International Standard ISO 7096

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION●МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ●ORGANISATION INTERNATIONALE DE NORMALISATION

Earth-moving machinery — Operator seat — Transmitted vibration

Engins de terrassement — Siège de l'opérateur — Vibrations transmises

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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 7096 was developed by Technical Committee ISO/TC 127, *Earth-moving machinery*, and was circulated to the member bodies in September 1980.

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

Australia	Finland	Pologne
Austria	France	Romania
Belgium	Germany, F. R.	South Africa, Rep. of
Brazil	Italy	United Kingdom
Czechoslovakia	Japan	USA
Egypt, Arab Rep. of		USSR

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Netherlands
Sweden

Earth-moving machinery — Operator seat — Transmitted vibration

1 Scope

This International Standard specifies a method for the measurement, evaluation and acceptance level of the whole body vibration transmitted through the seat to the operator during laboratory simulated machine vertical vibration.

2 Field of application

This International Standard is applicable to seats fitted to earth-moving machines within specified machine classes, each class defined as a group of machines having similar vibration characteristics. See table 2.

3 References

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 2631, *Guide for the evaluation of human exposure to whole-body vibration.*

ISO 4865, *Analog analysis and presentation of vibration and shock data.*[1]

ISO 5353, *Earth-moving machinery — Seat index point.*

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

IEC Publication 225, *Octave, half-octave and third octave band filters intended for the analysis of sounds and vibrations.*

IRIG Document 106, Inter Range Instrumentation Group, *Magnetic tape recorder, reproducer standards.*

4 General

The laboratory simulated machine vertical vibration, specified as the test input to the operator seat, is based on representative measured data from machines in typical hard working conditions. The test input for a machine class is a representative envelope for the machines within the class, therefore the laboratory test is more severe than the typical vibration environment of any specific machine.

The specification of procedures, instruments and evaluation methods allows the measurements to be made and reported with an acceptable precision.

The vibration is evaluated in accordance with ISO 2631. The procedure includes means of weighting the vibration level at different frequencies to account for the frequency sensitivity of the human operator.

NOTE — The vibration felt by the operator's feet on the platform or control pedals or by his hands on the steering wheel or control levers is not evaluated in this International Standard.

5 Definitions

The terminology used in this International Standard is generally in accordance with ISO 2041. Additional definitions applicable to this International Standard are given below.

5.1 whole body vibration : Vibration transmitted to the body as a whole through the buttocks of a seated operator.

5.2 operator seat : That portion of the machine provided for the purpose of supporting the buttocks of the seated operator, including the seat suspension system.

5.3 frequency analysis : Process of arriving at a quantitative description of the amplitude of a vibration as a function of frequency.

5.4 measuring period : The time duration in which vibration data for analysis is obtained.

1) At present at the stage of draft.

6 Symbols and abbreviations

a = instantaneous acceleration

a_f = rms value of 1/3 octave acceleration having centre frequency f

a_w = frequency weighted acceleration signal

a_{wf} = weighted rms acceleration calculated as described in 7.4.1, 7.4.2, or 7.4.3

a_{wfB} = a_{wf} at the base of the seat (see 7.2.2)

a_{wfS} = a_{wf} at the seat disc (see 7.2.1)

B_e = resolution bandwidth of a frequency analysis, in hertz

f = frequency

T = analysis time duration, in seconds

W_f = frequency dependent, dimensionless weighting factor

g = acceleration of gravity, by international agreement equal to 9,80665 m/s² at sea level

rms = root-mean-square

PSD = Power Spectral Density expressed as mean square acceleration per unit bandwidth in metres per second squared, squared per hertz

PDF = Probability Density Function of acceleration amplitudes

SIP = Seat Index Point (see ISO 5353)

7 Instruments

The instruments and analysis specifications are for vibration tests of seats in the laboratory on a vibration test stand. Specifications given as (* ...... *) are additions only for the purpose of extending the specifications to apply to field tests of machines.

7.1 Acceleration transducers

Vibration transmitted to the operator shall be sensed by an acceleration transducer (accelerometer) in the mounting device described in 7.2.1. The accelerometer, together with its associated amplifier, shall be capable of measuring rms acceleration levels ranging from 0,1 to 10 m/s² with a crest factor as great as 6. The accelerometer and amplifier, with proper calibration for the test, shall be capable of an accuracy of at least ± 2,5 % of the actual rms vibration levels in the frequency range from 0,8 to 40 Hz (* and at least ± 6,0 % of the actual rms vibration levels in the frequency range from 40 to 80 Hz *) as calculated from the instrument specifications and the actual test conditions. The resonant frequency of the accelerometer shall be greater than 300 Hz. The accelerometer shall sustain instantaneous acceleration levels up 100 m/s² without damage.

Vibration at the seat mounting base shall be sensed by an accelerometer of the same type, having a similar signal-to-noise ratio in this application, and capable of the preceding specifications.

7.2 Transducer mounting

7.2.1 Vibration transmitted to the operator

The accelerometer for sensing vibration transmitted to the operator shall be attached near the centre of a thin disc 250 ± 50 mm in diameter placed between the seated operator and the seat cushion. Either a rigid or semi-rigid disc may be used; however, the semi-rigid disc is recommended, especially for soft or highly contoured cushions. The resonance arising from the disc must be above the range of measured frequencies. Disc designs are shown in figures 1 and 2. Either disc shall be placed on the seat so that the accelerometer is located midway between the ischial tuberosities and is aligned parallel to the measurement axis a_z (see figure 3). The disc shall be taped or similarly attached to the cushion to maintain its location.

7.2.2 Vibration at the seat mounting base

The vibration at the base of the seat shall be sensed by an accelerometer attached to a rigid portion of the test stand or seat mounting base. The accelerometer shall be located within the vertical projection of the seat cushion, not more than 100 mm from the vertical, longitudinal plane through the centre of the seat, and shall be aligned parallel to the measurement axis a_z (see figure 3).

If the vibration test stand is of the pivoting type suggested in figure 5 (see 8.1), the seat mounting base accelerometer shall be the same distance (± 20 mm) from the pivot as the seat disc accelerometer.

7.3 Electronic tape recorders

The electrical signals generated by the transducers may be recorded on magnetic tape for later analysis. The magnetic tape recorder, with proper calibration for the test, shall be capable of a replay accuracy of at least ± 3 % of the rms value of the total signal within the frequency range from 1 to 80 Hz, as calculated from the instrument specifications and the actual test conditions. The tape recorder should meet current IRIG[1)] standards for alignment and distortion characteristics.

1) Inter Range Instrumentation Group

7.4 Frequency weighting

Frequency weighting may be achieved in any of three ways : by digital analysis of the acceleration into constant bandwidth levels, weighting the levels in individual bands and recombination; by analysis of the acceleration into 1/3 octave band levels, weighting the levels in individual bands and recombination; or by direct use of electrical filters in a broadband method. The three methods are described below in decreasing order of accuracy (accuracy as resulting from practical considerations of analysis equipment).

7.4.1 Constant bandwidth method

Each vibration tape recording, or vibration signal where a tape recorder is not used, shall be analyzed into constant bandwidth acceleration levels over the frequency range from 1 to 20 Hz (* to 80 Hz *) by appropriate digital methods (see ISO 4865). The sampling time, T (in seconds), and resolution bandwidth, B_e (in hertz), shall satisfy the following :

$$2\,B_eT \geqslant 140 \qquad B_e \leqslant 0{,}3\ \text{Hz}$$

The mean square value of the digitized time data (time domain) should be compared to the mean square value of the spectral estimate (frequency domain). If these values differ, then the analysis procedure should be reviewed and corrected as necessary for possible errors such as improper scaling, wrong correction factor for the data time window (sampling window), or programme errors.

The constant bandwidth rms levels shall each be multiplied by a weighting factor calculated for each centre frequency from figure 4 for a_z (vertical) vibration. A weighted acceleration value, a_{wf}, shall be calculated as the square root of the sum of the squares of the weighted constant bandwidth levels over the range 1 to 20 Hz (* to 80 Hz *).

7.4.2 One-third octave bandwidth method

Each vibration tape recording, or vibration signal where a tape recorder is not used, shall be analyzed into 1/3 octave component accelerations for the centre frequencies of table 1. (The centre frequencies of table 1 are an extrapolation of IEC Publication 225.) The rms value of each component, a_f, shall be averaged over the duration specified for the measurement. The 1/3 octave values shall each be multiplied by the weighting factors, W_f, listed in table 1, and a weighted acceleration value, a_{wf}, calculated for each recording as follows :

(* 80 *)

$$a_{wf} = \left[\sum_{f=1}^{20} W_f^2 \times a_f^2\right]^{1/2}$$

To satisfy the following,

$$2\,B_eT \geqslant 140$$

the minimum sampling time, T, is 300 s.

7.4.3 Broadband method

This method, if employed for direct indication of the weighted vibration, shall consist of an electronic weighting network incorporated between the transducer and a time integration stage. The weighting network shall have an insertion loss conforming to the curve in figure 4 for a_z (vertical) vibration. The loss shall not deviate from the curve by more than ± 1 dB for frequencies between 1,1 Hz and 10 Hz, and ± 2 dB at any other frequency. The integration stage shall be capable of indicating the integral of the square of weighted acceleration, a_w, for the time period of the test run T. That is,

$$(a_{wf})^2 = \frac{1}{T}\int_{t=0}^{T} a_w^2\,dt$$

The minimum sampling time, T, is 300 s.

7.5 Calibration

7.5.1 General

Operating manuals or other literature furnished by the instrument manufacturer should be reviewed for both recommended operation of the instrument and precautions to be observed. The entire measurement and analysis system should be regularly calibrated by technically trained instrumentation personnel following manufacturer's recommendations for the adjustment and application of individual components.

Acceleration transducers should be calibrated in accordance with a suitable recognized calibration method[1]. In particular, the calibration procedures should ensure that the acceleration sensitivity varies less than ± 2,5 % of a mean value over the frequency range of 0 to 40 Hz and less than ± 6,0 % of a mean value over the frequency range of 0 to 80 Hz.

The effects of ambient temperature and humidity on the performance of all instruments shall be known. Instruments shall be operated within the temperature limits at which the required accuracy can be expected.

7.5.2 For tests

It is strongly recommended that technically trained personnel select the instrumentation for the actual test conditions and

1) Additional information will be given in a forthcoming International Standard.

that the tests be conducted only by qualified persons trained in the current techniques of random vibration measurement and analysis.

Multi-instrument measurement systems shall be checked for proper signal levels, terminating impedances, and cable lengths.

The general procedures described in the tilting support method[1] for static calibration of acceleration transducers should be used to obtain overall system acceleration sensitivity. Tilting the sensitive axis of the transducer from the vertical through an angle of 180° in the field of gravity provides a peak-to-peak change in the output representing a 19,61 m/s² ($2g$) change in input acceleration. The sensitive axis of the accelerometer should be aligned with the vertical and the 180° inverted position to within ± 4°, and the peak-to-peak change in output voltage should be measured to within ± 0,5 %. Calibration should be made and recorded before and after each test series and at reasonable intervals during any extended test series. Each calibration shall be compared to the internal electronic calibration of the overall instrument system.

The transducer used to measure the vibration transmitted to the operator need not be removed from the mounting disc (see 7.2.1) provided the sensitive axis of the transducer can be located within the prescribed tolerance. Zero hertz frequency response of the instrumentation system is required for this calibration procedure.

An internal electronic calibration of the overall instrument system shall be checked immediately before and after each test run, and corrections made as necessary to maintain the required test accuracy.

The output from each accelerometer amplifier shall be nulled by proper balancing and zeroing techniques while the accelerometers are in the test position between the seat and the seated operator and on the seat mounting base or test stand.

The null or zero value of the overall instrument system shall be recorded immediately before and after each test run.

8 Vibration test stand

8.1 Physical characteristics

The minimum required facility is an electro-hydraulic feedback control system with an a_z degree of freedom. The system shall have dynamic response capable of driving the mounting base of the loaded seat in accordance with the defined test spectra.

The transfer function characteristics of the facility may be compensated for during the synthesis of the command input signal in order that a_z output PSD and PDF requirements are satisfied at the seat mounting base. Any appropriate digital or analog method may be used to generate the command signal providing that the output PSD and PDF requirements are satisfied at the seat mounting base.

The moving portion of the vibration test stand shall consist of a platform to provide for the seat mounting base and flat floor space for operator foot support. The stand shall be constrained to travel in an essentially vertical direction and shall be free from resonances and non-linearities, which would distort the output vibration beyond the correction capability of signal compensation.

If the platform is carried on an arm, as shown in figure 5, the radius from the arm pivot to the SIP shall be at least 2 000 mm.

8.2 Safety recommendations

The vibration test stand should have fail-safe provisions capable of automatic shut-down when the seat mounting base acceleration exceeds 15 m/s² for any reason. It is preferred that this provision be a hydraulic means, such as a supply pressure relief valve and/or a load-limiting valve across the piston of the actuator cylinder. If an acceleration transducer is used as the sensor for safety purposes, its signal should be passed through a low pass filter with a 20 Hz cut-off frequency to avoid automatic shut-down from high frequency components beyond the hydraulic capability of the test stand. If the test stand is not of the hydraulic type, adequate safety devices should be used.

The pump and/or servo-valves should be sized to limit the test stand velocity to 1,3 m/s, and the accumulator should be of the minimum size required to provide the proper system response.

Fail-safe shut-down switches should be provided to both the person in the test seat and the operator of the test facility. The shut-down switches should shut down the hydraulic power supply and actuate a valve to release the system hydraulic pressure.

In all tests, the excitation vibration should be increased slowly to allow the test to be terminated at the request of the person in the seat.

8.3 Technical characteristics

The following technical characteristics are only for the purpose of assisting in the selection of a vibration test stand.

Maximum dynamic thrust force = 1,5 × mass (platform, seat and subject).

Working frequency range = 0,5 to 20 Hz.

Piston stroke = 175 mm minimum (allowance for variable level at 0 Hz should be in addition to 175 mm).

1) Additional information will be given in a forthcoming International Standard.

9 Test arrangement

9.1 Test seats

The operator seat for test shall be representative of actual or intended series production with regard to construction, static and vibration characteristics and other features which may affect the vibration test results.

The seat shall be mounted on the vibration test stand at a height above the platform representative of the machine installation.

Before the test, suspension seats shall be run-in under the conditions set forth by the manufacturer. If the manufacturer does not state such conditions then the seat shall be run-in for 5 h before the test. For this purpose, the seat shall be loaded with a 75 kg mass such as lead shot, and a sinusoidal input vibration shall be applied at approximately the suspension natural frequency and of an amplitude sufficient to cause full motion of the seat suspension. Care must be taken to ensure against over-heating the shock absorber during the run-in.

The seat shall be adjusted for the stature and weight of the person (operator) according to the manufacturer's instructions.

9.2 Test persons

Tests shall be carried out with two test persons : one with a total mass of 55 kg (− 0 % ; + 10 %) of which not more than 5 kg may be carried in a weighting belt around the waist; the other with a total mass of 98 kg (− 0 %; + 10 %) of which not more than 8 kg may be carried in the belt.

The persons shall sit naturally in the seat with feet flat on the platform and hands folded on the lap. If a simulated steering wheel is provided on the platform, it should be representative of the machine layout, and the hands should be placed on the steering wheel as typical of machine operation. The persons shall be properly trained to ensure a passive behaviour with respect to the seat during all tests.

NOTE — If it is not possible to meet the above requirements for the 98 kg person, then a person of less mass can be selected and not more than 15 kg added mass can be used to achieve a total mass of 98 kg (− 0 %; + 10 %). The added mass should be distributed equally between a belt and a vest (or shoulder harness). If the test result of 11.3.4 for this person is marginal with respect to the acceptance level of 12.2, the result shall be rejected. Details of the added mass shall be included in the test report.

10 Test input vibration

10.1 Machine classes

Basic specifications for machines defined as having similar vibration characteristics are identified by class in table 2.

The machine classes of table 2 include a broad range of machine sizes within each class. The vibration characteristics of 10.2 are representative envelopes for the various size machines within the class to allow a single test to evaluate a single operator seat suitable for use on any machine within the class.

10.2 Vibration characteristics

The vibration characteristics for each class of machine are shown in figures 6 to 9. Exact equations for the acceleration power spectral density curves of figures 6 to 9 are included in table 3. These curves, defined by these equations, are the target values to be produced at the base of the seat for the random vibration test of 11.3.

10.2.1 Table 4 further defines the test input levels and shows the tolerances allowed on the actual test input PSD at the base of the seat.

10.2.2 Any means, including double integrators, analog signal generators and filters, and digital signal generators with digital-to-analog converters, may be used to produce the required PSD and rms characteristics at the base of the seat for the random vibration test.

10.2.3 Table 4 also specifies the probability density function required of the random vibration at the base of the seat during the test.

11 Test procedure

11.1 Test arrangement

The seat to be tested shall be mounted on the vibration test stand of clause 8 in accordance with the test seat arrangement of 9.1.

The instruments shall be arranged in accordance with clause 7 and calibrated in accordance with 7.5.

11.2 Test for damping

The seat shall be loaded with a 75 kg mass such as lead shot. The shot may be contained equally in two equal-size bags, suitable for secure and symmetrical placement on the seat cushion in the approximate operator seating location.

11.2.1 A sinusoidal vibration with a peak-to-peak displacement amplitude of 50 mm shall be applied to the base of the seat at the resonant frequency of the suspension (± 0,1 Hz). If the resonant frequency is greater than 2 Hz, the excitation shall be a sinusoidal vibration with a peak-to-peak acceleration amplitude of 7,9 m/s². Care shall be taken to ensure against over-heating the shock absorber during the test.

11.2.2 The test shall be repeated to obtain three consecutive test runs in which the frequency-weighted rms acceleration values (a_{wf} in accordance with 7.4), measured at the disc of 7.2.1, are within ± 5 % of their arithmetic mean. This arithmetical mean shall be recorded.

11.2.3 For the three rms of record in accordance with 11.2.2, the arithmetical mean of the three values of the frequency weighted rms acceleration values (a_{wf} according to 7.4), measured at the base of the seat, shall be recorded.

11.2.4 For the purposes of 11.2.2 and 11.2.3, any of the methods of 7.4 may be used to obtain the frequency weighted rms acceleration, except that the same method shall be used for 11.2.2 and 11.2.3.

11.2.5 The maximum transmissibility of the seat is calculated as the ratio of the recorded values of 11.2.2 and 11.2.3 as follows :

$$\text{Maximum transmissibility} = \frac{\text{Recorded value of 11.2.2}}{\text{Recorded value of 11.2.3}}$$

11.3 Random vibration test

Each test person shall be positioned in the seat according to 9.2. The vibration test stand shall be operated to produce the appropriate test input vibration spectra of clause 10 at the base of the seat and according to the class of machine to which the operator seat is to be fitted.

The test input vibration shall be continuous for sufficient time during each test run to provide at least 5 min of actual data. The instruments shall be nulled and calibrated before and after each test run in accordance with 7.5.2.

11.3.1 For each mass of test person (see 9.2), the test shall be repeated to obtain three consecutive test runs in which the frequency weighted rms acceleration values (a_{wf} in accordance with 7.4) measured at the seat disc of 7.2.1 are within ± 5 % of their arithmetical mean. This arithmetical mean shall be recorded as a_{wfS}.

11.3.2 For the runs of record according to 11.3.1, the vibration at the seat mounting base during each test must be within the allowed values of table 4. For each test person, the arithmetical mean of the three test values for the frequency weighted rms acceleration values (a_{wf} in accordance with 7.4) measured at the base of the seat shall be recorded as a_{wfB}.

11.3.3 For the purposes of 11.3.1 and 11.3.2, any of the methods of 7.4 may be used to obtain the frequency weighted rms acceleration, except that the same method shall be used for 11.3.1 and 11.3.2.

11.3.4 The frequency weighted rms acceleration transmitted to the person, a_{wfS} in accordance with 11.3.1, shall be corrected in the proportion that the actual test input frequency weighted rms acceleration, a_{wfB} in accordance with 11.3.2, differed from the target value of column 2 of table 4. The calculation is as follows :

$$\text{Corrected operator } a_{wfS} = a_{wfS} \frac{\text{Target value of table 4}}{a_{wfB}}$$

12 Acceptance levels

Under the test procedures of this International Standard, the following levels shall not be exceeded :

12.1 The maximum transmissibility of 11.2.5 shall not exceed a value of 2,0.

12.2 The corrected value of frequency weighted rms acceleration transmitted to the operator (corrected operator a_{wfS} of 11.3.4) shall not exceed 1,25 m/s².

13 Test report

The test report should contain the following :

a) Name and address of seat manufacturer;

b) Model of seat;

c) Date of test;

d) Time duration of pretest run-in; in hours

e) Type of transducer used : semi-rigid, rigid;

f) Height of SIP above platform for test;

g) Machine class number of test input;

h) Maximum transmissibility in this test : value and frequency at which it was measured;

j) Vibration transmitted to the operator;

i) operator mass in kilograms

ii) operator vibration (weighted rms) in metres per second squared

k) Test carried out by.

Table 1 — Frequency weighting factors
(In accordance with ISO 2631)

1/3 octave centre frequency f	Weighting factor W_f
1,0	0,50 = − 6 dB
1,25	0,56 = − 5 dB
1,6	0,63 = − 4 dB
2,0	0,71 = − 3 dB
2,5	0,80 = − 2 dB
3,15	0,89 = − 1 dB
4,0	1,00 = 0 dB
5,0	1,00 = 0 dB
6,3	1,00 = 0 dB
8,0	1,00 = 0 dB
10,0	0,80 = − 2 dB
12,5	0,63 = − 4 dB
16,0	0,50 = − 6 dB
20,0	0,40 = − 8 dB
25,0	0,315 = − 10 dB
31,5	0,25 = − 12 dB
40,0	0,20 = − 14 dB
50,0	0,16 = − 16 dB
63,0	0,125 = − 18 dB
80,0	0,10 = − 20 dB

Table 2 — Machine classes[1)]

Class	Machine	Configuration
1	Tractor-scraper	Open bowl or elevating. Two axles, articulated steer. Front axle or two axle drive. No axle suspension and no vibration absorber hitch.
2	Tractor-scraper	Same as class 1, except with either front axle suspension or vibration absorber hitch.
3	Wheel loader	Rigid or articulated frame. Two wheel or four wheel drive. Excluding three wheel machines, skid-steer machines, and utility machines under 5 000 kg operating weight.
	Wheel tractor	Same configuration range as wheel loader.
4	Crawler tractor	All.
	Crawler loader	All.

1) Future studies could result in additional classes (for example graders, backhoe loaders).