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Rotary and percussive pneumatic tools — Acceptance tests

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2787 was drawn up by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*, and circulated to the Member Bodies in June 1972.

It has been approved by the Member Bodies of the following countries :

Belgium	Hungary	Sweden
Chile	India	Switzerland
Czechoslovakia	Japan	Thailand
Egypt, Arab Rep. of	Netherlands	Turkey
Finland	Romania	United Kingdom
France	South Africa, Rep. of	U.S.A.
Germany	Spain	U.S.S.R.

No Member Body expressed disapproval of the document.

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0 INTRODUCTION

The purpose of this International Standard is to show how information on hand-held pneumatic rotary and percussive tools should be obtained and presented.

Such information is valuable for the following purposes :

a) enabling manufacturers of pneumatic rotary and percussive tools to offer their products under similar technical specifications;

b) helping users to compare different tools and to select the right type and size for a specific task;

c) instructing test personnel about how performance and acceptance tests shall be carried out, according to specified conditions described in this International Standard.

Impact wrenches present special problems and are therefore not covered by this International Standard. A separate International Standard for performance and acceptance tests of impact wrenches is under consideration, covering both stiff joint and soft joint conditions.

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies a method of acceptance tests and technical conditions for the supply of pneumatic tools and gives detailed instructions on the measurement of power output and air consumption and means of adjusting the measured values to guaranteed condition.

2 REFERENCES

ISO 31 (Quantities, units and symbols).

ISO/R 541, *Measurement of fluid flow by means of orifice plates and nozzles.*

ISO/R 554, *Standard atmospheres for conditioning and/or testing – Standard reference atmosphere – Specifications.*

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1217, *Displacement compressors – Methods for acceptance tests.* [1]

3 DEFINITION OF PHYSICAL TERMS, LETTER SYMBOLS AND UNITS

3.1 DEFINITION OF SOME GENERAL PHYSICAL TERMS

3.1.1 total pressure : The pressure measured on the stagnation point when a moving gas stream is brought to rest and its kinetic energy is converted by an isentropic compression from the flow condition to the stagnation condition. It is the pressure usually measured by a Pitot tube. In a stationary body of gas the static and the total pressures are numerically equal.

3.1.2 static pressure : The pressure measured in a gas in such a manner that no effect on measurement is produced by the gas velocity.

3.1.3 dynamic (velocity) pressure : The total pressure minus the static pressure.

3.1.4 atmospheric pressure : The absolute pressure of the atmosphere measured at the test place.

3.1.5 gauge (effective) pressure : The pressure measured above the atmospheric pressure.

3.1.6 absolute pressure : The pressure measured from absolute zero, i.e. from an absolute vacuum. It equals the algebraic sum of atmospheric pressure and gauge pressure.

3.1.7 free air : Air at the atmospheric conditions of the site.

1) At present at the stage of draft : ISO/DIS 1115.

3.1.8 total temperature : The temperature which would be measured at the stagnation point if a gas stream were brought to rest and its kinetic energy converted by an isentropic compression from the flow condition to the stagnation condition.

The temperature rise at stagnation of the gas stream can be neglected if the gas velocity around the measuring point is lower than 30 m/s.

3.2 DEFINITIONS CONCERNING ROTARY AIR MOTOR TORQUE PERFORMANCE

3.2.1 static starting torque : The torque that continues to be developed by the motor in response to an application of fluid pressure when the torque load is sufficient to prevent rotation.

NOTE — The value may depend upon the angular position of the motor shaft. The maximum static starting torque is the value obtained when the angular position of the motor shaft is in the most advantageous location. The minimum static starting torque is the value obtained when the angular position of the motor shaft is in the least advantageous location.

3.2.2 dynamic starting torque : The peak torque delivered by the output shaft of the motor in response to an application of fluid pressure when the torque load is sufficient to prevent rotation.

NOTE — The dynamic starting torque will often be in excess of the static starting torque where lost motion exists between the motor shaft and the load, allowing rotation and momentum to develop prior to application of the load.

3.2.3 brake loaded torque : The continuous torque delivered at a constant speed.

3.2.4 maximum brake loaded torque : The maximum continuous torque that can be delivered at a constant speed.

3.2.5 static stall torque : The torque that continues to be developed after a load has stalled the motor.

NOTE — The value may depend upon the angular position of the motor shaft in the stalled position. The maximum static stall torque is the value obtained when the angular position of the motor shaft is in the most advantageous location. The minimum static stall torque is the value obtained when the angular position of the motor shaft is in the least advantageous location.

3.2.6 dynamic stall torque : The peak torque delivered by the output shaft when a load is applied that stalls the motor.

NOTE — The peak torque will vary, dependent upon the rate of deceleration caused by the load.

3.3 LETTER SYMBOLS AND UNITS

According to ISO 31 and ISO 1000.

3.3.1 *General rules for letter symbols*

The use of the letter symbols given in 3.3.2 and 3.3.3 is recommended. The list is formulated in line with the following seven principles :

a) The same symbols shall be used for the same quantities regardless of the system of units.

b) For any one quantity a single symbol shall be used with subscripts to indicate readings other than the primary one.

c) The same symbols shall be used for a given concept regardless of the number of special values which occur.

d) Letter subscripts shall be used to denote values under special conditions.

e) Numerical subscripts shall be used to denote values at different points of a cycle.

f) Symbols shall be confined if possible to roman letters.

g) Where possible, capital letters shall be used for absolute quantities.

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3.3.2 *Table of letter symbols and units*

Symbol	Quantity	Unit
D	Piston diameter	mm
d	Pipe or hose internal diameter	mm
e	Impact energy	J
F	Force	N
L	Length	m or mm
M	Torque	N·m
m	Mass	kg
P	Power	kW
N	Number of tools	—*
n	Shaft speed	min^{-1}
f	Blow rate	Hz
p_a	Absolute pressure	bar**
p_e	Gauge pressure	bar
p_b	Atmospheric pressure	bar
q	Flow rate	l/s or kg/s
s	Standard deviation	—*
S	Stroke length	mm
T	Absolute temperature	K
t	Celsius temperature	°C
V	Volume	m^3

* Only applicable in 5.1.8, 5.1.9, 5.1.10, 5.1.11.

** 1 bar = 10^5 Pa.

3.3.3 *Subscripts*

0	refers to ambient conditions
av	refers to average value
max	refers to maximum value
min	refers to minimum value
s	refers to starting conditions (n or $f = 0$)
i	refers to no-load conditions
P	refers to conditions at stated power output

4 CLASSIFICATION OF PNEUMATIC TOOLS

4.1 Description of the pneumatic tools

	Symbol	Explanatory comments
4.1.1 Type of pneumatic tool		Manufacturer's type designation
4.1.2 Standard equipment		Pneumatic tool including tool holder as well as all devices for the prevention of accidents but without working tools, coupling hose fitting, hose and support
4.1.3 Mass of the pneumatic tool	m	Mass of the normally equipped tool defined as in 4.1.2
4.1.4 Dimensions of the pneumatic tool		In all cases the overall length of the pneumatic tool will be shown together with such other dimensions as are appropriate to the particular type of pneumatic tool
4.1.5 Piston diameter and mass	D m_p	Dimension of the striking piston at its largest outside diameter and its mass
4.1.6 Theoretical piston stroke	S	Possible axial movement of the piston in the working chamber with the tool shank fully introduced
4.1.7 Recommended hose, inner diameter and length	d L_h	Smallest inside diameter and length of the supply hose and of the necessary fittings
4.1.8 Type and dimensions of the working tool		According to ISO/TC 29/WG 8
4.1.9 Tool holder		According to ISO/TC 29/WG 8
4.1.10 Tool retainer		
4.1.11 Special and optional features		Flushing, dry suction, etc.

4.2 Tool performance data

	Symbol
4.2.1 Compressed air pressure for which test data are valid (recommended compressed air pressure)	p
4.2.2 Power output	P
4.2.3 Air consumption at given power output	q_P
4.2.4 Air consumption, no load	q_i
4.2.5 Rotational speed at given power output	n_P
4.2.6 Torque at given power output	M_P
4.2.7 Starting torque, max.	$M_{s,\ max}$
Starting torque, min.	$M_{s,\ min}$

NOTE — It should be clearly stated which starting torque, according to 3.2, is referred to.

4.2.8 Rotational speed under no load or blow rate under no load	n_i f_i
4.2.9 Impact energy	e
4.2.10 Blow rate	f
4.2.11 Maximum tightening torque	M_e

4.3 Data to be given for different types of tool

In principle, all data in accordance with 4.1 and 4.2 which are applicable to the pneumatic tool under consideration shall be given in the description of the tool.

4.3.1 *Percussive pneumatic tools without rotation*

- Type of pneumatic tool (4.1.1)
- Standard equipment (4.1.2)
- Mass of the pneumatic tool (4.1.3)
- Dimensions of the pneumatic tool (4.1.4)
- Piston diameter and mass (4.1.5)
- Theoretical piston stroke (4.1.6)

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- Recommended hose, inner diameter and length (4.1.7)
- Type and dimensions of the working tool (4.1.8)
- Tool holder (4.1.9)
- Tool retainer (4.1.10)
- Recommended compressed air pressure (4.2.1)
- Power output (4.2.2)
- Air consumption under load (4.2.3)
- Impact energy (4.2.9)
- Blow rate (4.2.10)

4.3.2 *Percussive pneumatic tools with rotating device* (e.g. rock drills)

- Type of pneumatic tool (4.1.1)
- Standard equipment (4.1.2)
- Mass of the pneumatic tool (4.1.3)
- Dimensions of the pneumatic tool (4.1.4)
- Piston diameter and mass (4.1.5)
- Theoretical piston stroke (4.1.6)
- Recommended hose, inner diameter and length (4.1.7)
- Type and dimensions of the working tool (4.1.8)
- Tool holder (4.1.9)
- Tool retainer (4.1.10)
- Special and optional features (4.1.11)
- Recommended compressed air pressure (4.2.1)
- Power output (4.2.2)
- Air consumption under load (4.2.3)
- Impact energy (4.2.9)
- Blow rate (4.2.10)

4.3.3 *Rotary pneumatic tools*

- Type of pneumatic tool (4.1.1)
- Standard equipment (4.1.2)
- Mass of the pneumatic tool (4.1.3)
- Dimensions of the pneumatic tool (4.1.4)
- Recommended hose, inner diameter and length (4.1.7)
- Type and dimensions of the working tool (4.1.8)
- Tool holder (4.1.9)
- Tool retainer (4.1.10)
- Special and optional features (4.1.11)
- Recommended compressed air pressure (4.2.1)
- Power output (4.2.2)
- Air consumption under load (4.2.3)
- Air consumption at no load (4.2.4)
- Rotational speed at no load (4.2.8)
- Rotational speed under load (4.2.5)

4.3.4 *Pneumatic screwdrivers and nutrunners*

- Type of pneumatic tool (4.1.1)
- Standard equipment (4.1.2)
- Mass of the pneumatic tool (4.1.3)
- Dimensions of the pneumatic tool (4.1.4)
- Recommended hose, inner diameter and length (4.1.7)
- Type and dimensions of the working tool (4.1.8)
- Tool holder (4.1.9)
- Tool retainer (4.1.10)
- Special and optional features (4.1.11)
- Recommended compressed air pressure (4.2.1)
- Air consumption (4.2.4)
- Rotational speed at no load (4.2.8)
- Maximum starting torque (4.2.7)

NOTE – The air consumption is given under no-load conditions.

5 METHODS FOR MEASUREMENT OF TOOL PERFORMANCE DATA

5.1 General rules for performance test on pneumatic tools

5.1.1 All measurements carried out in compliance with this International Standard shall be performed by competent persons and with accurate instrumentation, which is calibrated against existing standards or standard methods.

5.1.2 The performance of pneumatic tools is affected by different ambient conditions such as atmospheric pressure and temperature. Moreover, the temperature of the compressed air influences the behaviour of the tool. For that reason standard test conditions are defined according to ISO/R 554. The ordinary tolerances should be used.

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Atmospheric pressure	between 860 and 1 060 mbar
Ambient temperature	20 ± 2 °C
Relative humidity	65 ± 5 %
The compressed air temperature shall be	20 ± 5 °C

During the test run with the tool, the temperature shall be kept as close as possible to the standard test conditions. Any deviation shall be stated in the test report. The relative humidity of the ambient air shall also be stated in the test report. Tests shall be avoided if the atmospheric pressure deviates from the given conditions.

5.1.3 For ordinary pneumatic tools, the test shall be carried out with a compressed air working pressure of 4 and/or 6 bar gauge pressure. The testing can be performed either at one of these pressures only, or at both, depending upon which pressure is regarded as normal operating pressure, unless stated otherwise in the test report. A gauge pressure of 6 bar is preferred if there are no special reasons for the lower pressure.

In the case of another pressure being regarded as more suitable, the performance test can be carried out with such a pressure, but the pressure used shall be stated in addition to the other data for the machine.

5.1.4 During performance tests, the length of the connecting hose from the point of pressure measurement (5.2.4) to the tool shall be 3 to 5 m and preferably closer to the shorter length. Hose diameter shall be in accordance with 4.1.7. Any other hose length must be stated in the test report.

5.1.5 All performance data concerning pressure, number of revolutions and blows, power output and blow energy, etc. shall refer to the same running conditions, unless stated otherwise.

5.1.6 During the test run of the tool, the quality and quantity of lubricant recommended by the manufacturer to the customer shall be used.

5.1.7 Due to manufacturing tolerances, even tools of the same type and size give slightly different performance data. It is therefore insufficient to test one sample only of the type of tool in question. To obtain the performance data for the type, it is necessary to test several samples of the tool and then calculate the mean value.

All measured results are subject to errors due to imperfect measuring equipment, uncontrollable ambient conditions, influence from the persons performing the test, etc. Only an approximately correct result can be expected. By statistical methods a tolerance range can be calculated in which the true type value can be expected to lie within a certain degree of probability.

5.1.8 In tests according to this International Standard, only a total tolerance range for the mean values will be calculated from the primary test data under the assumption that the distribution of the measured data is Gaussian. This shall be made in the following way :

Assume that the tools have been tested and given the results $\kappa_1\ \kappa_2 ... \kappa_N$ respectively. The mean value $\bar{\kappa}$ is then calculated as

$$\bar{\kappa} = \frac{1}{N} \sum_{i=1}^{N} \kappa_i$$

For calculation of the tolerance range, the standard deviation, s, i.e. the root mean square deviation, is calculated by the formula

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (\kappa_i - \bar{\kappa})^2}$$

The tolerance range, r, which should be used according to this International Standard is calculated from

$$r_{95} = t_{95}\, s$$

t_{95} can be taken from the table or the diagram in 5.1.11.

The given values of the t-factor (Student's t) are based on a 95 % probability. This means that of a number of tested tools, 95 % can be estimated to lie within the range

$$\bar{\kappa} + r_{95} = \bar{\kappa} \pm t_{95}\, s$$

and 2,5 % fall outside on each side.

5.1.9 The distribution of the tool performance data will be better defined with a large number of tools tested (N), giving a smaller r-value. An accurate type test value with an acceptable tolerance can normally be expected by testing 10 samples or more of the tool in question.

5.1.10 Standard deviations, tolerance, etc. used in reports, type data tables, sales literature and the like, should be given in conformity with the respective sections of this International Standard.

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5.1.11 Table for t for estimating tolerances of performance data for pneumatic tools :

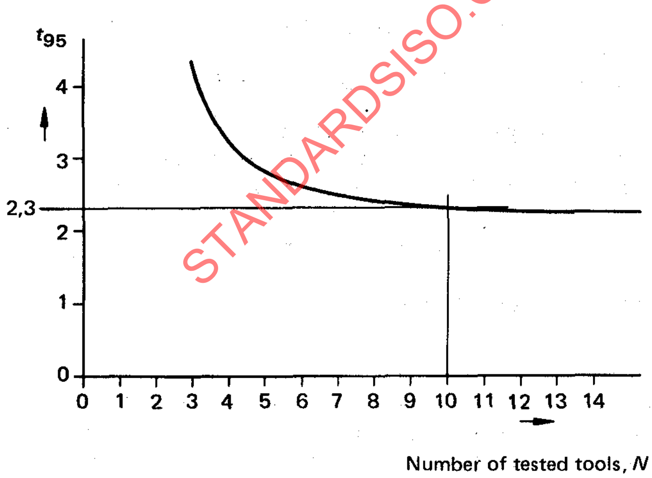
95 % probability level

Number of tested tools (N)	t_{95}
3	4,3
4	3,2
5	2,8
6	2,6
8	2,4
10	2,3
20	2,1
30	2,05
50	2,0
100	2,0
200	1,97
> 200	1,96

$$r_{95} = t_{95}\, s$$

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (\kappa_i - \overline{\kappa})^2}$$

$$\overline{\kappa} = \frac{1}{N} \sum_{i=1}^{N} \kappa_i$$



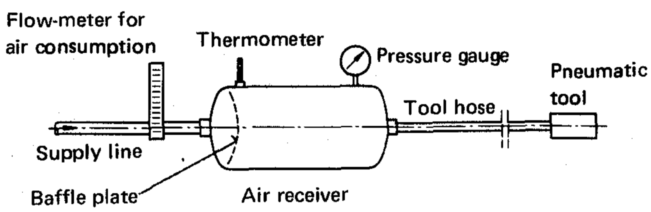
5.2 Pressure

5.2.1 Accurate measurement of the compressed air pressure to the pneumatic tool is of very great importance since the tool performance is strongly influenced by this factor.

5.2.2 For measurement of air pressure, gauges of any suitable type could be used. The gauges selected shall be of such size and quality that 0,5 % pressure difference of full scale reading can be read easily. The pressures to be read shall fall between one-fourth and three-fourths of full scale reading. The pressure gauge shall be checked and calibrated as often as necessary to make certain that sufficient accuracy is attained. For the calibration, dead-weight gauges can be used.

5.2.3 The compressed air pressure to the tool shall be measured as total pressure at the inlet of the tool hose as specified in the description of the tool, 4.1.7. This means that the air shall be at rest without any velocity or have a velocity small enough to give a negligible dynamic pressure. This means, in turn, that the velocity of the air at the point of the supply line where the pressure is to be measured shall not be higher than 15 m/s at 7 bar absolute pressure. In order to avoid the effect of pressure drop due to supply line losses, pressure measurements shall be carried out with the tool running.

5.2.4 A low air velocity at the point of pressure measurement is achieved by fitting an air receiver between the supply line and the inlet of the tool. The receiver will also damp the pulsations in the air stream to ensure a correct air flow measurement. A suitable arrangement is shown in the figure below.



The receiver shall have a cross-section, A m², perpendicular to the direction of the air stream of at least

$$A > 0{,}07 \frac{q_{max}}{p_a}$$

where

q_{max} is the maximum air flow for which the device is intended, expressed in l/s of free air;

p_a is the absolute pressure in the supply line in bars.

This corresponds to an air velocity of 15 m/s.

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When testing percussive tools, the volume of the receiver shall be at least 100 times the swept volume of the tool. The inlet to the receiver and the pressure tapping for the gauge shall be located relative to each other so that the incoming air stream does not impinge directly on the pressure tapping. In many cases the introduction of a baffle plate in front of the inlet as shown in the figure is advantageous.

It is also recommended that a thermometer be introduced to check the temperature of the compressed air in the receiver.

5.2.5 Before the device is used for testing pneumatic tools, it shall be made certain that the desired effect on the pressure measurements is obtained. This shall be controlled by increasing the air flow slowly to the maximum flow for which the device is intended. At the same time the pressure gauge is observed and its reading shall not change more than 0,5 % during this procedure. This also indicates that the supply line has sufficient capacity.

5.2.6 It shall also be checked that there are no pressure pulsations in the supply line, for example from the compressors. Such pulsations might introduce errors in the pressure measurement and the measurement of the air consumption.

If noticeable pulsations are present, they shall be damped before the air stream reaches the measuring device. This can be done by introducing another suitable receiver into the line between the compressors and the measuring device.

5.2.7 Tests carried out in accordance with 5.2.4 to 5.2.6 and with properly calibrated pressure gauges will keep the operating pressure within ± 2 % of the desired value.

5.3 Torque

The measurement of the torque of the pneumatic rotary tool shall be made according to generally accepted Test Codes or procedures.

In such a case, reference to the Test Code shall be made in the report.

5.3.1 The torque shall be measured by swinging arm dynamometers or brakes. These can be of the electrical, hydraulic, frictional or any other similar type.

5.3.2 Swinging arm dynamometers shall not be used below one-tenth of their rated torque capacity.

5.3.3 A correctly performed torque measurement will give a result which deviates less than ± 3 % from the true value.

5.3.4 In the test report, data tables, sales literature, etc. the torque of the tool is given with the upper tolerance limit and/or the lower tolerance limit ($\overline{K} + r_{95}$ and/or $\overline{K} - r_{95}$), whichever is of interest; for example, for nutrunners and screwdrivers, the lower tolerance limit shall be given for the starting torque.

5.4 Shaft speed

5.4.1 If possible, the total number of revolutions during a certain time period shall be measured. A revolution counter free from slip shall be used.

5.4.2 Since the shaft speed can vary due to different reasons, for example variations of load from dynamometer, regulator oscillations, etc., the test period chosen shall not be shorter than 30 s and in special cases it might be advisable to choose a longer test period to obtain an accurate average value of the shaft speed. A long test period also decreases the relative importance of inaccuracy during starting and terminating the time measurement. The use of electric clocks and electrical contacts instead of manually operated stopwatches can reduce these errors.

5.4.3 Stroboscopes and speedometers are normally not sufficiently accurate but may be used to check the shaft speed variations.

5.4.4 If the shaft speed is measured with good quality instruments according to the above-mentioned clauses, an accuracy of ± 2 % in shaft speed measurement can be expected.

5.4.5 In data tables, sales literature, etc. shaft speed is given with the upper tolerance limit and/or the lower tolerance limit ($\overline{K} \pm r_{95}$), whichever is of interest. In the case of grinding machines with governor, for example, $\overline{K} + r_{95}$ for the free-running condition shall be given, as this is of great importance from the safety point of view. In cases when only one of the two tolerance limits is stated, it shall be mentioned if it is the upper or lower limit.

5.5 Impact energy

The measurement of impact energy from percussive tools is a difficult problem for which many different methods have been proposed. Few of them, however, give a true measure of the actual impact energy. In this International Standard, one method has been adopted and is regarded as being suitable if properly handled and checked. This test method shall only be used as a comparative test for percussive tools, tested with identical energy-absorbing means.

5.5.1 When the hammer piston in the pneumatic tool hits the working tool, for example drill steel, chisel, etc., a strain wave (strain pulse) is generated in it and travels along it down to the bit end. The strain pulse can be recorded with suitable apparatus. The strain pulse carries a part of the impact energy of the piston, and the maximum stress level of the pulse is proportional to the impact velocity of the piston and hence the energy of the piston at impact. By suitable calibration the relation between the impact energy of the piston and maximum stress level can be determined.

5.5.2 Essential equipment for the strain gauge method is a measuring rod, or the normal working tool, with strain gauges cemented to it, a suitable electronic amplifier and a recording oscilloscope with fast enough response. The

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machine can be run under actual working conditions such as drilling in rock, etc. or in a test rig which absorbs the blow energy of the tool.

5.5.3 The measuring rod which is to be inserted in the pneumatic tool shall have an overall length of at least five to six times the length of the striking piston.

5.5.4 At least two, and preferably three, strain gauges shall be fixed in the same plane equally spaced around the circumference of the measuring rod and connected to the measuring bridge, so that bending waves in the rod are eliminated to the highest possible degree. The distance from the end surface of the rod, which is inserted in the machines, to the position of the strain gauges shall be as short as possible.

5.5.5 The measuring rod shall be well guided axially relative to the machine, so that the generation of bending waves is avoided as much as possible.

5.5.6 To obtain an accurate result at least 50 blow impacts shall be recorded and the mean impact energy per blow calculated.

5.5.7 The relation between blow energy and strain pulse size depends on the piston dimension and piston shape. The said relation shall thus be achieved by calibration in a drop hammer with the actual piston and the measuring equipment to be used during the performance test. The piston velocity during the calibration shall be chosen as closely as possible to the velocity of the piston in the machine during the performance test. The piston shall fall without frictional resistance during the drop test.

5.5.8 In the test report accurate information shall be given in respect of the test rig absorbing the impact energy, the length and diameter of the test rod, as well as the load applied to the machine.

5.5.9 For percussive tools with rotation driven by the motion of the hammer piston, the rotation mechanism shall be run without any torque applied to the working tool during the testing of impact energy.

5.5.10 The accuracy of the impact energy measurement can be estimated to be within ± 10 % if the test is performed thoroughly.

5.5.11 In data tables, sales literature, etc., the impact energy is given in the form of the range defined by the lower and upper tolerance limits $\overline{K} - r_{95}$ and $\overline{K} + r_{95}$ according to the calculations described in 5.1.8. If only one of the values is stated it shall be mentioned if it is the maximum or minimum value.

5.6 Blow rate

5.6.1 The measurement of the blow rate can be made with the help of any signal which is clearly related to the number of blows of the tool, for example movements of the working tool or number of stress pulses in the same, pressure fluctuations in the compressed air line in the neighbourhood of the inlet of the tool or movements of the working piston or the valve. These different pulses can be recorded by means of suitable pick-ups and recorders with a time marker. By counting the number of signal pulses during a certain time period the blow rate can be calculated.

5.6.2 Instead of recording the signal pulses on a diagram strip, they can be recorded on a counter, which is connected to the pick-up circuit during a defined and accurately measured time period.

5.6.3 The method where the pulses are recorded on a diagram strip is preferred as it also registers the variation in blow rate during the test period.

The diagram also gives the possibility of detecting and discriminating signals due to disturbances or harmonics, which do not correspond with the blow rate. In the case of a counter, this problem should be especially considered.

5.6.4 Since the blow rate often has a great variation, the test period chosen shall not be shorter than 30 s and in some cases it might be advisable to choose a longer test period to obtain an accurate average value of the blow rate. A long test period also decreases the relative importance of inaccuracy during starting and terminating the time measurement.

5.6.5 Stroboscopes and direct-reading frequency meters are normally not sufficiently accurate. The stroboscopic method is also difficult to use. The direct-reading frequency meter can be used to check the variations of the blow rate.

5.6.6 The vibrating spring meter, where one adjustable or several constant springs are tuned to different resonant frequencies, with their vibrations indicating the imposed frequency, are not so suitable for achieving test data according to this International Standard.

5.6.7 Since the blow rate of a percussive tool is dependent upon the reflections of the impact wave at the bit end, the measurement of the blow rate shall be made under normal working conditions for the tool. For example, for a rock drill the blow rate measurements shall be performed during actual drilling in rock.

5.6.8 The accuracy of a properly performed blow rate measurement can be expected to be better than ± 2 %.

5.6.9 In data tables, sales literature, etc., blow rate is given with the upper and/or lower tolerance limit ($\overline{K} + r_{95}$ and/or $\overline{K} - r_{95}$ according to 5.1.8), whichever is of interest. If only one of the two tolerance limits is stated in the report, it shall be mentioned if it is the upper or lower limit.

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5.7 Power output

5.7.1 *Rotary pneumatic tools*

In the case of a pneumatic rotary tool the power output is calculated from shaft speed and corresponding torque measured in the brake. The power output is :

$$P = \frac{2\pi n}{60} M \times 10^{-3}$$

where

P is the power, in kilowatts;

M is the torque, in newton metres;

n is the shaft speed, in revolutions per minute.

The power is calculated for each pair of values of torques and shaft speed. A diagram of power versus shaft speed is drawn. From this diagram the shaft speed at maximum power can be estimated. At this speed the power is accurately measured.

In the test report the measured maximum power and the corresponding shaft speed shall be stated.

5.7.1.1 The accuracy of the calculated power output for the pneumatic tool depends upon the accuracy of shaft speed and torque measurement. With the accuracy mentioned in 5.3.3 and 5.4.4 the accuracy of the calculated power output value can be estimated to be better than ± 5 %.

5.7.2 *Percussive pneumatic tools*

In the case of a pneumatic percussive tool the power output of the tool is calculated by multiplying blow rate and impact energy per blow according to the following formula :

$$P = 10^{-3}\, e\, f$$

where

P is the power, in kilowatts;

e is the impact energy, in joules;

f is the blow rate, in hertz.

In the test report the calculated power output of the percussive tool shall be stated.

5.7.2.1 The accuracy of the calculated power output of the pneumatic percussive tool depends upon the accuracy of impact energy and blow rate according to 5.5.10 and 5.6.7 respectively. The accuracy of the power output can thus be estimated to be better than ± 12 %.

5.7.2.2 In data tables, sales literature, etc., power output is given by using the lower tolerance limit ($\bar{x} - r_{95}$ according to 5.1.8). Tool samples with power output above this value are acceptable and those below are not. According to the definition of the lower tolerance limit roughly 97,5 % of the produced tools can be estimated to be acceptable and 2,5 % not.

5.8 Air consumption

5.8.1 The air consumption of the pneumatic tools shall be measured on the inlet side of the tool, i.e. in the compressed air line. For these measurements accurate methods and instruments shall be used. At intervals these instruments shall be calibrated and checked against the methods described in ISO/R 541.

5.8.2 For the measurement of the air consumption ISO/R 541 can be used direct and in such cases no special calibrations are necessary if the recommendations are carefully followed.

5.8.3 Instruments with constant pressure differential and variable cross-section for the air stream can be used. This type of instrument normally has a body which is lifted up by the air stream in a converging (conical) tube, very often made of glass. This type is very simple to use but shall be carefully treated in order to avoid damage to the body and the tube, especially when starting the air flow. They shall therefore be checked and calibrated at intervals. If the meter is to be used with different air pressures it shall be calibrated at these pressures since a certain scale reading corresponds to different air flows. In addition, the temperature dependence of the meter shall be known.

5.8.4 Instruments based on partial flow measurements are not recommended but can be used if carefully calibrated and checked. This type of instrument is especially advantageous for large air flows.

5.8.5 The air consumption shall be reported in l/s of free air (for definition see 3.1.7) to obtain full agreement with ISO 1217. This makes it easy to compare compressor capacity with air consumption of pneumatic tools.

5.8.6 In most cases it can be assumed that the atmospheric conditions during testing will be equal to or near the standard test conditions (see 5.1.2), making the difference between free air capacity and the capacity measured under standard conditions negligible.

5.8.7 The air consumption of the tool shall thus be reported in volume flow l/s of the standard condition + 20 °C and 1 bar (1 l in this state is equal to 1,189 g of air).

5.8.8 If the compressed air conditions in the flow-meter deviate from those for which it was calibrated, the meter reading shall be corrected.

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If the meter reading gives the compressed air flow at any state other than standard condition according to 5.8.7, the flow is converted into standard conditions with the use of the general gas law :

$$q_{stand} = q_{test} \frac{p_{met}}{p_{stand}} \times \frac{T_{stand}}{T_{met}} = q_{test} \frac{p_{met}}{1} \times \frac{293}{T_{met}}$$

where

q_{stand} is volume flow of air in standard condition;

q_{test} is volume flow of air in test condition;

p_{met} is absolute pressure at meter calibration;

p_{stand} is absolute pressure at standard condition;

T_{stand} is absolute temperature at standard condition;

T_{met} is absolute temperature at meter calibration.

5.8.9 With a properly performed measurement of the air consumption, the result of the measurement can be assumed to have maximum deviation ± 5 % from the true volume.

5.8.10 In data tables, sales literature, etc., air consumption is given with the value of the upper tolerance limit ($\overline{\kappa} + r_{95}$ according to 5.1.8). New tool samples with an air consumption below this figure are acceptable in respect to the air consumption. Tools with a higher air consumption are not. According to how the $\overline{\kappa} + r_{95}$ value is derived, roughly 97,5 % of the manufactured tools can be expected to be acceptable and 2,5 % not.

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ANNEX A

FORMAT FOR PNEUMATIC TOOLS TEST REPORT

ROTARY TOOL

The following test has been made in accordance with International Standard ISO 2787.

1 Subject

Manufacturer . . . .

Type of machine . . . . Model . . . .

Serial No. . . . .

2 Operating conditions

Max. load/no load. Effective air pressure in inlet . . . . bar

Shaft speed . . . . min^{-1}

Compressed air temperature . . . . °C

Length of hose . . . . m Type of lubricant . . . .

3 Test conditions

Atmospheric pressure . . . . bar Ambient temperature . . . . °C

Relative humidity . . . . %

4 Instrumentation

. . . .

. . . .

. . . .

. . . .

. . . .

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5 Test results

5.1 Air consumption measured . . . . l/s Corrected . . . . l/s

$\bar{\kappa}$: . . . .

$\bar{\kappa} - r_{95}$: . . . . l/s $\bar{\kappa} + r_{95}$ . . . . l/s

} Information according to manufacturer's technical specification concerning air consumption

5.2 Revolutions per minute/torque measurement

shaft speed (min^{-1})						
torque (N·m)						
calculated power output (kW)						