non-spring-suspended	I	4,155 3	2,352	1,715	from 0,708 Hz to 11,22 Hz	8
	with spring suspension	II	2,410 2	2,050	1,595		
Wheel-tractor, wheel-loader	load and carry	II	2,410 2	2,050	1,595		
	short cycle	III	0,764 6	1,976	1,678	from 0,708 Hz to 22,39 Hz	16
Wheel-tractor		III	0,764 6	1,976	1,678		
Crawler-tractor, crawler-loader		IV	0,341 4	1,692	1,397		

Table 3 — Report form for simulated input vibration testing of seats

Machine on test: ....

Axis of excitation: ....

Spectral class: ....

$a^*_P =$ .... m/s²

$a^*_{wP} =$ .... m/s²

Designation		a_P m/s²	a_{wP} m/s²	a_{wS} m/s²	SEAT-factor	a^*_{wS} m/s²
Light operator: .... kg Added mass: .... kg	1st test					
	2nd test					
	3rd test					
	Arithmetic mean value					
Heavy operator: .... kg Added mass: .... kg	1st test					
	2nd test					
	3rd test					
	Arithmetic mean value					

Required value for a^*_{wS} for acceptance of the seat = 1,25 m/s² (*z*-axis).

NOTE — The operator's seat on wheel-loaders shall be subjected to two tests: one each to simulate the typical operations of load and carry (coefficient 0,2) and short cycle (coefficient 0,8). The mean values for a^*_{wS} shall be compared with the required value for acceptance of the seat, 1,25 m/s², and be calculated as follows:

$$a^*_{wS} = \sqrt{0{,}2 {a^*_{wS1}}^2 + 0{,}8 {a^*_{wS2}}^2}$$

where

a^*_{wS1} is the value corresponding to the load and carry type test;

a^*_{wS2} is the value corresponding to the short cycle type test.

Table 4 — Report form for damping test

Machine on test:	....	
Axis of vibration:	....	
$a^*_P(f) =$	....	m/s²
$a_S(f_r) =$	....	m/s²
$a^*_S(f_r) =$	....	m/s²
$f_r =$	....	Hz
$T(f_r) =$	....	
NOTE — A graph of the frequency transfer function may also be provided.		

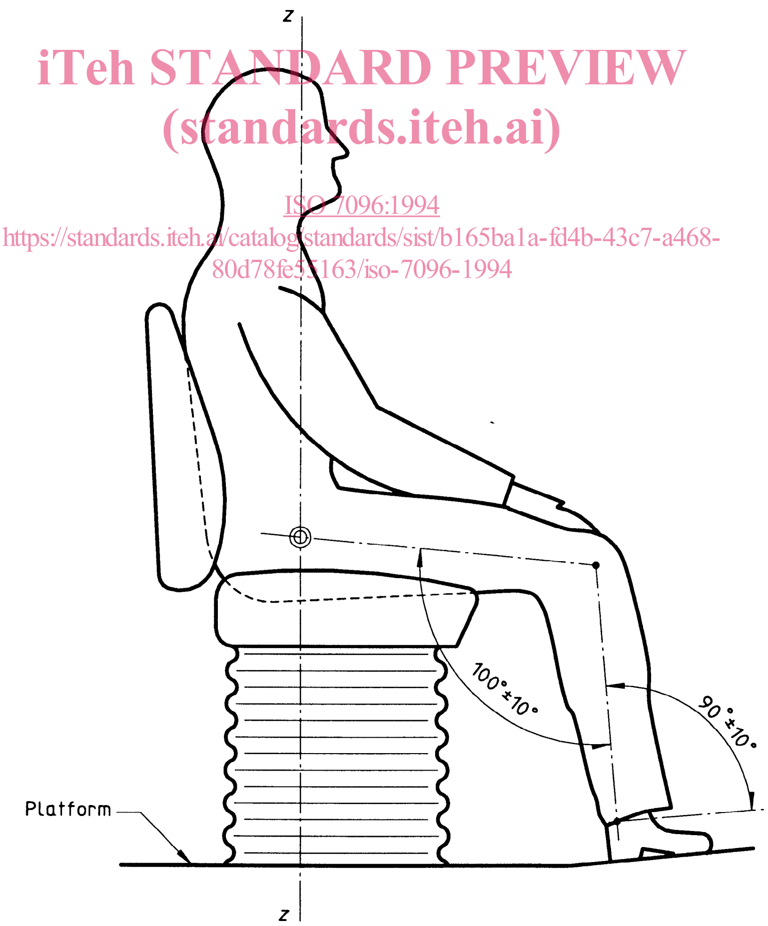

Figure 1 — Posture of test person