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Earth-moving machinery — Laboratory evaluation of operator seat vibration

Engins de terrassement — Évaluation en laboratoire des vibrations transmises à l'opérateur par le siège

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 151, *Construction equipment and building material machines - Safety*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 7096:2000), which has been technically revised.

The main changes compared to the previous edition are as follows:

— Clause 1, horizontal direction drills added to the list of machines with low vertical vibration inputs;

— crawler dumpers added to Table 4 and aligned with Figure 7;

— whole document, update of normative references;

— skid steer loaders with tracks have been added;

— 5.4, reference to the posture of the test person added and total mass of heavy person updated;

— 5.5.2, informative note for bag filling;

— 5.5.3, damping test for active and semi-active suspension systems added;

— Table 2, Power Spectral Density of class EM 1 and EM 3 modified;

— Table 3, Filter cut-off frequencies of class EM 1 modified;

— Table 4, Characteristics of the simulated input vibration modified for the following machine types:

  — Articulated or rigid frame dumper >4 500 kg;

  — Wheel loader >4 500 kg.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a type-C standard as stated in ISO 12100.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance etc.)

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e. g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

The operators of earth-moving machinery are often exposed to a low frequency vibration environment partly caused by the movement of the machines over uneven ground and the tasks carried out. The seat constitutes the last stage of suspension before the operator. To be efficient at attenuating the vibration, the suspension seat should be chosen according to the dynamic characteristics of the machine. The design of the seat and its suspension are a compromise between the requirements of reducing the effect of vibration and shock on the operator and providing him with stable support so that he can control the machine effectively.

Thus, seat vibration attenuation is a compromise of a number of factors and the selection of seat vibration parameters needs to be taken in context with the other requirements for the seat.

The performance criteria provided in this document have been set in accordance with what is attainable using what is at present the best design practice. They do not necessarily ensure the complete protection of the operator against the effects of vibration and shock. They could be revised in the light of future developments and improvements in suspension design.

The test inputs included in this document are based on a very large number of measurements taken in situ on earth-moving machinery used under severe but typical operating conditions. The test methods are based on ISO 10326-1:2016, which is a general method applicable to seats for different types of machines.

Earth-moving machinery — Laboratory evaluation of operator seat vibration

1 Scope

1.1 This document specifies, in accordance with ISO 10326-1:2016, a laboratory method for measuring and evaluating the effectiveness of the seat suspension in reducing the vertical whole-body vibration transmitted to the operator of earth-moving machines at frequencies between 1 Hz and 20 Hz. It also specifies acceptance criteria for application to seats on different machines.

1.2 This document is applicable to operator seats used on earth-moving machines as defined in ISO 6165.

1.3 This document defines the input spectral classes required for the following earth-moving machines. Each class defines a group of machines having similar vibration characteristics:

— rigid-frame dumpers >4 500 kg operating mass;

— articulated-frame dumpers;

— scrapers without axle or frame suspension[1)];

— wheeled loaders >4 500 kg operating mass;

— graders;

— wheeled dozers;

— soil compactors;

— backhoe loaders;

— crawler dumpers;

— crawler loaders;

— crawler-dozers ≤50 000 kg operating mass[2)];

— compact dumpers ≤4 500 kg operating mass;

— wheeled compact loaders ≤4 500 kg operating mass;

— skid-steer loaders, wheeled ≤4 500 kg and tracked ≤6 000 kg operating mass.

1.4 The following machines impart sufficiently low vertical vibration inputs at frequencies between 1 Hz and 20 Hz to the seat during operation that these seats do not require suspension for the attenuation of transmitted vibration:

— excavators, including walking excavators and cable excavators[3)];

1) For scrapers with suspension, either a seat with no suspension can be used, or one having a suspension with high damping.

2) For crawler dozers greater than 50 000 kg, the seat performance requirements are suitably provided by a cushion type seat.

3) For excavators, the predominant vibration is generally in the fore and aft (X) axis.

— trenchers;

— landfill compactors;

— non-vibratory rollers, except soil compactors;

— vibratory rollers, except soil compactors;

— pipelayers;

— horizontal directional drills (HDD).

1.5 The tests and criteria defined in this document are intended for operator seats used in earth-moving machines of conventional design.

NOTE Other tests can be appropriate for machines with design features that result in significantly different vibration characteristics.

1.6 Vibration which reaches the operator other than through the seat, for example that sensed by the operator's feet on the platform or control pedals or by the operator´s hands on the steering-wheel, is not covered.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041:2018, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 2631-1:1997/Amd 1:2010, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements; Amendment 1*

ISO 8041-1:2017, *Human response to vibration — Measuring instrumentation — Part 1: General purpose vibration meters*

ISO 10326-1:2016, *Mechanical vibration — Laboratory method for evaluating vehicle seat vibration — Part 1: Basic requirements*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13090-1:1998, *Mechanical vibration and shock — Guidance on safety aspects of tests and experiments with people — Part 1: Exposure to whole-body mechanical vibration and repeated shock*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100, ISO 2041 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp.

— IEC Electropedia: available at http://www.electropedia.org/.

3.1.1
whole-body vibration
vibration transmitted to the body as a whole through the buttocks of a seated operator

3.1.2
input spectral class
ride vibration characteristics at the seat attachment point for machines, grouped by virtue of various vibration characteristics

3.1.3
operating mass
mass of the base machine, with equipment and empty attachment in the most usual configuration as specified by the manufacturer, and with the operator (75 kg), full fuel tank and all fluid systems (i.e. hydraulic oil, transmission oil, engine oil, engine coolant) at the levels specified by the manufacturer and, when applicable, with sprinkler water tank(s) half full

[SOURCE: ISO 6016:2008, 3.2.1, modified — Notes 1 and 2 to entry have been deleted.]

3.1.4
operator seat
portion of the machine provided for the purpose of supporting the buttocks and back of the seated operator, including any suspension system and other mechanisms provided (for example, for adjusting the seat position)

3.1.5
active and semi-active suspension systems
seat suspension system with a control system that changes seat suspension performance automatically

3.1.6
frequency analysis
process of arriving at a quantitative description of a vibration amplitude as a function of frequency

3.1.7
measuring period
time duration in which vibration data for analysis is obtained

3.2 Symbols and abbreviated terms

$a_P(f_r)$	Unweighted rms value of the measured vertical acceleration at the platform at the resonance frequency
a^*_{P12}, a^*_{P34}	Unweighted rms value of the target vertical acceleration at the platform under the seat (see Figure 3) between frequencies f_1 and f_2, or f_3 and f_4
a_{P12}, a_{P34}	Unweighted rms value of the measured vertical acceleration at the platform between frequencies $f_1$and f_2, or f_3 and f_4
$a_S(f_r)$	Unweighted rms value of the measured vertical acceleration at the seat disk at the resonance frequency
a^*_{wP12}, a^*_{wP34}	Weighted rms value of the target vertical acceleration at the platform between frequencies f_1 and f_2, or f_3 and f_4
a_{wP12}	Weighted rms value of the measured vertical acceleration at the platform between frequencies f_1 and f_2
a_{wS12}	Weighted rms value of the measured vertical acceleration at the seat disk (see Figure 3) between frequencies f_1 and f_2
B_e	Resolution bandwidth, in hertz
f	Frequency, in hertz
f_r	Frequency at resonance

$G_P(f)$	Measured PSD of the vertical vibration at the platform (seat base)
$G^*_P(f)$	Target PSD of the vertical vibration at the platform (seat base)
$G^*_{PL}(f)$	Lower limit for the measured PSD of the vertical vibration at the platform (seat base)
$G^*_{PU}(f)$	Upper limit for the measured PSD of the vertical vibration at the platform (seat base)
$H(f_r)$	Transmissibility at resonance
PSD	Power Spectral Density, expressed as acceleration squared per unit bandwidth $(m/s^2)^2/Hz$
rms	root mean square
SEAT	Seat Effective Amplitude Transmissibility
T_s	Sampling time, in seconds

4 General

4.1 Machinery shall comply with the safety requirements and/or protective/risk reduction measures of this clause. In addition, the machine shall be designed according to the principles of ISO 12100:2010 for relevant but not significant hazards which are not dealt with by this document.

4.2 The laboratory-simulated machine vertical vibration, specified as input spectral class, is based on representative measured data from machines in severe but typical working conditions. The input spectral class is a representative envelope for the machines within the class, as measured under severe conditions.

4.3 Two criteria are used for the evaluation of seat:

a) the Seat Effective Amplitude Transmissibility (SEAT) factor according to ISO 10326-1:2016, 10.2, but with frequency weighting according to ISO 2631-1:1997/Amd 1:2010;

b) the maximum transmissibility ratio in the damping test according to ISO 10326-1:2016, 10.2.

4.4 The measuring equipment shall be in accordance with ISO 8041-1:2017 (type 1 instrument) and ISO 10326-1:2016, Clauses 4 and 5. The frequency weighting shall include the effects of the band limiting filters, and be in accordance with ISO 2631-1:1997/Amd 1:2010.

4.5 Safety precautions shall be in accordance with ISO 13090-1:1998.

Any compliant end-stops or devices normally fitted to production versions of the seat to be tested to minimise the effect of suspension overtravel shall be in place for the dynamic tests.

5 Test conditions and test procedure

5.1 General

The test conditions and test procedure shall be in accordance with ISO 10326-1:2016, Clauses 8 and 10.

5.2 Simulation of vibration

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

In the case of classes EM 1 and EM 2 the vibrator should be capable of simulating sinusoidal vibration having a displacement amplitude of at least ±7,5 cm at a frequency of 2 Hz; see 5.5.1.

5.3 Test seat

5.3.1 General

The operator seat for the test shall be representative of series-produced models, with regard to construction, static and vibration characteristics and other features which can affect the vibration test result.

5.3.2 Run-in

Before the test, the suspension seats shall be run-in under conditions stipulated by the manufacturer. If the manufacturer does not state such conditions, then the seat shall be run-in for 5 000 cycles, with measurements at 1 000 cycle intervals.

For this purpose, the seat shall be loaded with an inert mass of 75 kg and adjusted to the mass in accordance with the manufacturer's instructions. The seat and suspension shall be mounted on the platform of a vibrator, and a sinusoidal input vibration shall be applied to the platform at approximately the suspension natural frequency. This input vibration shall have a peak to peak displacement sufficient to cause movement of the seat suspension over approximately 75 % of its stroke. A platform peak to peak displacement of approximately 40 % of the seat suspension stroke is likely to achieve this. Care should be taken to ensure against overheating of the suspension damper during the running-in, for which forced cooling is acceptable.

The seat shall be considered to have been run-in if the value for the vertical transmissibility remains within a tolerance of ±5 % when three successive measurements are performed under the condition described above. The time interval between two measurements shall be half an hour, or 1 000 cycles (whichever is less), with the seat being constantly run-in.

5.3.3 Seat adjustment

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

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

With seats where the suspension stroke available is **affected** by the adjustment of the seat height or by test person weight, testing shall be performed in the lowest position which provides the full working suspension stroke as specified by the seat manufacturer.

When the inclination of the backrest is adjustable, it shall be set approximately upright, inclined slightly backwards (approximately 10° ± 5°).

5.4 Test person and posture

The posture of the test person during the testing shall be in accordance with Figure 1.

NOTE 1 See ISO 10326-1:2016, 8.2.

NOTE 2 The differences in the posture of the test person can cause a 10 % difference between test results. For this reason, recommended angles of knees and ankles have been specified in Figure 1.

The simulated input vibration test shall be performed with two persons. The light person shall have a total mass of 52 kg to 55 kg, of which not more than 5 kg may be carried in a belt around the waist. The heavy person shall have a total mass of 110 kg to 115 kg, of which not more than 12 kg may be carried in a belt around the waist.

5.5 Input vibration

5.5.1 Simulated input vibration test to evaluate the SEAT factor

This document specifies the input vibration in nine input spectral classes (EM 1 through EM 9) for earth-moving machinery for the purpose of determining the SEAT factor.

In accordance with ISO 10326-1:2016, 10.2.2, the SEAT factor is defined as

$$\text{SEAT} = a_{\text{wS12}} / a_{\text{wP12}}$$

The simulated input vibration used to determine the SEAT factor is defined in accordance with ISO 10326-1:2016, 9.2, but the frequency weighting shall be in accordance with ISO 2631-1:1997/Amd 1:2010. The test input for each class is defined by a power spectral density, $G^*_{\text{P}}(f)$, of the vertical (Z axis) acceleration of the vibrating platform, and by the unweighted rms vertical accelerations on that platform (a^*_{P12}, a^*_{P34}).

The vibration characteristics for each input spectral class EM 1 through EM 9 are shown in Figures 2 through 10, respectively. Formulae for the acceleration power spectral density curves of Figures 2 to 10 are included in Table 2. The curves defined by these equations are the target values to be produced at the base of the seat for the simulated input vibration test of 5.6.2.

The input vibration shall be determined (calculated) without components at frequencies outside the frequency range defined by f_1 and f_2.

Table 4 further defines the test input values for the actual test input PSD at the base of the seat.

Three tests shall be performed for each test person and each input vibration in accordance with ISO 10326-1:2016, Clause 10. The effective duration of each test shall be at least 180 s.

If none of the SEAT factor values relating to one particular test configuration deviate by more than ±5 % from the arithmetic mean, then, in terms of repeatability, the three tests mentioned above shall be deemed to be valid. If this is not the case, as many series of three tests as are necessary to satisfy this requirement shall be carried out.

The sampling time T_s and resolution bandwidth B_e shall satisfy the following:

$$2 \times B_e \times T_s > 140$$

$$B_e < 0{,}5 \text{ Hz}$$

NOTE 1 Class EM 7 is also used to test agricultural wheeled tractor seats for class I tractor (see ISO 5007:2003).

NOTE 2 Any means, including double integrators, analog signal generators and filters, and digital signal generators with digital-to-analog converters, can be used to produce the required PSD and rms characteristics at the base of the seat for the simulated input vibration test.

5.5.2 Damping test

The damping test is comprised of two steps: the first is a search to determine the resonant frequency of the suspension; the second determines the transmissibility of the suspension at that frequency.

