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ISO 20474-13

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Earth-moving machinery — Safety —

Part 13: Requirements for rollers

Engins de terrassement — Sécurité —

Partie 13: Exigences applicables aux compacteurs

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 20474-13 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*.

ISO 20474 consists of the following parts, under the general title *Earth-moving machinery — Safety*:

— *Part 1: General requirements*

— *Part 2: Requirements for tractor-dozers*

— *Part 3: Requirements for loaders*

— *Part 4: Requirements for backhoe loaders*

— *Part 5: Requirements for hydraulic excavators*

— *Part 6: Requirements for dumpers*

— *Part 7: Requirements for scrapers*

— *Part 8: Requirements for graders*

— *Part 9: Requirements for pipelayers*

— *Part 10: Requirements for trenchers*

— *Part 11: Requirements for earth and landfill compactors*

— *Part 12: Requirements for cable excavators*

— *Part 13: Requirements for rollers*

— Part 14: *Information on national and regional provisions* [Technical Specification]

Introduction

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

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 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.

Provisions that are applicable for Australia, EU, Japan or the USA, and which are mandatory for compliance with specific governmental laws, directives or regulations in force in the particular country or region, are given in ISO/TS 20474-14.

NOTE Other countries or regions may also have regional requirements.

Earth-moving machinery — Safety —

Part 13: Requirements for rollers

1 Scope

This part of ISO 20474 gives the safety requirements specific to rollers as defined in ISO 6165. It is intended to be used in conjunction with ISO 20474-1, which specifies general safety requirements common to earth-moving machine families, and with ISO/TS 20474-14, which gives information on provisions that are mandatory in particular countries or regions. The specific requirements given in this part of ISO 20474 take precedence over the general requirements of ISO 20474-1.

This part of ISO 20474 deals with all significant hazards, hazardous situations and events relevant to the earth-moving machinery within its Scope when used as intended or under conditions of misuse reasonably foreseeable by the manufacturer (see also ISO/TS 20474-14). It specifies the appropriate technical measures for eliminating or reducing risks arising from significant hazards, hazardous situations or events during commissioning, operation and maintenance. It is not applicable to machines manufactured before the date of its publication.

2 Normative references

The following referenced documents are indispensable for the application 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 3450, *Earth-moving machinery — Braking systems of rubber-tyred machines — Systems and performance requirements and test procedures*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane.*

ISO 6165:2006, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 6682, *Earth-moving machinery — Zones of comfort and reach for controls*

ISO 8811, *Earth-moving machinery — Rollers and compactors — Terminology and commercial specifications*

ISO 11201, *Acoustics — Noise emitted by machinery and equipment — Measurement of emission sound pressure levels at a work station and at other specified positions — Engineering method in an essentially free field over a reflecting plane*

ISO 13850, *Safety of machinery — Emergency stop — Principles for design*

ISO 17063, *Earth-moving machinery — Braking systems of pedestrian-controlled machines — Performance requirements and test procedures*

ISO 20474-1:2008, *Earth-moving machinery — Safety — Part 1: General requirements*

ISO 20643, *Mechanical vibration — Hand-held and hand-guided machinery — Principles for evaluation of vibration emission*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20474-1 and ISO 8811, and the following, apply.

3.1
roller
self-propelled or towed machine having a compaction device, consisting of one or more metallic cylindrical bodies (drums) or rubber tyres, which compacts material such as crushed rock, earth, asphalt or gravel through a rolling and/or vibrating action of the compaction device

[ISO 6165:2006, definition 4.10]

NOTE The metallic cylindrical bodies can be either rubber-coated or fitted with pads.

3.1.1
single-drum roller
self-propelled compaction machine with one vibrating metallic cylindrical body (drum) and two rubber tyres or two tracks

3.1.2
tandem roller
self-propelled compaction machine with one metallic cylindrical body (drum) in the front and one in the rear

NOTE The cylindrical drums can be either static or vibrating and can be split.

3.1.3
combined roller
self-propelled compaction machine with one or more metallic cylindrical body (drum) and more than two rubber tyres

3.1.4
three-wheel roller
self-propelled compaction machine with one metallic cylindrical body (drum) in the front (or rear) and two in the rear (or front)

NOTE The drums can be split.

3.1.5
pneumatic tyre roller
self-propelled compaction machine with three or more tyres in the front and the rear

3.2
direct-control machine
self-propelled earth-moving machinery where the machine is controlled by an operator in physical contact with the machine

[ISO 6165:2006, definition 3.2]

3.2.1
ride-on machine
self-propelled **direct-control machine** (3.2) where the control devices are located on the machine and the machine is controlled by a seated or standing operator

[ISO 6165:2006, definition 3.2.1]

3.2.2
non-riding machine
self-propelled **direct-control machine** (3.2) where the control devices are located on the machine and the machine is controlled by a pedestrian operator (neither seated nor standing on the machine)

[ISO 6165:2006, definition 3.2.2]

3.3
remote-control machine
self-propelled earth-moving machinery where the machine is controlled by the transmission of signals from a control box (transmitter) that is not located on the machine to a receiving unit (receiver) located on the machine

[ISO 6165:2006, definition 3.3]

3.4
towed roller
roller (3.1) that is not self-propelled but which is instead propelled by a towing machine on which the operator's station is located

[ISO 6165:2006, definition 4.10.1]

4 Safety requirements and/or protective measures

4.1 General

Rollers shall comply with the safety requirements and/or protective measures of ISO 20474-1, in as far as those are not modified by the specific requirements of this clause.

4.2 Non-riding machines

4.2.1 General

ISO 20474-1:2008, 4.1, shall apply, as applicable, together with the following (4.2.2 and 4.2.3).

4.2.2 Handle bar

To prevent dangerous vertical swinging of the steering element (handle bar) of the single-drum non-riding roller, movement of the handle shall be not less than 0,2 m and not more than 1,4 m above the ground (see Figure 1).

Dimensions in metres

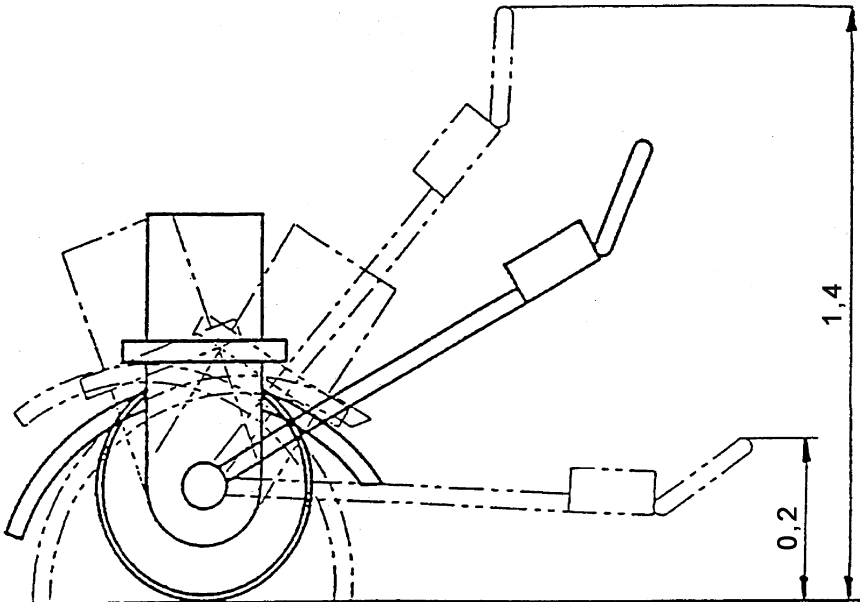


Figure 1 — Vertical swinging of single-drum non-riding roller

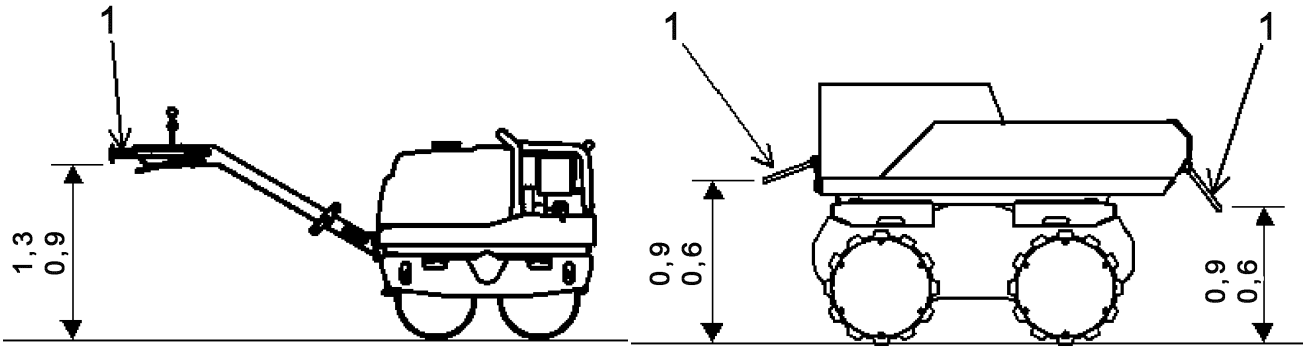
4.2.3 Protection device against crushing

Non-riding and remote-control machines shall be provided with a protection device against crushing that is designed to prevent the operator from being trapped between the machine and an obstacle.

The device shall be so designed as to stop the machine within a distance that is less than the total operating range of the device.

This device shall have an effective operating force not exceeding 230 N.

Dimensions in metres



a) Roller with handle bar **b) Remote-control roller**

Key

1 stopping device

Figure 2 — Position of safety device on non-riding machines

4.3 Operator's station (ride-on machines)

4.3.1 General

ISO 20474-1:2008, 4.3.1, shall apply, together with the following (4.3.2 to 4.3.4).

4.3.2 Operator's position

If the operator's position is offset from the space envelope width centreline, then the internal distance from the seat centreline to the side of the enclosure shall not be less than 295 mm.

4.3.3 Operator's station with cab

The first two paragraphs of ISO 20474-1:2008, 4.3.1.1, are not applicable to rollers.

Rollers with an operating mass $>$ 4500 kg shall be so designed that an operator’s cab can be fitted.

ISO 20474-1:2008, 4.3.1.2, is not applicable to rollers.

4.3.4 Doors and windows

Doors and windows latched in open positions shall not extend beyond the main outer dimensions of the machine, when the machine is in operation as intended.

4.4 Operator's seat

ISO 20474-1:2008, 4.4, shall apply, except for 4.4.1.4.

4.5 Controls and indicators

4.5.1 General

ISO 20474-1:2008, 4.5, shall apply, together with the following (4.5.2 to 4.5.4).

For mandatory national and regional provisions, see ISO/TS 20474-14.

4.5.2 Travel control of non-riding rollers with handle bar

The machine travel control of non-riding rollers with an attended operator shall be of the hold-to-run type for both directions.

4.5.3 Controls for towed machines

For towed rollers, it shall be possible to control the on-off operation of the vibration from the operator's station on the towing machine.

4.5.4 Remote control machines

For mandatory national and regional provisions, see ISO/TS 20474-14.

4.5.5 Brake systems

4.5.5.1 Ride-on machines

For ride-on rollers, ISO 20474-1:2008, 4.7, shall apply, together with the following.

The brake system shall be in accordance with ISO 3450.

For service and secondary brake systems:

— the brake system shall apply to all power-driven drums and wheels;

— in case of split drums, every drum part shall have the same brake torque;

— the brake systems of single drum rollers and combined rollers shall apply to all wheels and to the drum.

If a hydrostatic drive is provided, it shall be interrupted when the secondary brake is actuated.

Consideration should be given for the performance of the brake system to the intended slopes as foreseen by the manufacturer.

All brake systems shall be controlled from the operator's station.

4.5.5.2 Non-riding machines

The brake systems of non-riding rollers shall be in accordance with ISO 17063.

4.5.6 Emergency stop

An emergency stop in accordance with ISO 13850 shall be fitted within the zone of comfort as specified in ISO 6682. It shall stop all dangerous functions of the machine.

4.6 Access system to operator's station and to maintenance points

4.6.1 General

ISO 20474-1:2008, 4.2, shall apply, together with the following (4.6.2 and 4.6.3).

4.6.2 Lowest step

The lowest steps of the access systems to the operator's station shall not be situated more than 600 mm above ground level.

4.6.3 Guard rail

Walkways to the operator's station and to platforms shall be provided with guard-rails if the vertical drop exceeds 1 m.

4.7 Roll-over protective structure (ROPS)

ISO 20474-1:2008, 4.3.3, shall apply.

For mandatory national and regional provisions, see ISO/TS 20474-14.

4.8 Noise and vibration

4.8.1 Noise — General

ISO 20474-1:2008, 4.13, shall apply, together with the following (4.8.2 to 4.8.4).

For mandatory national and regional provisions, see ISO/TS 20474-14.

4.8.2 Noise reduction at source at the design stage

For mandatory national and regional provisions, see ISO/TS 20474-14.

4.8.3 Noise measurement of non-riding and remote-control machines with working width ⩽ 1 m

The noise emission of non-riding and remote-controlled rollers with a working width less than or equal to 1 m shall be determined according to Annex A.

4.8.4 Vibration measurement of non-riding rollers with a working width ⩽ 1 m

The hand-arm vibration of non-riding rollers with a working width less than or equal to 1 m shall be determined according to Annex B.

For mandatory national and regional provisions, see ISO/TS 20474-14.

5 Verification of safety requirements and/or protective measures

ISO 20474-1:2008, Clause 5, shall apply.

6 Information for use

6.1 Warning signals and devices

ISO 20474-1:2008, 6.1, shall apply.

6.2 Operator's manual

ISO 20474-1:2008, 6.2, shall apply with the following additions:

— reference to hand-arm vibration as specified in 4.8.4;

— instruction in the need for a stopping device for non-riding and remote controlled rollers;

— safety precautions for starting and stopping non-riding rollers;

— instructions for proper use, including cleaning and maintenance of the water sprinkler system;

— additional information concerning the stability of the machine (permissible slope, etc.).

6.3 Marking

ISO 20474-1:2008, 6.3, shall apply.

Annex A
(normative)

Noise-test code for non-riding and remote-control vibratory rollers with working width $\leqslant$ 1 m

A.1 General

This noise-test code specifies all the information necessary for carrying out efficiently and under standardized conditions the determination, declaration and verification of the noise-emission characteristics of non-riding and remote-controlled vibratory rollers with a working width less than or equal to 1 m.

NOTE The test track width according to this annex and as described in the Noise Directive 2000/14/EC does not practically allow measurement of machines with a working width exceeding 1 m, due to random effects from the test track boundary.

Noise-emission characteristics include emission sound-pressure levels at workstations and the sound-power level. The determination of these quantities is necessary for

— manufacturers' declarations of the noise emitted,

— comparing the noise emitted by machines in the machine family concerned, and

— for noise control at the source at the design stage.

The use of this noise-test code will ensure reproducibility of the determination of the noise-emission characteristics within specified limits determined by the grade of accuracy of the basic noise-measurement method used. The noise-measurement methods allowed by this part of ISO 20474 are engineering methods in accordance with ISO 3744:1996, Grade 2.

Test conditions and procedures for the determination of noise emission (according to this annex) and hand-arm vibration (according to Annex B) are identical. It is therefore possible and recommended to record the noise emission and the hand-arm vibration simultaneously during one measurement. The measuring effort is thereby reduced.

A.2 Test area

A.2.1 Design of test site

The test may be carried out outdoors or in an appropriate room.

Sound-reflecting material (e.g. concrete, closed-pore asphalt or steel plates) of at least 10 m $\times$ 10 m and a zone of at least 25 m $\times$ 25 m with no reflecting obstacles are required around the test track.

A.2.2 Design of test track

The test course of gravel shall be designed as shown in Figure A.1.

The compression ground shall have the following characteristics:

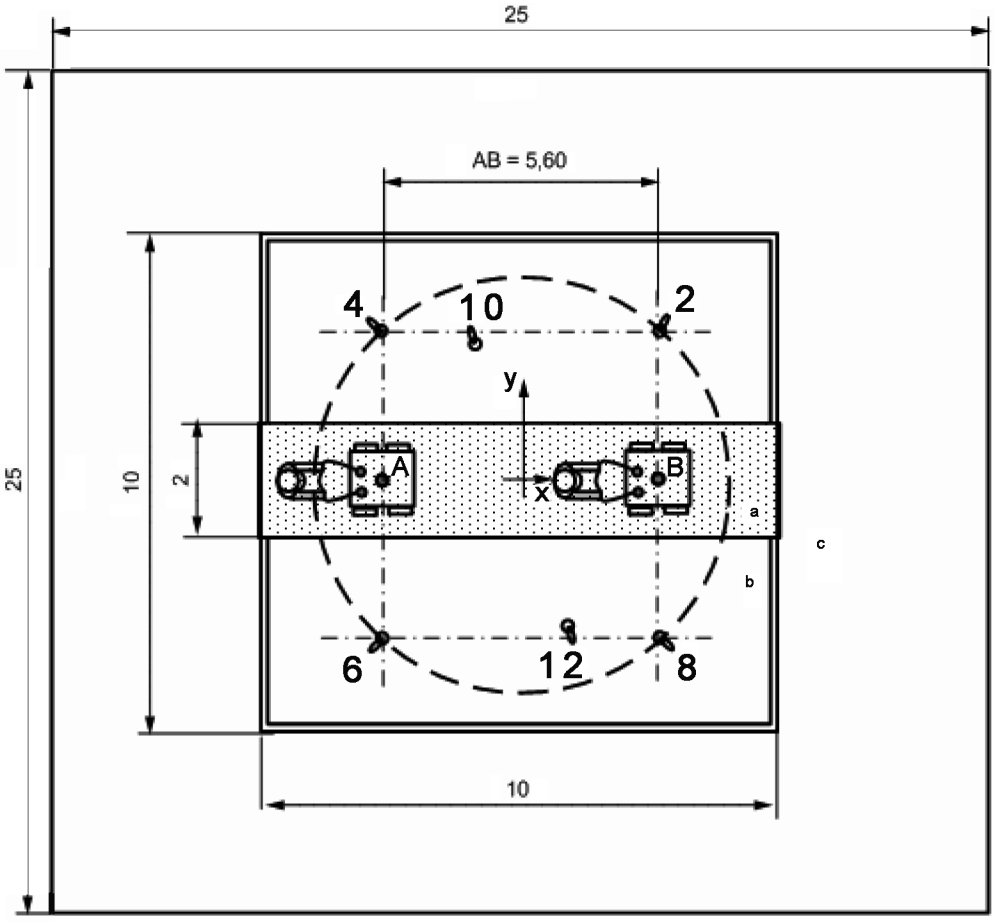
— dry gravel with sufficient hardness of a mean gravel diameter of 16 mm (particle size 10 mm to 22 mm), with a grading curve as shown in Figure A.2;

— the gravel shall be replaced if the mean gravel diameter decreases by 30 % or more;

— the dumping height of the gravel shall be at least 0,50 m due to the depth effect of the compacting machines;

— the test course of gravel shall have the same horizontal level as the sound-reflecting surface being rammed in order to prevent the gravel from creeping.

Dimensions in metres



Key

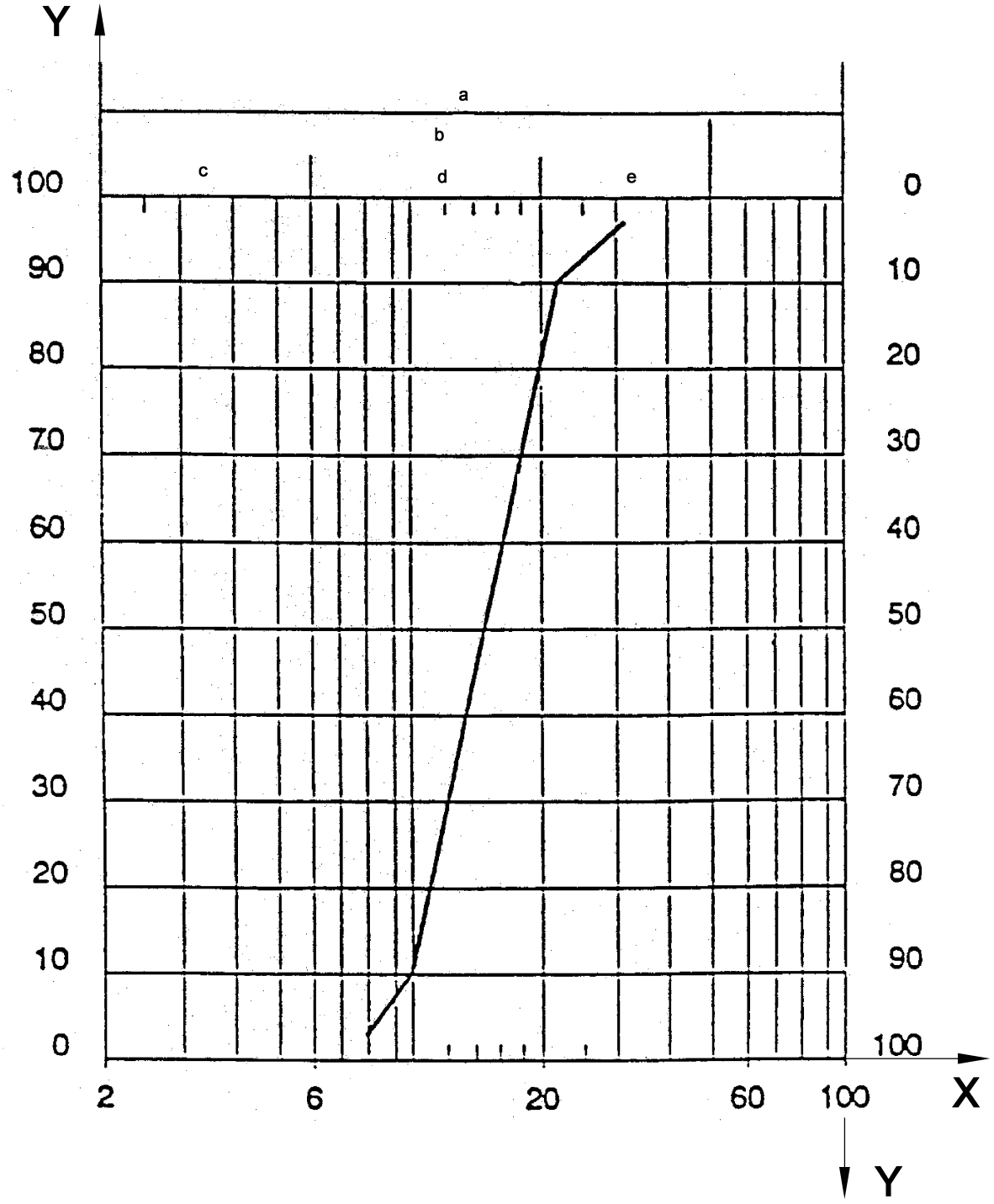
AB	measuring length
A	start
B	end
2, 4, 6, 8, 10, 12	microphone positions for sound-power level determination

[a] Gravel test course (depth = 0,50 m).

[b] Hard reflecting plane 10 m × 10 m.

[c] Plane without reflecting obstacles 25 m × 25 m.

Figure A.1 — Test site and arrangement with test track



Key

X Percentage of mass of the total volume.

Y Grain size.

a Screening gravel.

b Gravel size.

c Fine grain.

d Middle grain.

e Coarse grain.

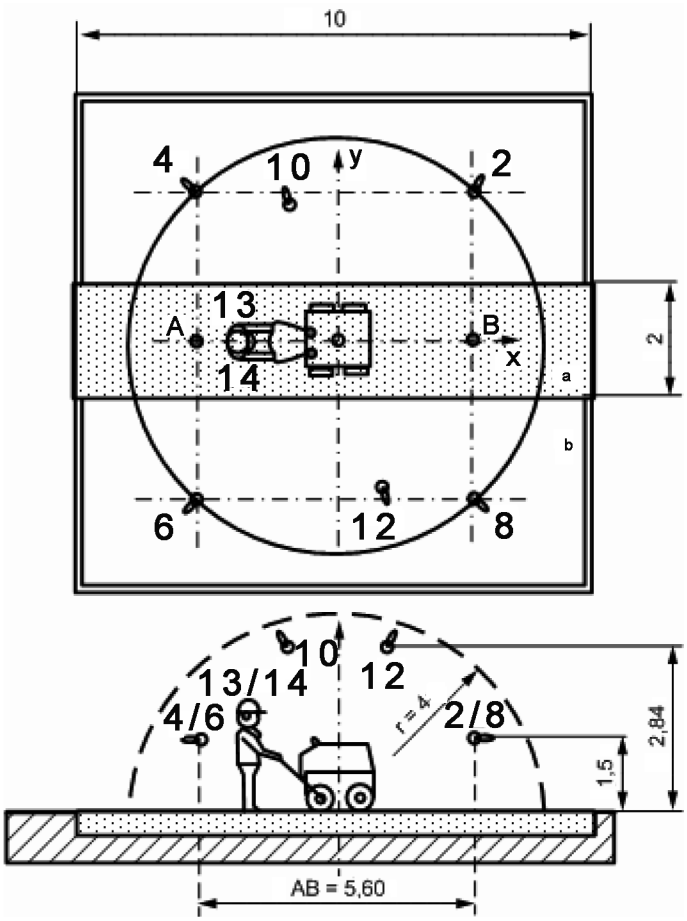
Figure A.2 — Grading size diagram of the material to be compacted (gravel)

A.2.3 Measurement surface

A.2.3.1 Shape and size of measurement surface

The measurement surface used for determining the A-weighted sound-power level shall be a hemisphere of radius $r = 4$ m, bounded by the sound-reflecting surface (see Figures A.3 and A.4).

Dimensions in metres



Key

AB	measuring length (AB = 5,60 m)
A	start
B	end
2, 4, 6, 8, 10, 12	microphone positions for sound-power level determination (see Table A.1)
13, 14	microphone positions for emission sound-pressure level determination

a Gravel test course (depth = 0,50 m).

b Hard reflecting plane 10 m × 10 m.

Measuring travel time, t_F, in seconds:

$$t_F = \frac{AB}{v_F}$$

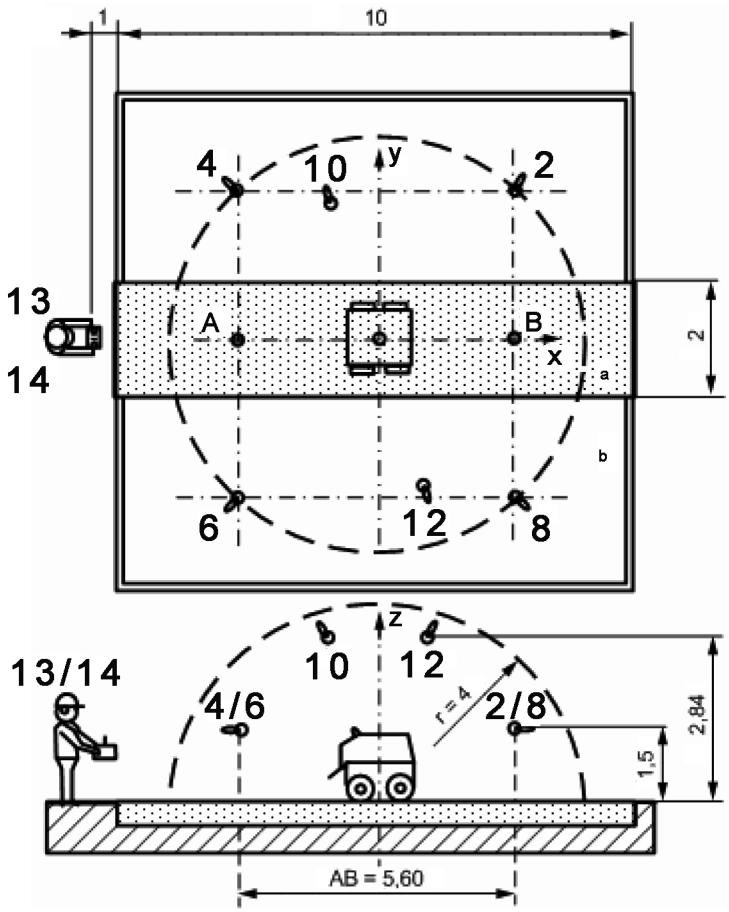
where

v_F is the working speed in m/s;

measuring travel time (t_F) = measuring time, t_M.

Figure A.3 — Arrangement of test positions for direct control non-riding rollers

Dimensions in metres



Key

AB	measuring length (AB = 5,60 m)
A	start
B	end
2, 4, 6, 8, 10, 12	microphone positions for sound-power level determination (see Table A.1)
13, 14	microphone positions for emission sound-pressure level determination

[a] Gravel test course (depth = 0,50 m).

[b] Hard reflecting plane 10 m × 10 m.

Figure A.4 — Arrangement of test positions for remote-controlled rollers

A.2.3.2 Microphone positions

Six microphone positions are specified on the hemisphere (see Figures A.3, A.4 and Table A.1).

Table A.1 — Coordinates of microphones

Measuring point	Coordinates m		
	x	y	z
2	2,8	2,8	1,5
4	−2,8	2,8	1,5
6	−2,8	−2,8	1,5
8	2,8	−2,8	1,5
10	−1,08	2,6	2,84
12	1,08	−2,6	2,84

A.3 Determination of A-weighted sound-power level

A.3.1 General

This clause specifies additional requirements for the determination of the A-weighted sound-power level according to ISO 3744.

A.3.2 Test procedure

A.3.2.1 Operating conditions

For the measurements, the machine shall be in accordance with the manufacturer's specifications.

Water and fuel tanks shall be half-filled. The sprinkler facility shall not be switched on.

The drawbar of hand-guided machines shall be freely movable between the upper and lower stops.

The engine shall be at the rated speed (± 5 %) as specified by the manufacturer.

The maximum forward working speed shall be selected. Ensure that the machine runs at the correct speed. The vibration setting that gives the highest noise contribution shall be selected.

Before starting the measurement, the operating temperature shall be reached.

A.3.2.2 Test track preparation and conditions

The compacted material of the test surface shall be loosened before starting the whole test procedure.

Test track material shall be dry. If it is wet or frozen this could influence the measurement result.

Machines with smooth drums could have difficulties running the first pass on the loosened track with vibrations. If that is the case, pre-compact the material by running over the track without vibrations.

The test track for remote-controlled rollers shall be identical to that of non-riding rollers (see Figure A.1).

A.3.2.3 Environment

Air temperature should be above 10 °C.

A.3.2.4 Measurement procedure

Simultaneous measurement at all microphone positions is preferred (it is also possible to perform consecutive measurements).

For the measurement duration, t_M, the surface of the test track AB = 5,60 m is compacted by the machine in forward operation. Subsequently, the machine is moved back to the starting point.

Start the measurement when the middle of the machine is in line with point A and stops at point B of the measuring stretch (see Figures A.3 and A.4). In all cases, the compaction shall go on along the whole stretch of gravel. Therefore, it shall be ensured that the machine works with the full compaction power within the measuring distance.

For each machine, three passes over the test track shall be carried out. The completion of the three passes is considered as a measuring cycle.

The compacted material of the test surface shall not be loosened between the three passes.

The r.m.s. values of the sound-pressure levels shall be taken for each pass.

The machine shall be moved along the centreline of the test course as in usual operation.

The same person shall operate the machine during the whole test. That person shall be skilled in handling and operating the machine.

A.3.3 Calculation of the sound-power level

The A-weighted sound-power level is calculated as the arithmetic mean value of the three passes.

The A-weighted sound-power level of the machine shall be rounded down or up to the nearest integral value in decibels ($< 0,5$ round down, $\geqslant 0,5$ round up).

A.3.4 Determination of emission sound-pressure spectra

If required, sound-pressure spectra may be registered at microphone position 10 in accordance with ISO 3744.

A.4 Determination of A-weighted emission sound-pressure level at operator's position

A.4.1 General

This clause specifies additional requirements for the determination of the A-weighted emission sound-pressure level of non-riding and remote-controlled vibratory rollers according to ISO 11201.

A.4.2 Test procedure

The test shall be carried out in accordance with A.3.2.

For non-riding rollers, the position of the operator shall be as shown in Figure A.3.

For remote-controlled rollers, the position of the operator shall be as shown in Figure A.4.

Since the sound-pressure level varies in relation to the operator's height, this height shall be 1,80 m ± 0,05 m.

NOTE For a source with an A-weighted sound-power level of 100 dB situated 0,3 m above the ground (centre of machine), the theoretical difference in A-weighted sound-pressure level between a position at 1,5 m behind the source and 1,8 m above the ground (operator) and a position at 1,5 m behind and 1,6 m above ground (0,20 m shorter operator) is 0,6 dB.

A.4.3 Calculation of the emission sound-pressure level

The A-weighted sound-pressure level is calculated as the arithmetic mean value of the three passes. The reported value is the highest of the two measurement positions (13, 14).

The A-weighted sound-pressure level at the operator's position shall be rounded down or up to the nearest integral value in dB (< 0,5 round down, ⩾ 0,5 round up).

A.4.4 Determination of emission sound-pressure spectra

If required, sound-pressure spectra may be registered at the workstation in accordance with ISO 11201 (microphone position 14, right ear, see Figures A.3 and A.4).

A.4.5 Sound-pressure level as function of time

If required, the sound-pressure level may be recorded as a function of time at microphone positions 10 and 14 (right ear).

A.5 Uncertainty

The measurement uncertainty and, in the case of series machines, the uncertainty due to production variations shall be considered when determining the value of the A-weighted sound-power level and that of the A-weighted emission sound-pressure level at the operator's position.

Current experience shows that the total uncertainty (measurement plus production), K_{WA} for the A-weighted sound-power levels and K_{pA} for the A-weighted emission sound-pressure level of non-riding and remote-controlled rollers is less than the values given in Table A.2.

Table A.2 —Uncertainties

K_{WA} dB	K_{pA} dB
1,0–2,0	2,0–3,0

A.6 Information to be recorded

ISO 3744 and ISO 11201 shall apply, with the addition of the following:

— engine speed for each run;

— vibration frequency for each run;

— measurement duration, t_M, for each run;

— height of the operating personnel;

— grading curve of the gravel;

— description of the test environment;

— A-weighted sound-power level for each run and the resulting sound-power level as an emission value;

— A-weighted emission sound-pressure level at the operator's position for each run and the arithmetic mean value (separately for left and right ear) of each;

— sound-pressure spectra, where appropriate;

— sound-pressure level as a function of time, where appropriate.

A.7 Information to be reported

Report all the information specified in A.6.

The test report shall include the statement that the sound-power level and the emission sound-pressure level at the operator's position have been determined entirely in accordance with the specifications of this annex.

A.8 Declaration and verification of noise-emission values

The declared A-weighted sound-power level shall be the sum of the measured value and the associated uncertainty, K_{WA} (see A.5).

NOTE The declared value of the A-weighted sound-power level is identical to the guaranteed sound-power level according to the Noise Directive 2000/14/EC.

The declared A-weighted emission sound-pressure level at the operator's position shall be the sum of the measured value and the associated uncertainty, K_{pA} (see A.5).

The noise declaration shall explicitly state that the noise-emission values have been obtained according to this noise-test code.

Any verification shall be done using this noise-test code. If the value measured during verification is less than or equal to the declared value, the declared value shall be verified.

Annex B
(normative)

Test code for hand-arm vibration of non-riding vibratory rollers with working width $\leqslant$ 1 m

B.1 General

In this annex, specifications are laid down for machines as a supplement to ISO 20643 for non-riding vibratory rollers with a working width less than or equal to 1 m. These specifications serve to determine the characteristic vibration amplitudes under practical conditions. The machines are characterized by their possession of a module for producing vibration, so as to cause compacting of the ground.

This annex contains the same conditions for operation and arrangements as apply to the measurement of noise (see Annex A). It is therefore possible, and also preferable, to record the hand-arm vibration and the noise emission simultaneously during one measurement. This leads to a considerable reduction in the equipment required for testing the machine.

B.2 Characterization of vibration

B.2.1 Measurement direction

The directions of measurement are shown in Figure B.1. The coupling device shall be directed, depending on the size of the operator, such that the z-axis runs parallel to the ground during the measurements.

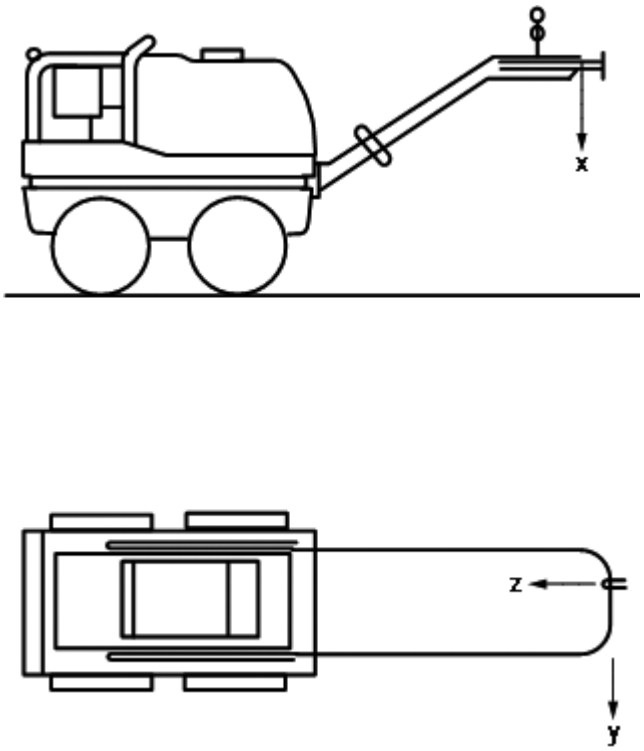
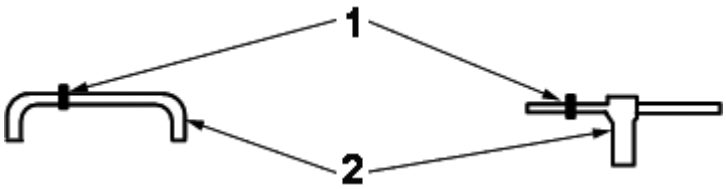


Figure B.1 — Directions of measurement

B.2.2 Measurement location

The measurement position shall be located on the drawbar between two fingers, or as close as possible to the hand (see Figure B.2). If the drawbar has a resilient cover, it is important that the hand be held on the transducer (coupling device), in order to avoid resonance phenomena.



Key

1 coupling device

2 drawbar

Figure B.2 — Arrangement of coupling device on drawbar

B.2.3 Combination of vibration directions

The quantities to be measured are the r.m.s. values of the weighted vibration accelerations, $a_{\mathrm{xhw},i}$, $a_{\mathrm{yhw},i}$, $a_{\mathrm{zhw},i}$, of the $i = 1$ to 3 measurements of a test run, in accordance with A.4.2. These are formed according to Equation (B.1):

$$\overline{a}_{\mathrm{hwx}} = \frac{1}{3}\sum_{i=1}^{3} a_{\mathrm{hwx},i} \; ; \; \overline{a}_{\mathrm{hwy}} = \frac{1}{3}\sum_{i=1}^{3} a_{\mathrm{hwy},i} \; ; \; \overline{a}_{\mathrm{hwz}} = \frac{1}{3}\sum_{i=1}^{3} a_{\mathrm{hwz},i} \tag{B.1}$$

for each co-ordinate into the result of the test run.

The acceleration sum of the test run is formed according to Equation (B.2):

$$a_h = \sqrt{\overline{a}_{\mathrm{hwx}}{}^2 + \overline{a}_{\mathrm{hwy}}{}^2 + \overline{a}_{\mathrm{hwz}}{}^2} \tag{B.2}$$

B.3 Instrumentation requirements

B.3.1 Specification of acceleration transducer

The measurement is preferably done with a triaxial transducer, but may also be done with three separate transducers. The total mass of the transducer(s) should be less than 60 g. The mass of the coupling device for the acceleration transducers should be kept as low as possible (maximum 60 g).

B.3.2 Mounting of acceleration transducer

Fasten the transducer rigidly to the drawbar with a coupling device. The coupling device shall be adapted to the diameter of the respective drawbar. Rigidly attach (screw or glue) the transducer to the coupling device.

The axes of the acceleration transducers shall be directed in accordance with B.2.1.

The acceleration transducer cables shall be pulled along by the machine or by the operator during measurement. Therefore, the cables shall be attached to the machine or the operator's waist, so that no tensile force develops at the acceleration transducers.

B.4 Testing procedure

B.4.1 General

Testing shall be in accordance with A.4.2 and B.4.2 to B.4.4.

B.4.2 Test track

Unless simultaneous sound measurements are carried out, there are no requirements for the test site and background outside the gravel frame.

B.4.3 Operating conditions

The machine shall be guided with both hands during measurement. Since the acceleration values measured at the drawbars can be influenced by the operating forces (gripping, feed, and guiding forces) exerted by the operator the following shall be applied:

— a gripping force at the drawbar appropriate to typical operation;

— a feed force at the drawbar appropriate to typical operation;

— a guiding force at the drawbar appropriate to typical operation.

NOTE The three named forces cannot yet be measured by simple means according to the present state of the art.

B.4.4 Measurement procedure

B.4.4.1 General

Record the signals in all three directions of measurement simultaneously.

B.4.4.2 Calculation of hand-arm vibration value

Calculate the hand-arm vibration values in accordance with B.2.

B.4.4.3 Frequency analysis

If required, frequency analyses from the acceleration time signals may be determined for one measurement direction (x-axis) or for all directions of measurement. The analyses shall not be weighted with the hand-arm filter.

B.4.4.4 Time records

If required, the variations of the signals with time may be recorded for one measurement direction (x-axis) or for all three measurement directions.

B.5 Information to be recorded

ISO 20643 shall apply, with the addition of the following:

— engine speed for each run;

— vibration frequency for each run;

— measurement duration, t_M, for each run;

— drawbar height (from the ground maintained during the measurement;

— grading curve of the gravel;

— description of the test environment;

— acceleration in the three directions for each run ($a_{hwx,i}$, $a_{hwy,i}$, $a_{hwz,i}$) as a weighted r.m.s. value;

— the arithmetic mean value of all runs for each measuring direction (a_{hwx}, a_{hwy}, a_{hwz});

— the acceleration vector sum for each test cycle (a_{hv});

— the acceleration vector sum of all measuring directions (a_h);

— acceleration spectra, if appropriate;

— time records, if appropriate.

B.6 Information to be reported

Report all the information specified in B.5.

The report shall include the statement that the vibration accelerations given fully comply with the requirements of this annex. The vibration accelerations shall be rounded to one decimal.

B.7 Measurement uncertainty

When applying this test procedure, a measurement uncertainty of 3 m/s^2 should be allowed for in the determination of the arithmetic mean values of the three vibration accelerations. The same applies to the sum of accelerations.

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