INTERNATIONAL STANDARD

ISO 28927-4

First edition
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Hand-held portable power tools — Test methods for evaluation of vibration emission —

Part 4: **Straight grinders**

Machines à moteur portatives — Méthodes d'essai pour l'évaluation de l'émission de vibrations —

Partie 4: Meuleuses droites

Reference number
ISO 28927-4:2010(E)

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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 28927-4 was prepared by Technical Committee ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 3, *Pneumatic tools and machines*.

This first edition of ISO 28927-4, together with ISO 28927-1, cancels and replaces ISO 8662-4:1994, of which it constitutes a technical revision. The most important changes are

— vibration measurement in three axes and at both hand positions;

— new transducer locations with improved definitions of the transducer positions and orientation are used;

— rotational speed is raised to no load free running speed;

— the test wheels are modified and the definition is improved.

ISO 28927 consists of the following parts, under the general title *Hand-held portable power tools — Test methods for evaluation of vibration emission*:

— *Part 1: Angle and vertical grinders*

— *Part 2: Wrenches, nutrunners and screwdrivers*[1)]

— *Part 3: Polishers and rotary, orbital and random orbital sanders*[2)]

— *Part 4: Straight grinders*[3)]

— *Part 5: Drills and impact drills*[4)]

1) Replaces ISO 8662-7, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 7: Wrenches, screwdrivers and nut runners with impact, impulse or ratchet action*. All screwdrivers and nutrunners except for one-shot tools now covered.

2) Replaces ISO 8662-8, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 8: Polishers and rotary, orbital and random orbital sanders.*

3) Together with ISO 28927-1, replaces ISO 8662-4, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 4: Grinders.*

— *Part 6: Rammers*[5)]

— *Part 7: Nibblers and shears*[6)]

— *Part 8: Saws, polishing and filing machines with reciprocating action and small saws with oscillating or rotating action*[7)]

— *Part 9: Scaling hammers and needle scalers*[8)]

— *Part 10: Percussive drills, hammers and breakers*[9)]

— *Part 11: Stone hammers*[10)]

— *Part 12: Die grinders*[11)]

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4) Replaces ISO 8662-6, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 6: Impact drills.* Non-impacting drills now covered.

5) Replaces ISO 8662-9, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 9: Rammers.*

6) Replaces ISO 8662-10, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 10: Nibblers and shears.*

7) Replaces ISO 8662-12, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 12: Saws and files with reciprocating action and saws with oscillating or rotating action*.

8) Together with ISO 28927-11 (to be published), replaces ISO 8662-14, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 14: Stone-working tools and needle scalers.*

9) To be published. Replaces ISO 8662-2, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 2: Chipping hammers and riveting hammers,* ISO 8662-3, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 3: Rock drills and rotary hammers*, and ISO 8662-5, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 5: Pavement breakers and hammers for construction work.* It also incorporates the Amendments ISO 8662-2:1992/Amd.1:1999, ISO 8662-3:1992/Amd.1:1999 and ISO 8662-5:1992/Amd.1:1999. Chipping and riveting hammers, rock drills and rotary hammers all covered.

10) To be published. Together with ISO 28927-9, replaces ISO 8662-14, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 14: Stone-working tools and needle scalers.*

11) To be published. Replaces ISO 8662-13, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 13: Die grinders*. It also incorporates the Technical Corrigendum ISO 8662-13:1997/Cor.1:1998.

Introduction

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

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.

The vibration test codes for portable hand-held machines given in ISO 28927 (all parts) are based on ISO 20643, which gives general specifications for the measurement of the vibration emission of hand-held and hand-guided machinery. ISO 28927 (all parts) specifies the operation of the machines under type-test conditions and other requirements for the performance of type tests. The structure/numbering of its clauses follows that of ISO 20643.

The basic principle for transducer positioning first introduced in the EN 60745 series of European standards is followed, representing a deviation from ISO 20643 for reasons of consistency. The transducers are primarily positioned next to the hand in the area between the thumb and the index finger, where they give the least disturbance to the operator gripping the machine.

It has been found that vibrations generated by grinders vary considerably in typical use. The variation is largely due to the variances in the unbalance of the machine with the grinding wheel mounted. The unbalance also changes when the wheel is worn through the operation.

In order to provide a method that gives good measurement reproducibility, the procedure adopted in this part of ISO 28927 uses a test wheel of known unbalance mounted on a machine and run under no-load conditions. The unbalance for the different types of test wheels are chosen to give vibration values that are as far as possible in accordance with ISO 20643. The procedures of ISO 5349 (all parts) are required whenever exposure at the workplace is to be assessed.

Underestimation of the vibration for machines equipped with technical means to automatically reduce unbalances is taken into account by multiplying the vibration values of such machines with a correction factor of 1,3.

The values obtained are type-test values intended to be representative of the average of the upper quartile of typical vibration magnitudes in real-world use of the machines. However, the actual magnitudes vary considerably from time to time and depend on many factors, including the operator, the task and the inserted tool or consumable. The state of maintenance of the machine itself might also be of importance. Under real working conditions the influences of the operator and process can be particularly important at low magnitudes. It is therefore not recommended that emission values below 2,5 m/s^2 be used for estimating the vibration magnitude under real working conditions. In such cases, 2,5 m/s^2 is the recommended vibration magnitude for estimating the machine vibration.

If accurate values for a specific work place are required, then measurements [according to ISO 5349 (all parts)] in that work situation could be necessary. Vibration values measured in real working conditions can be either higher or lower than the values obtained using this part of ISO 28927.

Higher vibration magnitudes can easily occur in real work situations caused by the use of excessively unbalanced grinding wheels, worn flanges or bent spindles.

The vibration test codes given in ISO 28927 (all parts) supersede those given in ISO 8662 (all parts), which has been replaced by the corresponding parts of ISO 28927 (see Foreword).

NOTE ISO 8662-11, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 11: Fastener driving tools* could be replaced by a future part of ISO 28927.

Hand-held portable power tools — Test methods for evaluation of vibration emission —

Part 4: **Straight grinders**

1 Scope

This part of ISO 28927 specifies a laboratory method for measuring hand-transmitted vibration emission at the handles of straight grinders. It is a type-test procedure for establishing the magnitude of vibration in the gripping areas of a machine fitted with a specified test wheel and run under no-load conditions.

This part of ISO 28927 is applicable to hand-held machines (see Clause 5), driven pneumatically or by other means, intended for grinding and surface finishing using straight grinding wheels type 1, tapered wheels type 4 and cylindrical plugs, e.g. of type 16 (cylindrical plug, tapered cone), 18 (cylindrical plug, flat end), 18R (cylindrical plug, rounded end) and 19 (cylindrical plug, taper-roll shaped), for use on all kinds of materials. It is not applicable to grinders used with wire brushes, nor is it applicable to die grinders where the inserted tool is mounted in a collet.

NOTE 1 Typical machines covered by this part of ISO 28927 are illustrated in Figures 1 to 3.

It is intended that the results be used to compare different models of the same type of machine.

NOTE 2 To avoid confusion with the terms “power tool” and “inserted tool”, “machine” is used hereinafter for the former.

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 603-12:1999, *Bonded abrasive products — Dimensions — Part 12: Grinding wheels for deburring and fettling on a straight grinder*

ISO 2787:1984, *Rotary and percussive pneumatic tools — Performance tests*

ISO 4026:2003, *Hexagon socket set screws with flat point*

ISO 4027:2003, *Hexagon socket set screws with cone point*

ISO 4029:2003, *Hexagon socket set screws with cup point*

ISO 5349-1:2001, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements*

ISO 5349-2:2001, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace*

ISO 5391:2003, *Pneumatic tools and machines — Vocabulary*

ISO 17066:2007, *Hydraulic tools — Vocabulary*

ISO 20643:2005, *Mechanical vibration — Hand-held and hand-guided machinery — Principles for evaluation of vibration emission*

EN 755-2:2008, *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles — Part 2: Mechanical properties*

EN 12096:1997, *Mechanical vibration — Declaration and verification of vibration emission values*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 5391, ISO 17066 and ISO 20643, and the following apply.

3.1 Terms and definitions

3.1.1
straight grinder
grinder where the handle, motor and the spindle are coaxially aligned

[ISO 5391:2003, definition 2.1.3.1]

3.1.2
test wheel
aluminium wheel geometrically similar to a real grinding wheel with holes on specified radii to give defined unbalances

3.2 Symbols

Symbol	Description	Unit
a_{hw}	root-mean-square (r.m.s.) single-axis acceleration value of the frequency-weighted hand-transmitted vibration	m/s^2
a_{hv}	vibration total value of frequency-weighted r.m.s. acceleration; is the root sum of squares of the a_{hw} values for the three measured axes of vibration	m/s^2
a_{hvmeas}	a_{hv} as measured during the test	m/s^2
a_{hvrat}	a_{hv} at rated no-load speed	m/s^2
$\overline{a_{\mathrm{hv}}}$	arithmetic mean value of a_{hv} values of runs for one operator for one hand position	m/s^2
a_{h}	arithmetic mean value of $\overline{a_{\mathrm{hv}}}$ values for all operators for one hand position	m/s^2
$\overline{a_{\mathrm{h}}}$	arithmetic mean value of a_{h} values for one hand position on several machines	m/s^2
a_{hd}	declared vibration emission value	m/s^2
n_{meas}	measured no-load speed during the test with the test wheel mounted	r/min
n_{rat}	rated no-load speed is the maximum rotational-speed of the machine according to the speed marking of the machine	r/min
s_{n-1}	standard deviation for a test series (for a sample)	m/s^2
σ_{R}	standard deviation of reproducibility (for a population)	m/s^2
C_V	coefficient of variation for a test series	—
K	uncertainty	m/s^2

4 Basic standards and vibration test codes

This part of ISO 28297 is based on the requirements of ISO 20643 and corresponds to its structure in respect of clause subjects and numbering, except for the annexes.

Annex A presents a model test report, Annex B the means for determining the uncertainty, K, and Annex C specifies test wheel design.

5 Description of the family of machines

This part of ISO 28927 applies to hand-held machines intended for grinding and surface finishing using straight grinding wheels type 1, tapered wheels type 4 and cylindrical plugs type 16, 18, 18R and 19, for use on all kinds of materials. Machines equipped with a collet intended for inserted tools with a shaft are covered by ISO 28927-12. Typical machines are shown in Figures 1 to 3.

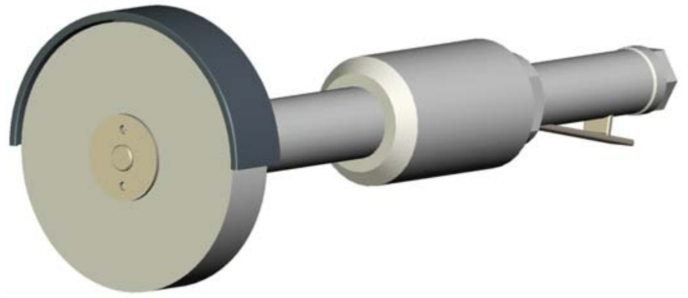


Figure 1 — Straight grinder with type 1 wheel

Figure 2 — Straight grinder with type 18R cylindrical plug

Figure 3 — Extended straight grinder with type 18R cylindrical plug

6 Characterization of vibration

6.1 Direction of measurement

The vibration transmitted to the hand shall be measured and reported for three directions of an orthogonal coordinate system. At each hand position, the vibration shall be measured simultaneously in the three directions shown in Figures 4 to 6.

6.2 Location of measurements

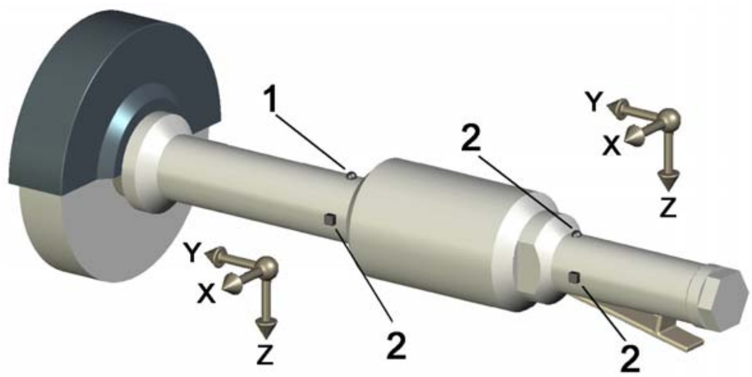
Measurement shall be made at the gripping zones, where the operator normally holds the machine and applies the feed force. For machines intended for one-hand operation, it is only necessary to measure at a single point.

The prescribed transducer location shall be as close as possible to the hand between the thumb and index finger. This shall apply to both hand positions, with the machine held as in normal operation. Whenever possible, measurements shall be made at the prescribed locations.

A secondary location is defined as being on the side of, and as close as possible to, the inner end of the handle where the prescribed location is found. If the prescribed location of the transducer cannot be used, this secondary location shall be used.

The prescribed or secondary location shall also be used on anti-vibration handles.

Figures 4 to 6 show the prescribed and secondary locations and measurement directions for the hand positions normally used for the different types of machines in this family.

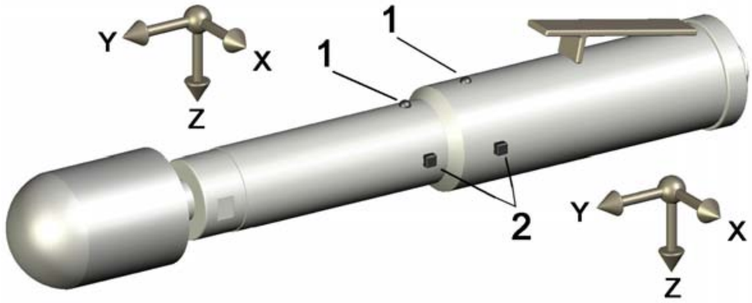


Key

1 prescribed location

2 secondary location

Figure 4 — Straight grinder with type 1 wheel

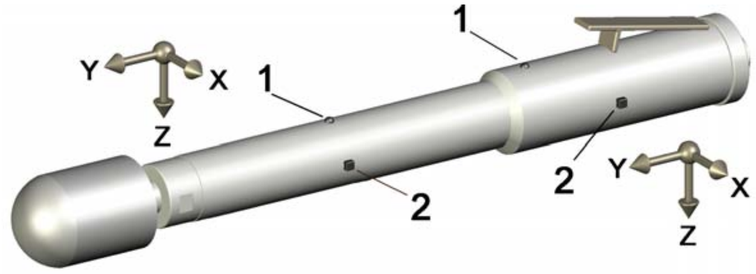


Key

1 prescribed location

2 secondary location

Figure 5 — Straight grinder with type 18R cylindrical plug



Key

1 prescribed location

2 secondary location

Figure 6 — Extended straight grinder with type 18R cylindrical plug

6.3 Magnitude of vibration

The definitions for the magnitude of vibration given in ISO 20643:2005, 6.3, apply.

6.4 Combination of vibration directions

The vibration total value defined in ISO 20643:2005, 6.4, shall be reported for both hand positions as applicable. It is acceptable to report on and carry out tests on the hand position having the highest reading. The vibration total value at that one hand position shall be at least 30 % higher than the other. This result may be obtained during a preliminary test carried out by a single operator during five test runs.

To obtain the vibration total value of the frequency-weighed acceleration, a_{hvmeas}, at the measured no-load speed for each test run, the result in each direction shall be combined using Equation (1):

$$a_{\text{hvmeas}} = \sqrt{a_{\text{hwx}}^2 + a_{\text{hwy}}^2 + a_{\text{hwz}}^2} \qquad (1)$$

The a_{hvmeas} value for each test run is corrected to the frequency-weighed acceleration, a_{hvrat}, at the rated no-load speed using Equation (2):

$$a_{\text{hvrat}} = a_{\text{hvmeas}} \frac{n_{\text{rat}}}{n_{\text{meas}}} \qquad (2)$$

where

n_{rat} is the rated no-load speed, i.e. the maximum rotational speed of the machine as marked on the machine;

n_{meas} is the measured no-load speed during testing.

7 Instrumentation requirements

7.1 General

The instrumentation shall be in accordance with ISO 20643:2005, 7.1.

7.2 Mounting of transducers

7.2.1 Specification of transducer

The specification of the transducer given in ISO 20643:2005, 7.2.1, applies.

The total mass of the transducers and mounting device shall be small enough, compared with that of the machine, handle, etc., so as not to influence the measurement result.

This is particularly important for low-mass plastic handles (covered in ISO 5349-2).

7.2.2 Fastening of transducers

The transducer or mounting block used shall be rigidly attached to the surface of the handle.

If three single-axis transducers are used, these shall be attached to three sides of a suitable mounting block.

For the two axes aligned parallel to the vibrating surface, the measurement axes of the two transducers — or the two transducer elements in a triaxial transducer — shall be at a maximum of 10 mm from the surface.

NOTE It is normally not necessary that mechanical filters be used for the measurements.

7.3 Frequency-weighting filter

Frequency-weighting filters shall be in accordance with ISO 5349-1.

7.4 Integration time

The integration time shall be in accordance with ISO 20643:2005, 7.4. The integration time for each test run shall be at least 16 s, so as to be consistent with the duration of machine operation defined in 8.4.3.

7.5 Auxiliary equipment

For pneumatic machines, the air pressure shall be measured using a pressure gauge with an accuracy equal to or better than 0,1 bar[12)].

For hydraulic machines, the flow shall be measured using a flow meter with an accuracy equal to or better than 0,25 l/min.

For electrical machines, the voltage shall be measured using a volt meter with an accuracy equal to or better than 3 % of the actual value.

The rotational speed shall be measured and reported with an accuracy better than 5 % of the actual value, using either a tachometer or frequency analysis of the measured vibration signal. When a tachometer transducer is placed on the machine, it should be small enough not to influence the vibration of the machine.

The feed force shall be measured with an accuracy equal to or better than 5 % of the actual value.

7.6 Calibration

The specifications for the calibration given in ISO 20643:2005, 7.6, apply.

8 Testing and operating conditions of the machinery

8.1 General

Measurements shall be carried out on new, and properly serviced and lubricated, machines. During testing, the machine shall be equipped and held in a manner similar to that when grinding (see Figure 7). If, for some types of machine, a warming-up period is specified by the manufacturer, this shall be undertaken prior to the start of the test.

The grinders shall be run under no-load conditions, equipped with the appropriate test wheel according to Table 1.

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12) 1 bar = 0,1 MPa = 0,1 N/mm^2 = 10^5 N/m^2.

Machines intended for one-handed operation shall be held with only one hand during testing. Measurements shall be made in one location only and for the hand position used. During measurement, a support handle shall not be mounted.

During testing, the energy supply to the machine shall be at rated conditions, as specified by the manufacturer. The operation shall be stable.

8.2 Operating conditions

8.2.1 Pneumatic machines

During testing, the machine shall be operated at the rated air pressure, and shall be used in accordance with the manufacturer's specifications. The operation shall be stable and smooth. The air pressure shall be measured and reported.

Air shall be supplied to the machines by means of a hose of the diameter recommended by the machine manufacturer. The test hose shall be attached to the machine via a threaded hose connector, preferably the one supplied with the machine. The length of the test hose shall be 3 m. The test hose shall be secured with a hose clip. Quick-couplings shall not be used, since their mass influences the vibration magnitude.

The air pressure of pneumatically powered machines shall be measured in accordance with ISO 2787 and maintained as specified by the manufacturer. During testing, the air pressure measured immediately before the test hose shall not drop by more than 0,2 bar below the pressure recommended by the manufacturer.

8.2.2 Hydraulic machines

During testing, the machine shall operate at the rated power supply, i.e. the rated flow, and shall be used in accordance with the manufacturer's specifications. The operation shall be stable and smooth. A warming-up period of about 10 min should be allowed before starting the measurements. The flow shall be measured and reported.

8.2.3 Electrical machines

During testing, the machine shall operate at the rated voltage and shall be used in accordance with the manufacturer's specifications. The operation shall be stable and smooth. The voltage shall be measured and reported.

8.3 Other quantities to be specified

The rotational speed of the spindle with test wheel mounted shall be measured and reported for each machine used in the test.

The feed force used shall be reported.

8.4 Attached equipment, work piece and task

8.4.1 Test wheel

A test wheel is an aluminium wheel geometrically similar to a real grinding wheel. The test wheel has one or two holes located on specified radii to give the defined unbalance.

The dimensions and the production methods for the different test wheels used in this test code are specified in Annex C.

Type 1 test wheels shall be mounted on the grinder in five orientations with 72° rotation about the spindle from the preceding position. Reference lines shall be drawn on the wheel and on the spindle to mark these positions.

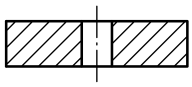
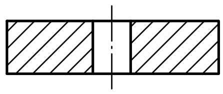
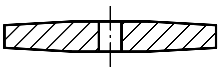
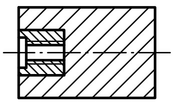
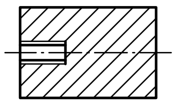
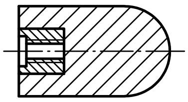
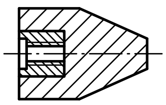
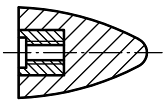
The test wheel shall be mounted as a normal grinding wheel, with flanges as recommended by the manufacturer. It shall be mounted concentrically with the grinder spindle and with zero play. To achieve this, a concentric adaptor bushing, as specified in Annex C, shall be used.

Type 18 cylindrical test plugs have mounting threads. These plugs can not be rotated to five different positions. Instead, the plug shall be remounted five times for each of the three operators performing the test (see 8.4.3). The cylindrical test plugs shall be mounted on the machine using the flanges and the mounting torque recommended by the manufacturer.

Test wheels/plugs for different types of machines shall be chosen in accordance with Table 1.

All combinations of machines and guards need to be tested separately. In those cases where more than one type of grinding wheel can be used in one specific guard, the test wheel specified for the heaviest possible grinding wheel shall be used.

Table 1 — Wheel types and corresponding test wheels

Grinding wheel type and designation in accordance with ISO 603-12		Grinding wheel diameter mm	Designation of test wheel used	Test wheel description		Diameter of the test wheel mm	Unbalance g·mm
Type 1 Straight wheel		32,40	1:25	Type 1 Straight test wheel		25	3,6
		50,63	1:50			50	14,5
		80	1:80			80	18
		100	1:100			100	29
		125	1:125			125	45
		150,180	1:150			150	65
		200	1:200			200	115
Type 4 Tapered straight wheel		80	1:80				
		100	1:100				
		125	1:125				
		150,180	1:150				
		200	1:200				
Type 18 Cylindrical plug, flat end		32,40	18:32	Type 18 Cylindrical test plug		32	3,6
		50,63	18:50			50	14,5
		80	18:80			80	18
Type 18R Cylindrical plug, rounded end							
Type 16 Cylindrical plug, tapered end							
Type 19 Cylindrical plug, taper-roll shaped							

8.4.2 Feed force

During testing, the machine shall be held in the same way as when grinding on a horizontal surface. A force (to simulate the feed force) shall be applied to the handles during testing. The feed force and the mass of the machine shall be counterbalanced by an upward force equal to the sum of the feed force given in Table 2 and the mass of the machine.

The upward force should be applied as close as possible to the grinding wheel.

The upward force shall be applied through a cord attached to the sling. The friction between the sling and the cord should be kept low enough as to not restrict the movement of the machine. The force may be applied using a mass and pulley arrangement as shown in Figure 7. Alternatively, a dynamometer may be attached to the cord. The application of the force shall be achieved with minimum adaptation of the grinder.

For machines with anti-vibration handles, the sling shall be attached to the machine's body. Check that the action of the resilient mounting of the handle is not restrained.

The forces and torques applied to the handles influence the vibration. It is therefore important that the force and torque distribution between the handles be comparable to that under real work conditions.

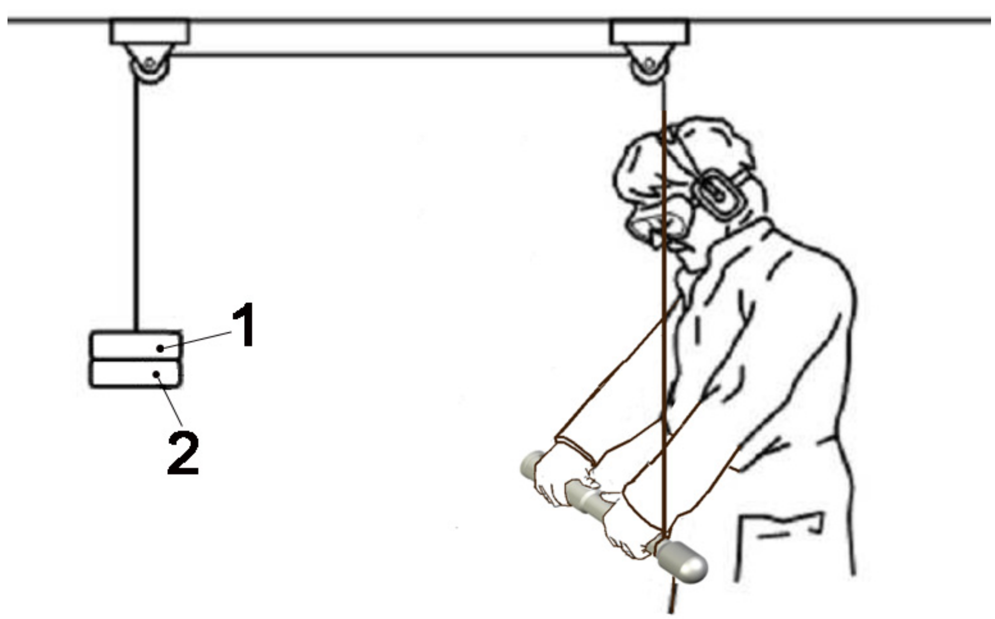
NOTE Any mass added to the machine, e.g. fixing devices for the upward force, alters the inertia of the machine and thereby alters the vibration magnitude.

Table 2 — Feed force for grinders tested with type 1 test wheel

Diameter of the wheel, mm	25	50	80	100	125	150	200
Feed force, N ± 5 N	15	15	15	30	30	30	45

Table 3 — Feed force for grinders tested with type 18 test wheel

Diameter of the wheel, mm	32	50	80
Feed force, N ± 5 N	15	30	30



Key

1 mass of grinder

2 feed force mass

Figure 7 — Working position of operator and application of feed force using a sling of cord

8.4.3 Test procedure

During the test, the machine shall be held in the same way as when grinding on a horizontal surface.

Choose a test wheel/plug in accordance with 8.4.1; perform the test as follows.

— For machines tested with a type 1 test wheel, each operator (see 8.5) shall carry out a series of five consecutive measurements, one in each orientation, by unfastening and refastening the test wheel. The sequence of measurements shall be 0°, 72°, 144°, 216° and 288°.

— For machines tested with type 18 cylindrical plug, each operator (see 8.5) shall each carry out a series of five consecutive measurements. Between each test, the cylindrical test plug shall be unfastened and refastened. Due to the design of the plug, repositioning of the plug is not possible.

A complete test sequence is set out in the model test report given in Annex A.

Each test run shall be such that the measurements can be carried out for not less than 16 s, when stable operation has been established.

It is accepted to run all three operators for each orientation without remounting the wheel.

8.5 Operator

Three different operators shall operate the machine during testing. The vibration of the machine is influenced by the operators. They shall therefore be skilled enough to be able to hold and operate the machine correctly.

9 Measurement procedure and validity

9.1 Reported vibration values

Three series of five consecutive tests shall be carried out on each machine tested, using a different operator for each series.

The values (see also 6.4) should be reported for each machine as in Annex A.

The coefficient of variation, C_V, and the standard deviation, s_{n-1}, shall be calculated for each hand position for each of the three operators. The C_V of a test series is defined as the ratio of s_{n-1} to the mean value of the series:

$$C_V = \frac{s_{n-1}}{\overline{a_{\text{hv}}}} \tag{3}$$

where the standard deviation of the i^{th} value, $a_{\text{hvrat}i}$, measured and corrected using Equation (2) and expressed in m/s^2, is:

$$s_{n-1} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(a_{\text{hvrat}i} - \overline{a_{\text{hv}}}\right)^2} \tag{4}$$

where

$\overline{a_{\text{hv}}}$ is the mean value of the series, in m/s^2;

n is equal to five, the number of measured values.

If C_V is greater than 0,15, or s_{n-1} is greater than 0,3 m/s^2, then the measurements shall be checked for error before the data are accepted.

9.2 Declaration and verification of the vibration emission value

The $\overline{a_{hv}}$ value for each operator shall be calculated as the arithmetic mean of a_{hvrat} values for the five test runs.

For each hand position, the result from the three operators should be combined to one value, a_h, using the arithmetic mean of the three $\overline{a_{hv}}$ values.

For tests using only one machine, the declared value a_{hd} is the highest of the a_h values reported for the two hand positions.

For tests using three or more machines, $\overline{a_h}$ values for each hand position shall be calculated as the arithmetic mean of the a_h values for the different machines on that hand position. The declared value, a_{hd}, is the highest of the $\overline{a_h}$ values reported for the two hand positions.

Both the declared value, a_{hd}, and the uncertainty, K, shall be presented with the precision determined in EN 12096. The value of a_{hd} is to be given in m/s^2 and presented by using two and a half significant digits for numbers starting with 1 (e.g. 1,20 m/s^2, 14,5 m/s^2); otherwise, two significant digits are sufficient (e.g. 0,93 m/s^2, 8,9 m/s^2). The value of K shall be presented with the same number of decimals as a_{hd}.

K shall be determined in accordance with EN 12096, based on the standard deviation of reproducibility, σ_R. The value of K shall be calculated in accordance with Annex B.

Underestimation of the vibration for machines equipped with technical means to automatically reducing unbalances shall be taken into account by multiplying the declared vibration values of such machines with a correction factor of 1,3 before the values are reported.

10 Measurement report

The following information shall be given in the test report:

a) reference to this part of ISO 28927, i.e. ISO 28927-4:2010;

b) name of the measuring laboratory;

c) date of measurement and names of the persons responsible for the test;

d) specification of the hand-held machine (manufacturer, type, serial number, etc.);

e) declared emission value, a_{hd}, and uncertainty, K, as well as information on any correction applied;

f) attached or inserted tools;

g) energy supply (air pressure/input voltage, etc., as applicable);

h) instrumentation (accelerometer, recording system, hardware, software, etc.);

i) position and fastening of transducers, measuring directions and individual vibration value;

j) operating conditions, as specified in 8.2 and 8.3;

k) detailed results of the test (see Annex A).

If transducer positions or measurements other than those specified in this part of ISO 28927 are used, they shall be clearly defined and an explanation of the reason for the change in the position of the transducer shall be inserted in the test report.

Annex A
(informative)

Model test report for vibration emission of straight grinders

See Tables A.1 and A.2.

Table A.1 — General information

The test has been carried out in accordance with ISO 28927-4: *Hand-held portable power tools — Test methods for evaluation of vibration emission — Part 4: Straight grinders*	
Tester	
Measured by (company/laboratory):	Tested by: Reported by: Date:
Test object and declared value	
Machine tested (power supply and machine type, manufacturer, machine model and name):	Declared vibration emission value (a_{hd}, K and correction if applied):
Measuring equipment	
Transducers (manufacturer, type, positioning, fastening method, photos, mechanical filters, if used):	
Vibration instrumentation:	Auxiliary equipment:
Operating and test conditions and results	
Test conditions(test wheel used, location of upward force, operator posture and hand position photos):	
	Power supply (air pressure, hydraulic flow, voltage):
Feed force:	Any other quantities:

Table A.2 — Measurement results for one machine

Date:			Machine type:						Serial number:				Measured speed:					
			Main handle (hand position 1)								Support handle (hand position 2)							
Test	Operator	Wheel mounting[a]	a_{hwx}	a_{hwy}	a_{hwz}	a_{hvmeas}	a_{hvrat}	Statistics for operator			a_{hwx}	a_{hwy}	a_{hwz}	a_{hvmeas}	a_{hvrat}	Statistics for operator		
								$\overline{a_{hv}}$	s_{n-1}	C_V						$\overline{a_{hv}}$	s_{n-1}	C_V
1	1	1																
2	1	2																
3	1	3																
4	1	4																
5	1	5																
6	2	1																
7	2	2																
8	2	3																
9	2	4																
10	2	5																
11	3	1																
12	3	2																
13	3	3																
14	3	4																
15	3	5																
			a_h for hand position 1:								a_h for hand position 2:							
			s_R for hand position 1:								s_R for hand position 2:							

NOTE The a_{hvrat} and $\overline{a_{hv}}$ values are calculated according to 6.4 and 9.2, s_{n-1} and C_V are calculated according to 9.1, and s_R is calculated according to Annex B.

[a] For unthreaded test wheels, 1 to 5 equals mounting angles 0°, 72°, 144°, 216°, 288°. For threaded test wheels, a remount shall be done for each test.

Annex B
(normative)

Determination of uncertainty

B.1 General

The uncertainty value, K, represents the uncertainty of the declared vibration emission value, a_{hd}, and, in the case of batches, production variations of machinery. It is expressed in m/s^2.

The sum of a_{hd} and K indicates the limit below which the vibration emission value of a single machine, and/or a specified large proportion of the vibration emission values of a batch of machines, are stated to lie when the machines are new.

B.2 Test on single machines

For tests made on only one single machine, the K value shall be given by:

$$K = 1{,}65\ \sigma_R$$

where σ_R is the standard deviation of reproducibility, estimated by the value s_R, given as:

$$s_R = 0{,}2\ a_h$$

For the hand position having the highest a_h value, a_{hd} equals a_h:

$$K = 0{,}33\ a_{hd}$$

NOTE The value of the standard deviation of reproducibility, s_R, is based on a round-robin test made on grinders (see ISO/TR 27609): s_R was found to vary with the measured vibration magnitude and could be estimated to be $0{,}2 a_h$.

B.3 Tests on batches of machines

For tests on three or more machines, K shall be given as:

$$K = 1{,}5\ \sigma_t$$

where σ_t is estimated by s_t:

$$s_t = \sqrt{s_R^2 + s_b^2}$$

The calculations are performed on the hand position having the highest a_h value and where:

$s_R = 0,2\ a_{hd}$

s_b is the standard deviation of the test results for individual machines, i.e.

$$s_b^2 = \frac{1}{n-1}\sum_{i=1}^{n}(a_{hi} - \overline{a_h})^2$$

where

a_{hi} is the single-machine emission for the i^{th} machine;

$\overline{a_h}$ is the mean value of the single-machine emissions for one hand position;

a_{hd} is the highest of the $\overline{a_h}$ values reported for the two hand positions;

n is the number of machines tested ($\geqslant$ 3).

Annex C
(normative)

Design of test wheel

C.1 General

The test wheel shall have machined holes on specified radii to give defined unbalances. Aluminium of type EN AW 2014 (AlCu4SiMg), as specified in EN 755-2 or an equivalent material, shall be used.

The density should be within 2 700 Kg/m^3 to 2 800 Kg/m^3.

Test wheels shall be manufactured in accordance with Figures C.1 to C.4. They shall be measured and adjusted to the given unbalance with an accuracy higher than 5 % of the actual unbalance.

To simplify the adjustment of the unbalance, the test wheels in this part of ISO 28927 are designed with threaded holes. A test screw is mounted in the hole while the wheels are balanced to zero unbalance. When the screw is taken off, the test wheel has an unbalance equal to the mass of the test screw times the radii to the hole where it was mounted. The tables in this annex give the mass of the screws.

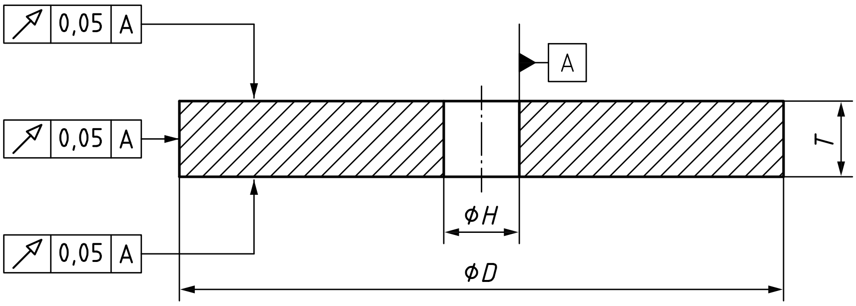
C.2 Basic geometry of aluminium test wheels

C.2.1 Type 1 Straight test wheels

Figure C.1 and Table C.1 give the geometrical dimensions and tolerances for type 1 straight test wheels.

Table C.1 — Geometrical dimensions and machining tolerances for type 1 test wheels

Designation of test wheel	Outside diameter D mm ± 0,02 mm	Thickness T mm ± 0,05 mm	Bore diameter H mm H7	Unbalance g·mm
1:25	25	10	10	3,6
1:50	50	10	10	14,5
1:80	80	10	10	18
1:100	100	25	25	29
1:125	125	25	25	45
1:150	150	25	25	65
1:200	200	25	25	115



Key

D outside diameter

H bore diameter

T thickness

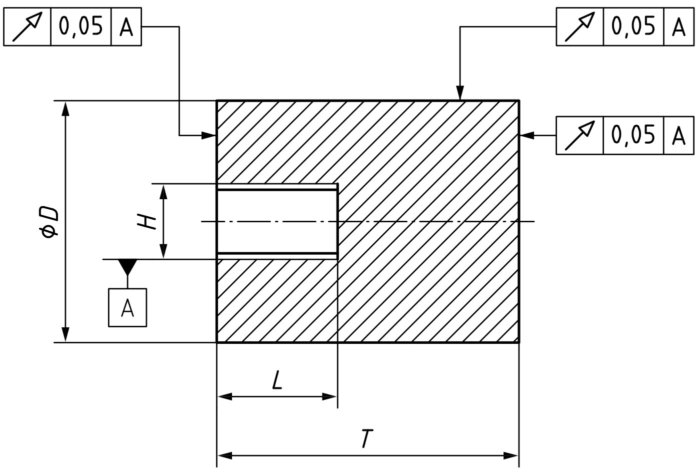
Figure C.1 — Geometrical dimensions and machining tolerances for type 1 straight test wheel

C.2.2 Type 18 Cone test wheels

Figure C.2 and Table C.2 give the geometrical dimensions and tolerances for Type 18 cylindrical test plugs.

Table C.2 — Geometrical dimensions and machining tolerances for type 18 cylindrical test plugs

Designation of test wheel	Outside diameter *D* mm ± 0,1 mm	Mounting thread *H*	Depth of thread *L* mm ± 0,2 mm	Length *T* mm ± 0,1 mm	Unbalance g·mm
18:32	32	M10	16	40	3,6
18:50	50	M14	20	50	14,5
18:80	80	M16	25	80	18



Key

D outside diameter

H thread

L depth of thread

T length

Threads and depth of thread are in accordance with ISO 603-12. For machines with other spindle threads or spindle lengths, the test wheels shall be adapted accordingly.

Figure C.2 — Geometrical dimensions and machining tolerances for type 18 cone test wheels

C.3 Unbalance holes

C.3.1 Type 1 straight test wheels

The unbalance is generated by machining one or two threaded holes in the aluminium wheel. Machine the hole to a depth smaller than required. During the adjustment increase the depth of the hole until the test wheel with the balance screw is in balance. Adjustment can, alternatively, be made by drilling separate balancing holes.

For type 1 straight test wheels, the unbalances, the diameter of the thread and holes and the radius to the centre of the hole are given in Table C.3 and Figure C.3.

Table C.3 — Unbalance for type 1 test wheels

Designation of test wheel	**Outside diameter** D mm	**Unbalance** g·mm ± 5 %	**Radius to centre of hole** r_h mm ± 0,05 mm	**Hole diameter** e_h mm ± 0,05 mm	**Thread** e_t	**Depth of hole** d_h mm ± 0,05 mm	**Depth of thread** d_t mm ± 0,05 mm
1:25	25	3,6	8,4	4,3	M5	10	5
1:50	50	14,5	18 9,8	5,1 5,1	M6 M6	8 8	6 6
1:80	80	18	34,5	5,1	M6	8	6
1:100	100	29	33,4	5,1	M6	13,8	8,8
1:125	125	45	26,5	6,9	M8	14,8	8,8
1:150	150	65	38,3	6,9	M8	14,8	8,8
1:200	200	115	67,7	6,9	M8	14,8	8,8

NOTE Test wheel 1:25 has the hole drilled through and threaded to a depth of 5 mm.

Test wheel 1:50 has two holes in the same plane, but on different diameters. To get balance, balance screws should be mounted in both holes during balancing.

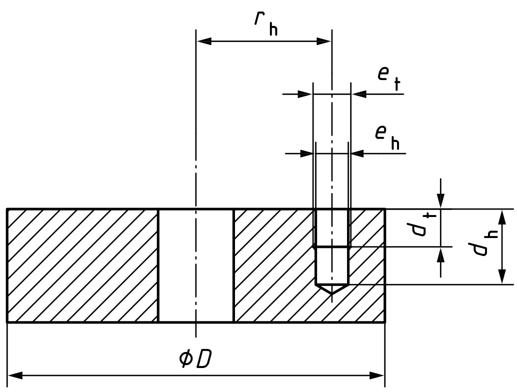


Figure C.3 — Geometrical dimensions for unbalance holes in type 1 straight test wheels

The balance screws are the screw types given in Table C.4. They are nominally too heavy and need to be adjusted to get the screw weight within the given tolerances.

Table C.4 — Balance screws for type 1 test wheels

Designation of test wheel	Outside diameter D mm	Unbalance g·mm ± 5 %	Screw type	In accordance with	Screw mass g ± 0,01
1:25	25	3,6	M5 × 6	ISO 4026	0,43
1:50	50	14,5	M6 × 6 M6 × 6	ISO 4026 ISO 4026	0,52 0,52
1:80	80	18	M6 × 6	ISO 4026	0,52
1:100	100	29	M6 × 8	ISO 4027	0,87
1:125	125	45	M8 × 8	ISO 4027	1,70
1:150	150	65	M8 × 8	ISO 4027	1,70
1:200	200	115	M8 × 8	ISO 4027	1,70

C.3.2 Type 18 cylindrical test plugs

The unbalance is generated by machining a threaded hole in the aluminium test plug. Machine the hole to a depth smaller than required. During the adjustment increase the depth of the hole until the test plug with the balance screw is in balance.

For type 18 cylindrical test plugs, the unbalances, the diameter of the thread and holes and the radius to the centre of the hole are given in Table C.5.

Table C.5 — Unbalance for Type 18 cone test wheels

Designation of test wheel	Outside diameter D mm	Unbalance g·mm ± 5 %	Radius to centre of hole r_h mm ± 0,05 mm	Hole diameter e_h mm ± 0,05 mm	Thread e_t	Depth of hole d_h mm ± 0,05 mm	Depth of thread d_t mm ± 0,1 mm
18:32	32	3,6	13	2,5	M3	18,2	12
18:50	50	14,5	19,5	4,2	M5	17	13
18:80	80	18	24,2	4,2	M5	17	13

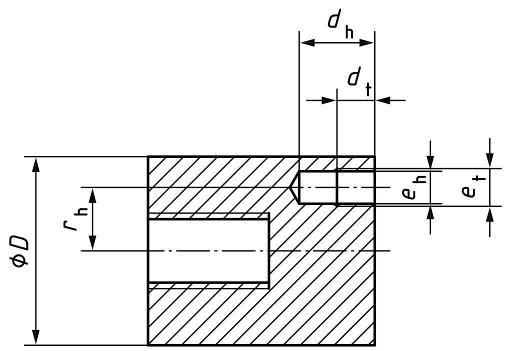


Figure C.4 — Geometrical dimensions for unbalance holes in type 18 cone test wheels

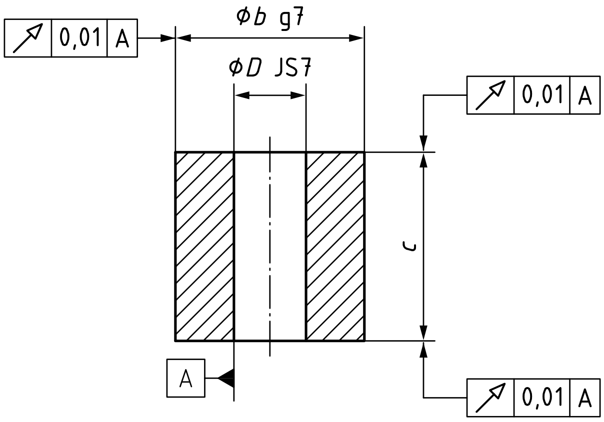
The balancing screws are the screw types given in Table C.6. They are nominally too heavy and need to be adjusted to get the screw weight within the given tolerances.

Table C.6 — Balance screws for type 18 cone test wheels

Designation of test wheel	Outside diameter *D* mm	Unbalance g·mm ± 5 %	Screw type	In accordance with	Screw mass g ± 0,01
18:32	32	3,6	M3 × 8	ISO 4027	0,28
18:50	50	14,5	M5 × 10	ISO 4029	0,74
18:80	80	18	M5 × 10	ISO 4029	0,74

C.4 Bushings for type 1 test wheels

The test wheel shall be mounted with zero play. When mounting, choose the bushing with the best fit to the spindle in accordance with Table C.7. Other inner diameters may be used if they are found to give a better fit to the spindle. See Figure C.5 for a description of the dimensions.



Key

b diameter

c thickness

D bore

Figure C.5 — Geometrical dimensions and machining tolerances for mounting bushings

Table C.7 — Dimension of bushings to be used with type 1 test wheels

Dimensions in millimetres

Diameter *b* g7	Thickness *c* – 0,1 mm – 0,2 mm	Bore diameter *D* JS7
10	10	3,76
		3,80
		3,84
		3,88
		3,92
		3,96
		4,00

Diameter *b* g7	Thickness *c* – 0,1 mm – 0,2 mm	Bore diameter *D* JS7
25	25	9,525
		12,7
		15,875
		18,76
		18,80
		18,84
		18,88
		18,92
		18,96
		19,00

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