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ISO 28927-1

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

Part 1: Angle and vertical grinders

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

Partie 1: Meuleuses verticales et meuleuses d'angles

Reference number
ISO 28927-1:2019(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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 3, *Pneumatic tools and machines.*

This second edition cancels and replaces the first edition (ISO 28927-1:2009) and (ISO 28927-1:2009/Amd.1:2017), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:.

— Table C.4, in "Radius to centre of hole", change *rh* to r_h;

— Table C.4, in "Radius to centre of threaded hole", change *rt* to r_t;

— Figure C.4, change r_s to r_t;

— Figure C.4, change r_t to r_h;

— Figure C.4, in the key, change r_s to r_h.

A list of all parts in the ISO 28927 series can be found on the ISO website.

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.

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 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 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. This 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 operation.

In order to provide a method that gives good measurement reproducibility, the procedure adopted in this document 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 wheel are chosen to give vibration values that are as far as possible in accordance with ISO 20643. The procedures of ISO 5349 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.

For grinders that are intended to be used with cupped wire brushes, the vibration value is obtained by using a correction factor of 1,6.

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 will 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) 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 document.

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 supersede those given in ISO 8662, whose parts have 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 1: Angle and vertical grinders

1 Scope

This document specifies a laboratory method for measuring hand-transmitted vibration emission at the handles of hand-held power-driven angle and vertical 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. The method has been established for surface grinding tasks only. Cutting and sanding generally create lower vibrations. It is intended that the results be used to compare different models of the same type of machine.

This document is applicable to hand-held machines (see Clause 5), driven pneumatically or by other means, intended for grinding, cutting-off and rough sanding, with bonded, coated and super-abrasive products and with wire brushes for use on all kinds of materials. It is not applicable to die grinders or straight grinders.

NOTE To avoid confusion with the terms "power tool" and "inserted tool", *machine* is used for the former throughout this document.

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 2787, *Rotary and percussive pneumatic tools — Performance tests*

ISO 5349 (all parts), *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration*

ISO 5391, *Pneumatic tools and machines — Vocabulary*

ISO 17066, *Hydraulic tools — Vocabulary*

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

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

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

3 Terms and definitions

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

3.1.1
grinder
machine driving a rotary output spindle adapted to carry an abrasive wheel/device for material removal

[SOURCE: ISO 5391:2003, 2.1.3, modified — Definition rephrased and note deleted.]

3.1.2
angle grinder
grinder where the output spindle is at a given angle (usually a right angle) to the motor axis

[SOURCE: ISO 5391:2003, 2.1.3.3]

3.1.3
vertical grinder
grinder where the handle or handles are at an angle to the coaxially aligned motor and output spindle axis

[SOURCE: ISO 5391:2003, 2.1.3.2]

3.1.4
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; root sum of squares of a_{hw} values for the three measured axes of vibration	m/s^2
a_{hvmeas}	a_{hv} as measured during testing	m/s^2
a_{hvrat}	a_{hv} at rated no-load speed	m/s^2
$\overline{a_{hv}}$	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 $\overline{a_{hv}}$ values for all operators for one hand position	m/s^2
$\overline{a_h}$	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 testing with the test wheel mounted	r/min
n_{rat}	rated no-load speed: 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, s)	m/s^2
σ_R	standard deviation of reproducibility (for a population, σ)	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 document 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 document applies to hand-held machines fitted with guards, which are intended for grinding, cutting-off and rough sanding, with bonded, coated and super abrasive products for use on all kinds of materials.

For sanders without guards, see ISO 28927-3.

For applicable wheel types, as defined in ISO 603-14 and ISO 603-16, see Table 1.

The family of machines covered by this document comprises the following machines:

— angle and vertical grinders with type 27 wheels of diameters 80 mm to 300 mm; when the same guard is also used for type 41 cutting-off wheels then only the vibration value for the type 27 test wheel need be declared (see 8.4.1 for test wheel specifications);

— angle and vertical grinders with special guards for type 41 cut off wheels; the test shall be carried out using a type 27 test wheel (see 8.4.1 for test wheel specifications);

— angle and vertical grinders with special guards for stone cutting wheels; the test shall be carried out using the most appropriate wheel from the types described in Table 2;

— angle and vertical grinders for types 6 and 11 cup wheels with diameters 100 mm to 180 mm;

— angle and vertical grinders, as well as sanders, for fibre discs and flap wheels with diameters 80 mm to 300 mm.

NOTE For wheels with a diameter less than 80 mm, see ISO 603-14.

Figures 1 to 6 show examples of typical grinders covered by this document.

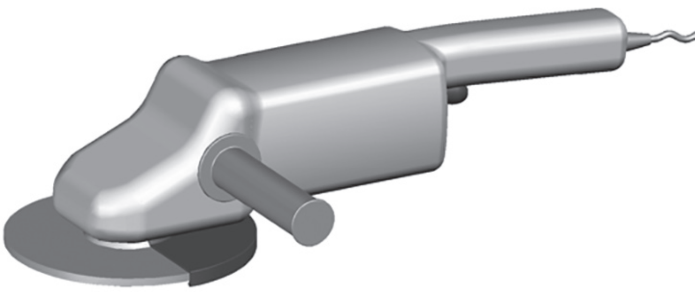


Figure 1 — Electrical angle grinder with separate main handle

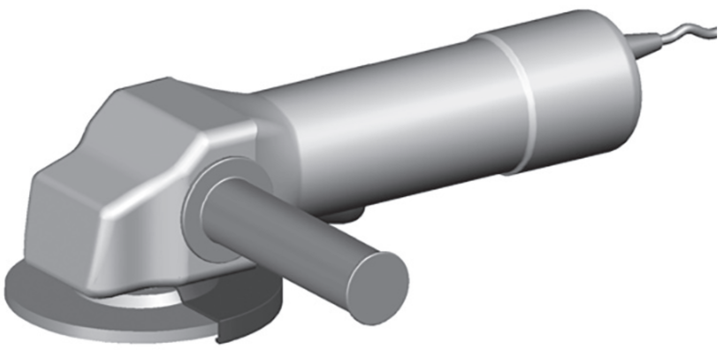


Figure 2 — Electrical angle grinder whose motor serves as main handle

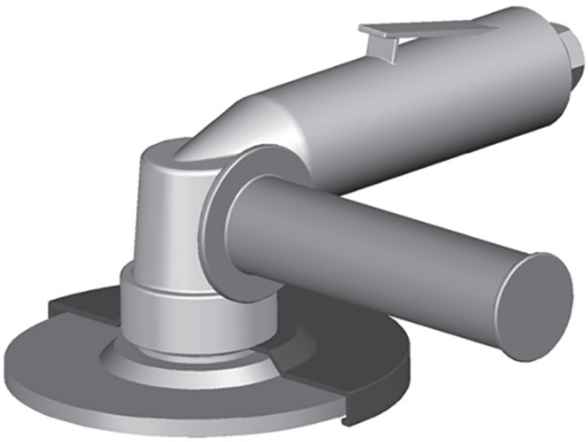


Figure 3 — Pneumatic angle grinder whose motor serves as main handle

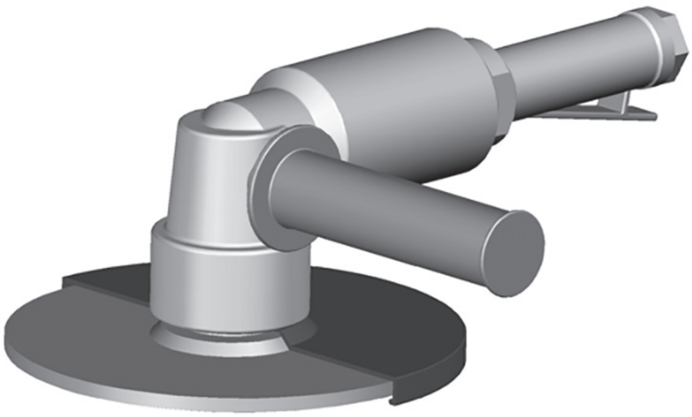


Figure 4 — Pneumatic angle grinder with separate main handle

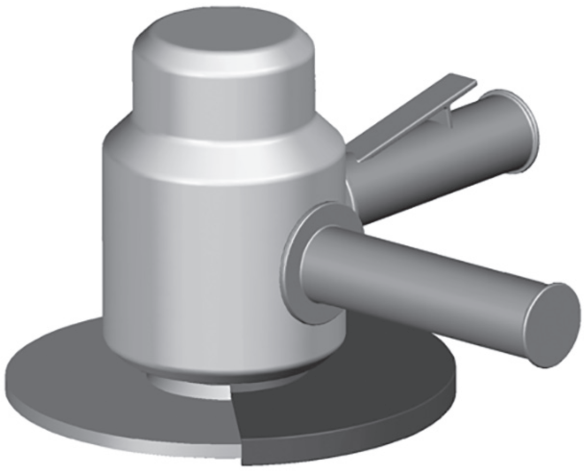


Figure 5 — Pneumatic vertical grinder

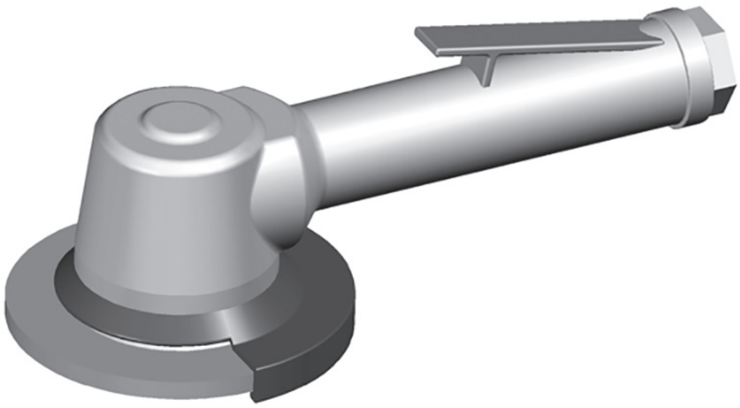


Figure 6 — Angle grinder intended for one-handed operation

NOTE This document only covers wheel dimensions included in ISO 603-14. For other wheel dimensions, use ISO 20643.

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 7 to 12.

6.2 Location of measurements

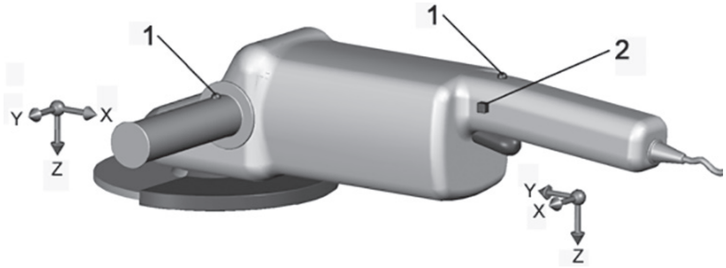
Measurements shall be made at the gripping zones, where the operator normally holds the machine and applies the feed force. For machines intended for one-handed operation, it is only necessary to measure at a single point.

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 a prescribed location of the transducer cannot be used, this secondary location shall be used instead.

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

Figures 7 to 12 show the prescribed and secondary locations and measurement directions for the hand positions normally used for the different types of machines in this family.

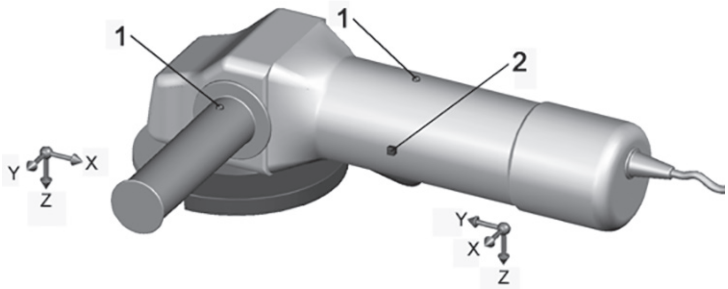


Key

1 prescribed location

2 secondary location

Figure 7 — Measurement locations — Electrical angle grinder with separate main handle

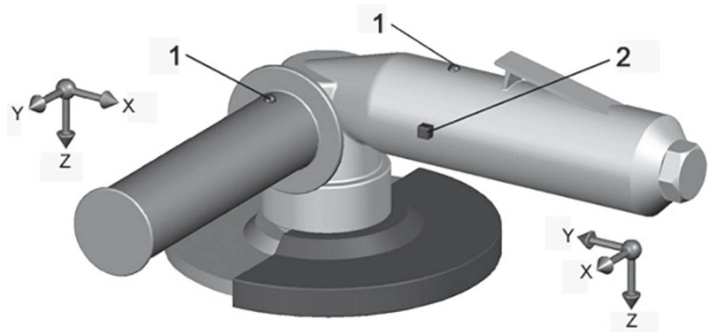


Key

1 prescribed location

2 secondary location

Figure 8 — Measurement locations — Electrical angle grinder whose motor serves as main handle

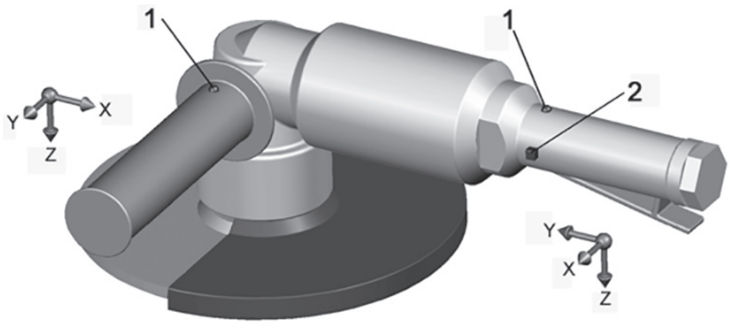


Key

1 prescribed location

2 secondary location

Figure 9 — Measurement locations — Pneumatic angle grinder whose motor serves as main handle

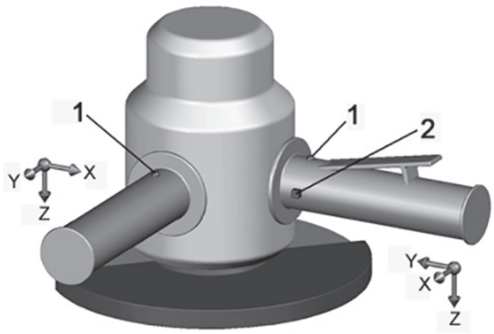


Key

1 prescribed location

2 secondary location

Figure 10 — Measurement locations — Pneumatic angle grinder with separate main handle

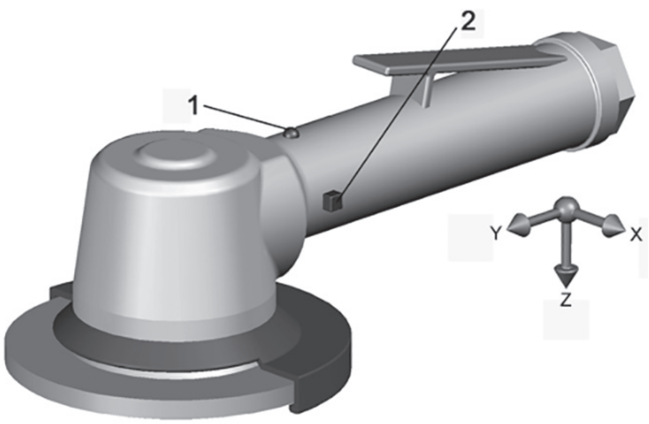


Key

1 prescribed location

2 secondary location

Figure 11 — Measurement locations — Pneumatic vertical grinder



Key

1 prescribed location

2 secondary location

Figure 12 — Measurement locations — Angle grinder intended for one-handed operation

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 when applicable. It is acceptable to report and carry out tests on the hand position having the highest reading. The vibration total value at that 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 Formula (1):

$$a_{hvmeas} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \tag{1}$$

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

$$a_{hvrat} = a_{hvmeas} \frac{n_{rat}}{n_{meas}} \tag{2}$$

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 (see 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[1)].

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 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 13). If, for some types of machines, 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 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 the rated conditions, as specified by the manufacturer. The operation shall be stable.

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

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 will influence 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 tool used in the test.

The feed force used shall be reported.

8.4 Attached equipment, work piece and task

8.4.1 Test wheel

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

Type 27 test wheels shall be mounted on the grinder in five orientations with a 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.

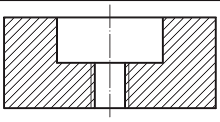
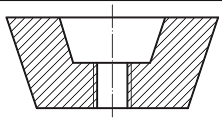
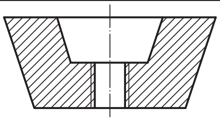
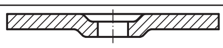
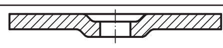
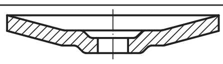
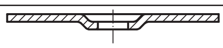
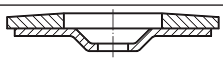
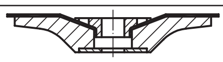
The test wheel shall be mounted as a normal grinding wheel, with flanges as recommended by the manufacturer. It shall be mounted concentrically with the grinder spindle and with zero play. To achieve this, a concentric adaptor bushing as specified in Annex C shall be used.

Type 11 test wheels have mounting threads. These wheels cannot be rotated to five different positions. Instead, the wheel shall be remounted five times for each of the three operators performing the test (see 8.4.3). The test wheel shall be mounted on the machine using the flanges and the mounting torque recommended by the manufacturer.

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

All combinations of machines and guards shall 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 according to ISO 603-14, ISO 603-16 et al		Grinding wheel diameter mm	Designation of test wheel used	Test wheel description		Diameter of test wheel mm	Unbalance gmm
Type 6 Straight cup wheel		100	11:100	Type 11 tapered cup test wheel		100	85
		125	11:125			125	140
		150	11:150			150	200
Type 11 tapered cup wheel		100	11:100			180	390
		125	11:125				
		150	11:150				
		180	11:180				
Type 27 depressed centre wheel		80	27:80	Type 27 depressed centre test wheel		80	37
		100	27:100			100	58
		115	27:115			115	76
		125	27:125			125	90
Type 28 depressed centre wheel, cone shaped		150	27:150			150	130
		180	27:180			180	190
		230	27:230			230	305
		300	27:300			300	520
Type 41 straight cutting wheel							
Type 42 depressed centre cutting off wheel							
Type D1 flap disc							
Type D3 fibre disc							

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.

For angle grinders, the upward force should be applied using the threaded holes for the support handle. For machines where the support handle can be mounted on either side, a short bolt should be inserted in the empty hole and a short sling of cord should be attached between this bolt and the inner part of the support handle.

For vertical grinders, the sling should be attached to the two handles as close as possible to the motor housing.

For machines with anti-vibration handles, the sling shall be attached between the machine body and the handle and acting on the machine body. Check that the action of the resilient mounting of the handle is not restrained.

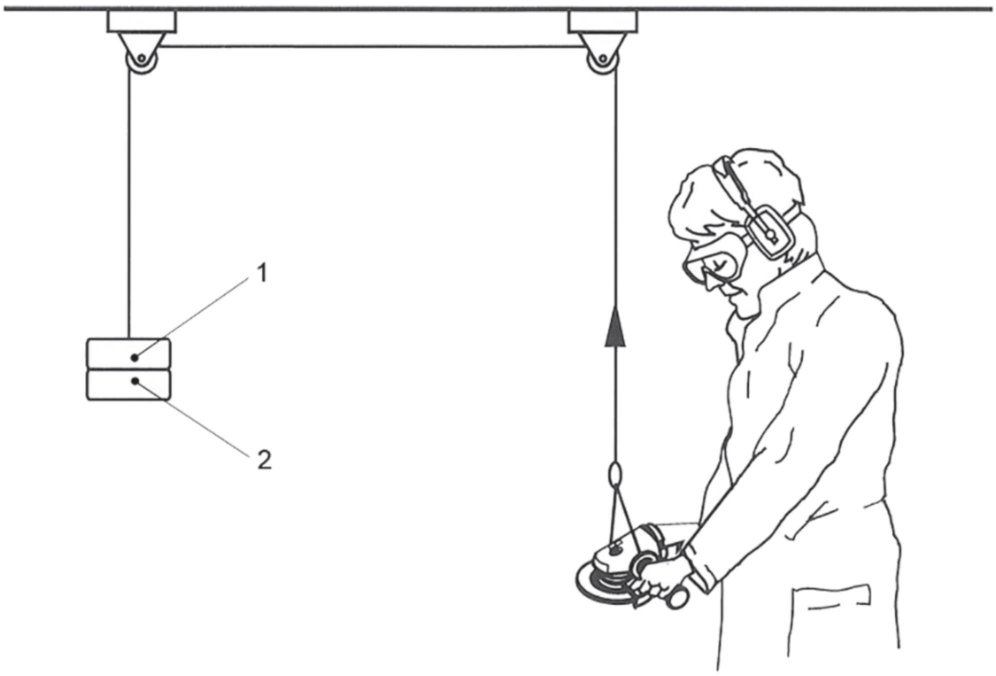
The upward force shall be applied through a cord attached to the sling. The friction between the sling and the cord should be kept low enough as to not restrict the movement of the machine. The force may be applied using a mass and pulley arrangement as shown in Figure 13. Alternatively, a dynamometer may be attached to the cord. The application of the force shall be achieved with minimum adaptation of the grinder.

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. The machine shall be held with the main handle lifted to give an angle of attack of approximately 20° to the horizontal plane.

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

Table 2 — Feed forces

Diameter of wheel, mm	80	100	115	125	150	180	200	230	300
Feed force, N ± 5 N	15	30	30	30	30	45	45	45	50



Key

1 mass of grinder

2 feed force mass

Figure 13 — Working position of operator and application of feed force using sling

8.4.3 Test procedure

Using a test wheel chosen in accordance with 8.4.1, perform the test as follows.

— For machines tested with type 27 test wheels, 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 11 threaded test wheels, each operator (see 8.5) shall each carry out a series of five consecutive measurements. Between each test, the test wheel shall be unfastened and re-fastened. Due to the design of the wheel, repositioning of the wheel 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.

8.5 Operators

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:

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

where the standard deviation of the i^{th} value, a_{hvrati}, measured and corrected using Formula (2) and expressed in m/s^2, is

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

where

$\overline{a_{hv}}$ 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 into 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 a_{hd} and the uncertainty, K, shall be presented with a precision determined in accordance with EN 12096. The value of a_{hd} is to be given in m/s^2 and presented 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 for 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 (see ISO/TR 27609).

9.3 Correction factor

For grinders that are intended to be used with cupped wire brushes, the corresponding declared value $a_{hd,brush}$ shall be given, where $a_{hd,brush}$ is obtained by multiplying a_{hd} by a factor of 1,6.

10 Measurement report

The following information shall be given in the test report:

a) reference to this document, i.e. ISO 28927-1:2019;

b) name of the measuring laboratory;

c) date of measurement and name 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 and other quantities to be specified according to 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 document 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 angle and vertical grinders

See Tables A.1 and A.2.

Table A.1 — General information and reported results

The test has been carried out in accordance with ISO 28927-1, *Hand-held portable power tools — Test method for evaluation of vibration emission — Part 1: Angle and vertical 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} and 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 Tests on single machines

For tests made on a single machine only, K shall be given as

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

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

$$s_R = 0{,}2a_{\mathrm{h}}$$

For the hand position having the highest a_{h} value, a_{hd} is equal to a_{h}:

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

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 $0{,}2a_{\mathrm{h}}$.

B.3 Tests on batches of machines

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

$$K = 1{,}5\sigma_{\mathrm{t}}$$

where σ_{t} is estimated by s_{t}:

$$s_{\mathrm{t}} = \sqrt{s_R{}^2 + s_{\mathrm{b}}{}^2}$$

The calculations are performed on the hand position having the highest a_{hd} value and where

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

s_{b} is the standard deviation of the test results for individual machines, i.e.

$$s_{\mathrm{b}}{}^2 = \frac{1}{n-1}\sum_{i=1}^{n}(a_{\mathrm{h}i} - \overline{a_{\mathrm{h}}})^2$$

where

$a_{\mathrm{h}i}$ is the single-machine emission for the i^{th} machine;

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

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

n is the number of machines tested (≥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 of wheels shall be manufactured in accordance with Figures C.1 to C.5.

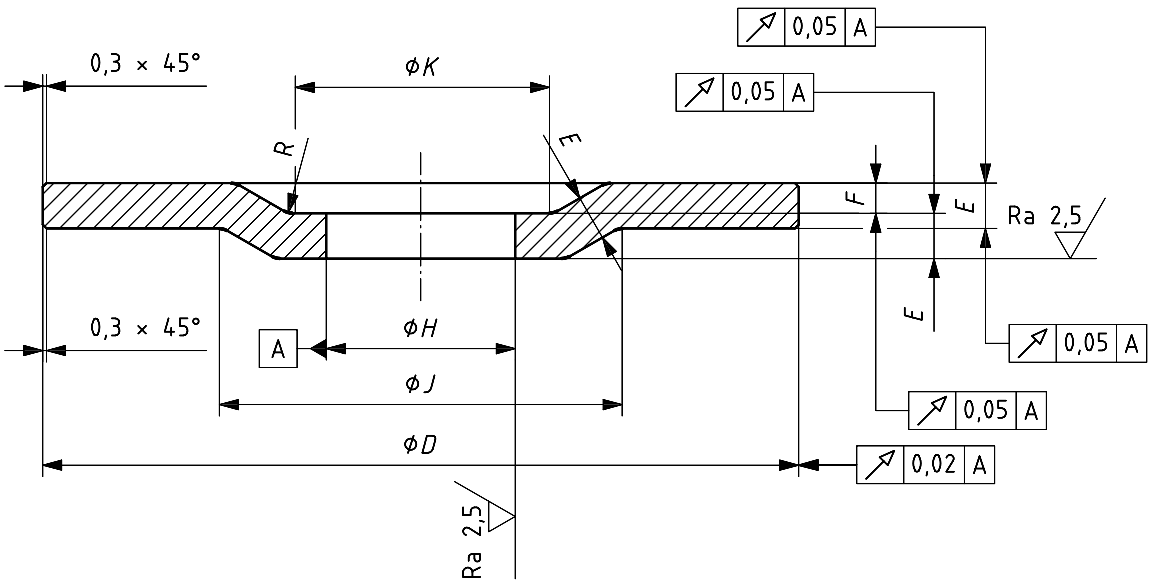
C.2 Basic geometry of aluminium test wheels

C.2.1 Type 27 depressed centre test wheels

Figure C.1 and Table C.1 give the required geometrical dimensions and machining tolerances for type 27 depressed centre test wheels. The information on how to machine the unbalance holes and the bushings required for assembly on the machines are given in separate clauses.

Table C.1 — Dimensions and tolerances of type 27 test wheels

Designation of test wheel	Outside diameter *D* ±0,02 mm	Thickness *E* ±0,05 mm	Bore diameter *H* g7	Internal diameter of recess *K* ±0,5 mm	Depth of recess *F* ±0,1 mm	Corner radius of recess *R*	Diameter of the depressed centre *J* ±0,5 mm
27:80	80	6	16	23	4	2	42
27:100	100	6	25	35,5	4	2	54,5
27:115	115	6	28	45	4,6	2	64
27:125	125	6	28	45	4,6	2	64
27:150	150	6	28	45	4,6	2	64
27:180	180	6	28	45	4,6	2	64
27:230	230	6	28	45	4,6	2	64
27:300	300	6	28	45	4,6	2	64



Key

D outside diameter
E thickness
F depth of recess
H bore diameter
J diameter of depressed centre
R corner radius of recess
K internal diameter of recess

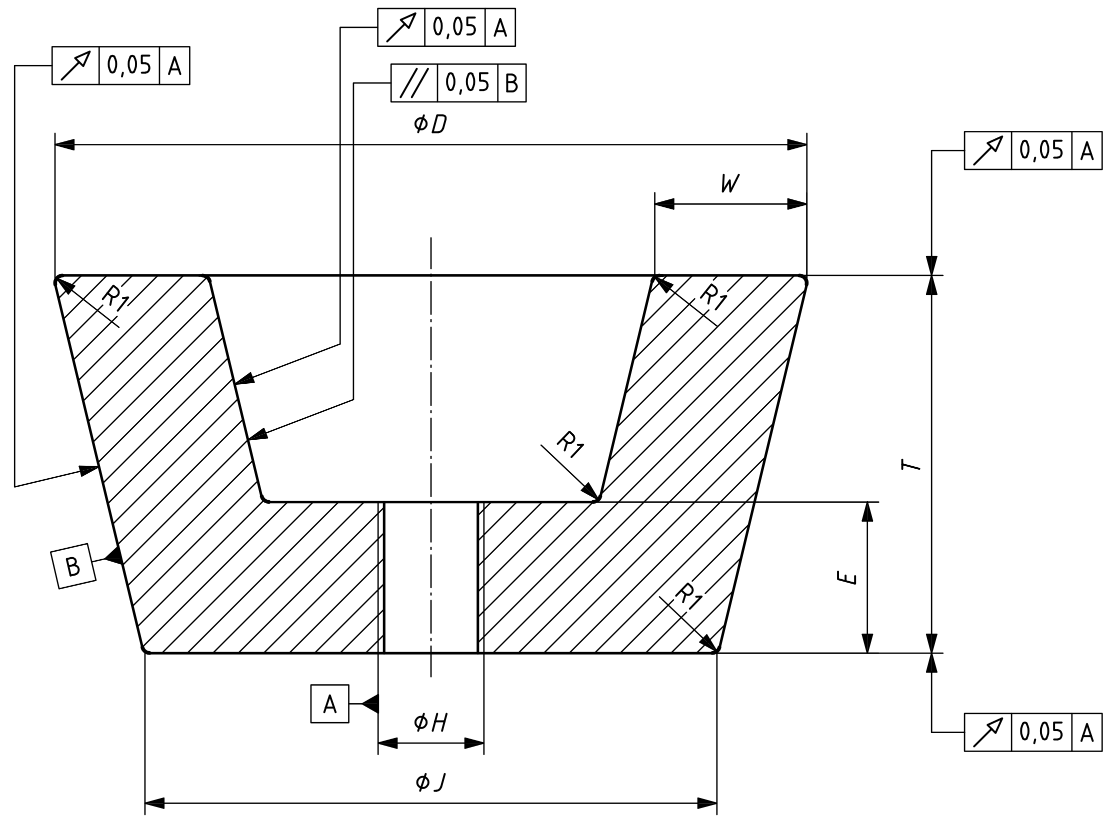
Figure C.1 — Geometrical dimensions and machining tolerances for type 27 test wheels

C.2.2 Type 11 tapered cup test wheels

Figure C.2 and Table C.2 give the required geometrical dimensions and machining tolerances for type 11 tapered cup test wheels.

Table C.2 — Dimensions and tolerances of type 11 test wheels

Designation of test wheel	Outside diameter *D* ±0,2 mm	Thickness *T* ±0,2 mm	Thread *H*	Smallest diameter *J* ±0,2 mm	Rim width *W* ±0,1 mm	Thickness at threaded bore *E* ±0,2 mm
11:100	100	50	M14 or UNC 5/8''	76	20	20
11:125	125	50	M14 or UNC 5/8''	94	25	20
11:150	150	50	M14 or UNC 5/8''	120	30	20
11:180	180	80	M14 or UNC 5/8''	120	41	25



Key

D outside diameter

E thickness at threaded bore

H thread

J smallest diameter of tapered wheel

T thickness

W rim width

Figure C.2 — Geometrical dimensions and machining tolerances for type 11 test wheels

C.3 Unbalance holes

C.3.1 Type 27 depressed centre test wheels

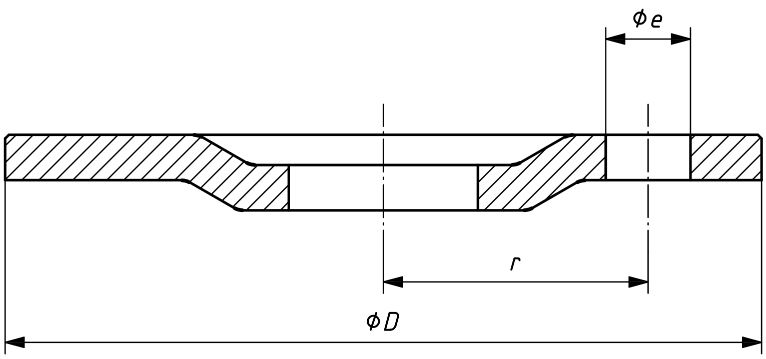
The unbalance is generated by machining a hole in the aluminium wheel. First, machine the hole to a bore smaller than needed to reach the defined unbalance. Measure the unbalance and increase the bore until the defined unbalance is reached.

The defined unbalance is chosen to be in the area of 40 % of the maximum allowed unbalance according to ISO 6103.

For type 27 depressed centre test wheels the unbalances, the diameter of the drilled hole and the radius for the centre of the hole shall be in accordance with Table C.3 and Figure C.3. The holes shall be drilled through.

Table C.3 — Unbalance hole dimensions for type 27 test wheels

Designation of test wheel	Wheel diameter *D* mm	Unbalance gmm ±5%	Hole diameter *e* mm	Radius to centre of hole *r* mm ±0,1 mm
27:80	80	37	9,8	30
27:100	100	58	11,3	35
27:115	115	76	12,1	40
27:125	125	90	12,4	45
27:150	150	130	12,9	60
27:180	180	190	14,0	75
27:230	230	305	15,4	100
27:300	300	520	17,3	135



Key

D wheel diameter

e hole diameter

r radius to centre of hole

Figure C.3 — Unbalance hole dimensions for type 27 test wheels

C.3.2 Type 27 depressed centre test wheels, alternative design

This alternative design is made for an easier calibration of the unbalance. By mounting a calibrating screw, and adjusting the unbalance wheel to balance, the unbalance will be more accurate and easy to make.

The unbalance is generated by machining one threaded hole in the aluminium wheel, in addition to the unbalance hole. During the adjustment, remove material from the unbalance wheel until the test wheel, with the calibration screw mounted, is in balance.

For the alternative type 27 depressed centre test wheels, the unbalances, the diameter of the drilled holes and the radius for the centre of the holes shall be in accordance with Table C.4 and Figure C.4. The holes shall be drilled through.

NOTE Figure C.4 shows an example for wheel diameters $D \geq 115$ mm.

The calibrating screw has the same unbalance as the unbalance hole and the screw hole together. See Table C.5 for screw dimensions and weights.

The calibrating screws should be removed before the unbalance wheel is mounted on the grinder.

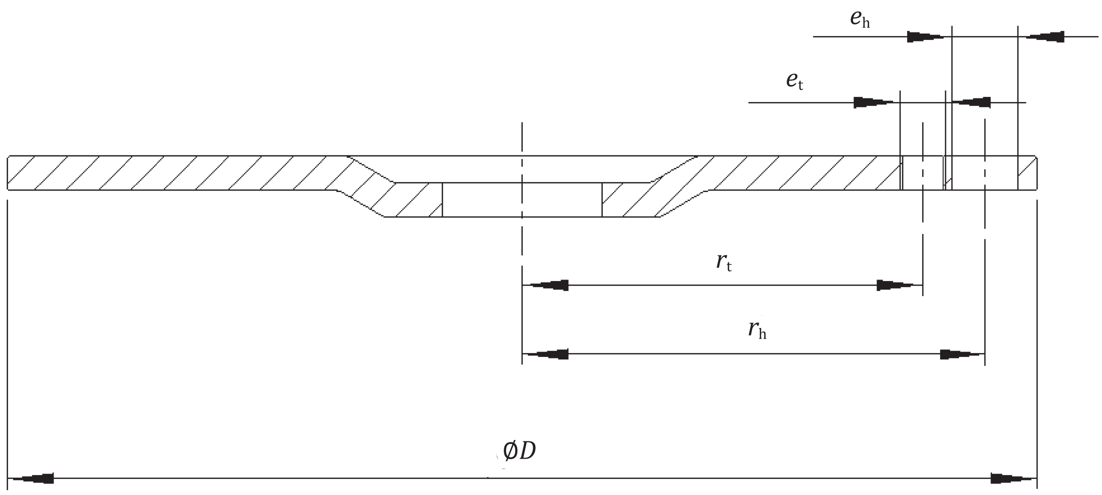
Table C.4 — Unbalance hole dimensions for type 27 test wheels, alternative design

Designation of test wheel	Wheel diameter D mm	Unbalance gmm ±5%	Hole diameter e mm	Radius to centre of hole r_h mm ±0,05 mm	Thread	Radius to centre of threaded hole r_t mm ±0,05 mm
27:80	80	37	8,3	26,5	M6	36
27:100	100	58	8,3	33	M8	45
27:115	115	76	8,9	50	M8	37,5
27:125	125	90	9,6	53	M8	37,5
27:150	150	130	10,6	66	M8	48,5
27:180	180	190	11,5	81	M8	70
27:230	230	305	15,4	84	M8	61
27:300	300	520	16,5	125,2	M8	104

The calibration screws are the screw types given in Table C.5. They are nominally too heavy and need to be adjusted to get the screw weight within the given tolerances

Table C.5 — Calibration screw dimensions for type 27 test wheels, alternative design

Designation of test wheel	Screw type	In accordance with	Screw mass g ±0,01 g
27:80	M6 × 10	ISO 4026	1,0
27:100	M8 × 8	ISO 4026	1,3
27:115	M8 × 10	ISO 4026	2,0
27:125	M8 × 12	ISO 4026	2,4
27:150	M8 × 12	ISO 4026	2,7
27:180	M8 × 12	ISO 4026	2,7
27:230	M8 × 20	ISO 4026	5,0
27:300	M8 × 20	ISO 4026	5,0



Key

D wheel diameter

e_h unbalance hole diameter

e_t threaded hole diameter

r_h radius to centre of unbalance hole

r_t radius to centre of threaded hole

Figure C.4 — Unbalance hole dimensions for type 27 test wheels, alternative design

C.3.3 Type 11 taper cup test wheel

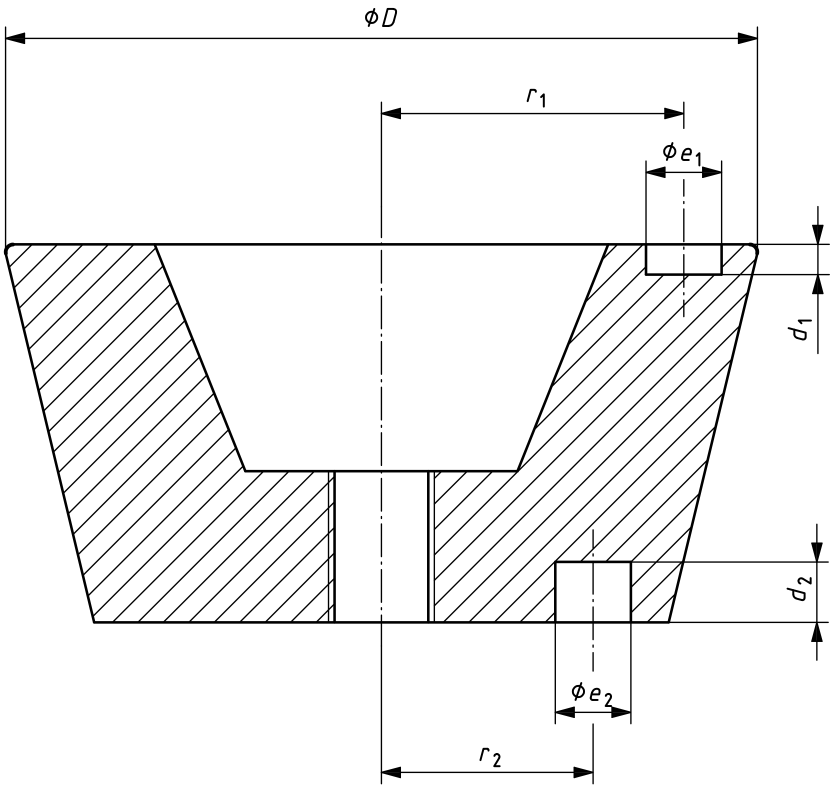
For type 11 test wheels, the unbalance is created by drilling two holes, one from the front and one from the rear. The holes shall have a flat bottom and be positioned in the same plane. The direction is parallel

to the centre hole. Two holes are needed in order to realistically distribute the unbalance over the thickness of the test wheel. The diameters of the drilled holes and the radius for the centre of the holes shall be in accordance with Table C.6 and Figure C.5.

Machine the holes on the rear side to the depth given and machine the holes on the front side to a smaller depth. Measure the unbalance and increase depth or diameter until the defined unbalance is reached.

Table C.6 — Unbalance hole dimensions for type 11 test wheels

Designation of test wheel	Wheel diameter D mm	Unbalance gmm ±5 %	Front hole diameter e_1 mm	Radius to centre of front hole r_1 mm ±0,1 mm	Front hole depth d_1 mm	Rear hole diameter e_2 mm ±0,05 mm	Radius to centre of rear hole r_2 mm ±0,1 mm	Rear hole depth d_2 mm ±0,05 mm
11:100	100	85	10	40	4	10	28	8
11:125	125	140	10	50	5,5	10	37	9,7
11:150	150	200	10	60	7,7	10	50	9
11:180	180	390	10	70	13,4	10	50	16,7
The front and rear holes are located in the same plane and should have a flat bottom and surface.								



Key

D wheel diameter

d_1 front hole depth

d_2 rear hole depth

e_1 front hole diameter

e_2 rear hole diameter

r_1 radius to centre of front hole

r_2 radius to centre of rear hole

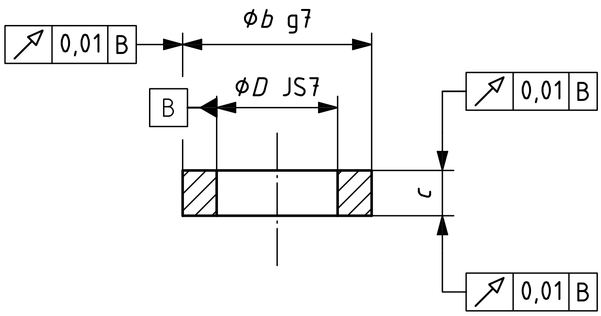
Figure C.5 — Unbalance hole dimensions for type 11 test wheels

C.4 Bushing for type 27 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 found to give a better fit to the spindle. See Figure C.6 for a description of the dimensions. The material is mild steel, similar to type S235 according to ISO 630-2.

Table C.7 — Dimension of bushings to be used with type 27 test wheels

Diameter *b*	Thickness *C*	Bore diameter *D*
mm		
g7	−0,1 mm −0,2 mm	JS7
16	6	10 10,04 10,08 10,12
25	6	16 16,04 16,08 16,12
28	6	22,00 22,04 22,08 22,12 22,16 22,20



Key

b diameter

c thickness

D bore

Figure C.6 — Geometrical dimensions and machining tolerances for mounting bushings

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