

INTERNATIONAL
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5393

Second edition
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**Rotary tools for threaded fasteners —
Performance test method**

*Outils rotatifs pour éléments de fixation filetés — Méthode d'essai des
caractéristiques de fonctionnement*



Reference number
ISO 5393:1994(E)

Foreword

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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.

International Standard ISO 5393 was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*, Sub-Committee SC 3, *Pneumatic tools and machines*.

This second edition cancels and replaces the first edition (ISO 5393:1981), which has been technically revised.

Annexes A and B of this International Standard are for information only.

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International Organization for Standardization

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Introduction

The test method specified in this International Standard is designed to measure the capability of power assembly tools. It is not intended as a routine in-plant inspection test.

This International Standard is intended

- a) to give users of threaded fasteners a method for evaluating and specifying the performance of power assembly tools, and
- b) to enable the producers of power tools to offer their products under correlated technical specifications.

Rotary tools for threaded fasteners — Performance test method

1 Scope

This International Standard specifies a laboratory performance test method for power assembly tools for installing threaded fasteners. It gives instructions on what to test for and how to evaluate and present the test data.

It is applicable to tools which apply torque continuously. It is, however, not applicable to impact wrenches, ratchet wrenches or wrenches with ratcheting clutches, or other tools which advance fasteners in discontinuous increments, overcoming static friction at each increment, in particular because the applied torque of these tools cannot be measured using conventional types of instrumentation.

The test method is not intended as a routine in-plant inspection test.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 torque: Product of the force turning the fastener and the perpendicular distance between the line of force and the centre of the fastener.

It is expressed in newton metres (N·m).

3.2 angle: Measure of the angular displacement through which a fastener is turned.

It is expressed in degrees (°).

3.3 torque rate: Increase in torque with angular displacement while advancing a fastener in a threaded joint.

It is expressed in newton metres per revolution (N·m/rev).

3.4 mean torque, \bar{T} : Arithmetic average of several torque readings on a specific joint under stated conditions, calculated by dividing the sum of the readings by the number of readings.

3.5 range: For a group of readings, the numerical difference between the highest reading and the lowest reading.

3.6 standard deviation, s : Measure of the dispersion (scatter) based on the mean-squared deviation from the arithmetic mean derived from a sample of a statistical population.

3.7 six sigma, $6s$: Range of probability, plus and minus three standard deviations from the mean, derived from a sample of a statistical population. For a normally distributed statistical population, 99,73 % of all members of that population are encompassed.

3.8 $6s$ torque scatter: Predictable range of torque over which a tool will perform using a single torque-rate joint under controlled conditions. For a normally distributed statistical population, 99,73 % of all members of that population are encompassed.

For the practical purposes of this International Standard, $6s$ torque scatter is the total probable range of torque of a tool run on a single joint at the same setting of the tool torque adjustment.

3.9 6 σ torque scatter as a percentage of the mean torque: Single numerical value designating the torque capability of a tool run on a single torque-rate joint under controlled conditions.

3.10 mean shift: Difference in mean torque of a tool run on threaded joints of two different torque rates at the same setting of the tool torque adjustment.

3.11 combined torque scatter, ΔT_{comb} : Predictable range of torque over which a tool will perform, encompassing 99,73 % or more of all possible torque readings, taken on a range of joints of varying torque rate, from a defined high torque rate through and beyond a defined low torque rate.

For the practical purposes of this International Standard, combined torque scatter of a tool is the total probable range of torque of a tool run on all joints used in practice at the same setting of the tool torque adjustment.

3.12 combined mean torque, \bar{T}_{comb} : Midpoint of the combined torque scatter of a tool between the lowest and highest predictable torque readings, encompassing 99,73 % or more of all possible readings.

3.13 combined torque scatter as a percentage of the combined mean torque: Single numerical value designating the torque capability of a tool run on joints of varying torque rate, from a defined high torque rate through and beyond a defined low torque rate at the same setting of the tool torque adjustment.

3.14 stall-type tool: Power assembly tool for tightening threaded fasteners, which delivers an output torque as long as power is applied to the motor, via a valve or a switch.

For pneumatic stall tools the torque setting is accomplished through the setting of an air pressure regulator.

3.15 torque control tool: Power assembly tool for tightening threaded fasteners, which is provided with a torque control mechanism which shuts off or disconnects the power to the tool when a predetermined set output torque level is attained.

3.16 rated torque: Highest mean torque attainable by a tool tested on a low torque-rate joint (L) in accordance with this International Standard.

For pneumatic tools, it is necessary to state the inlet air pressure. If not stated, the inlet air gauge pressure is 6,3 bar¹⁾.

Electric and hydraulic tools shall be tested under rated input conditions.

3.17 test torque level: Specified mean torque level attainable on a low torque-rate joint (L) in accordance with this International Standard.

3.18 torque adjustment range: Range over which a power tool can be adjusted from the rated torque to the lowest mean torque recommended by the manufacturer.

NOTE 1 Adjustments can be made within the torque range by manipulating the torque control mechanism or, for some pneumatic tools, by adjusting the air pressure. Some pneumatic tools require adjustment of both the torque control mechanism and the air pressure to cover their adjustment range. Adjustments over the range may be continuous, or, in some tools, may be made in a finite number of steps.

4 Symbols

The subscript H is used to denote high torque-rate joints and the subscript L to denote low torque-rate joints as specified in 5.2.

5 Method for measurement of performance

5.1 General rules for performance tests

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

5.1.2 If torque output is adjusted by means other than by changing the air pressure, the adjustment shall be constant throughout the test and shall be such that the torque control mechanism operates each time.

5.1.3 The performance of pneumatic tools is affected by the ambient conditions such as atmospheric pressure and temperature. For this reason, the ambient conditions shall be kept within the limits specified in ISO 2787.

5.1.4 During performance tests of pneumatic tools, the air pressure at the inlet to a 3-metre hose of the tool manufacturer's specification attached to the tool inlet shall be kept within the following limits:

- free-running conditions: between the static value and -2% of the static value;
- approaching the test torque level: $\pm 1\%$ of the static value.

1) 1 bar = 0,1 MPa

NOTE 2 A lubricator with insufficient flow properties can affect these values.

No pressure adjustments shall be made during the course of a given test. An example of a suitable test installation is shown in figure 1.

5.1.5 During the test run of the tool, lubrication in accordance with the manufacturer's specification shall be provided.

5.2 Test joint

5.2.1 The torque increase with angular displacement, or torque rate, of a threaded joint varies widely from application to application and can vary appreciably on a specific assembly. Any test of torque performance of a tool shall be conducted on joints having controlled torque rates. The test shall include a joint having a low torque rate and a joint having a high torque rate (see 5.2.4). The high and low torque rates straddle the practical range of conditions which affect the torque output of the tool.

On a low torque-rate joint ("soft joint"), the tightening is usually accomplished with several revolutions of the fastener.

On a high torque-rate joint ("hard joint"), the tightening is accomplished in a fraction of a revolution. On a high torque-rate joint, the kinetic energy of the rotating parts of the tool may cause the torque delivered to the fastener to be higher than that on a low torque-rate joint.

5.2.2 To satisfy the conditions specified in 5.2.1, test fixtures for use with this International Standard shall comply with the following requirements.

- a) In a diagram where the required torque is plotted as a function of the angular displacement of the input drive of the test joint, the resulting curve shall be a straight line from 5 % to 100 % of the test torque level. The slope of this straight line is used to calculate the torque rate of the joint by regression analysis of the torque angle measurement points from 5 % to 100 % of the test torque level.

Between 5 % and 100 % of the test torque level, the values of the high torque-rate joint curve shall not deviate from a straight line by more than $\pm 2\%$ of the test torque level.

Between 5 % and 100 % of the torque level, the values of the low torque-rate joint curve shall not deviate from a straight line by more than $\pm 10\%$ of the test torque level.

- b) The moment of inertia of rotating parts in the test joint shall be small in relation to the effective moment of inertia of the rotating parts of the tool and shall have no effect on the measured mean torque of a test.

NOTE 3 The H and L test joints specified in this International Standard require higher precision than the test joints specified in the previous edition of this standard in order to achieve similar results. They better reflect the common extremes of actual fastening practice, so that the tool precision revealed through tests on these new joints can be applied to the range of fastening tasks encountered in the workplace.

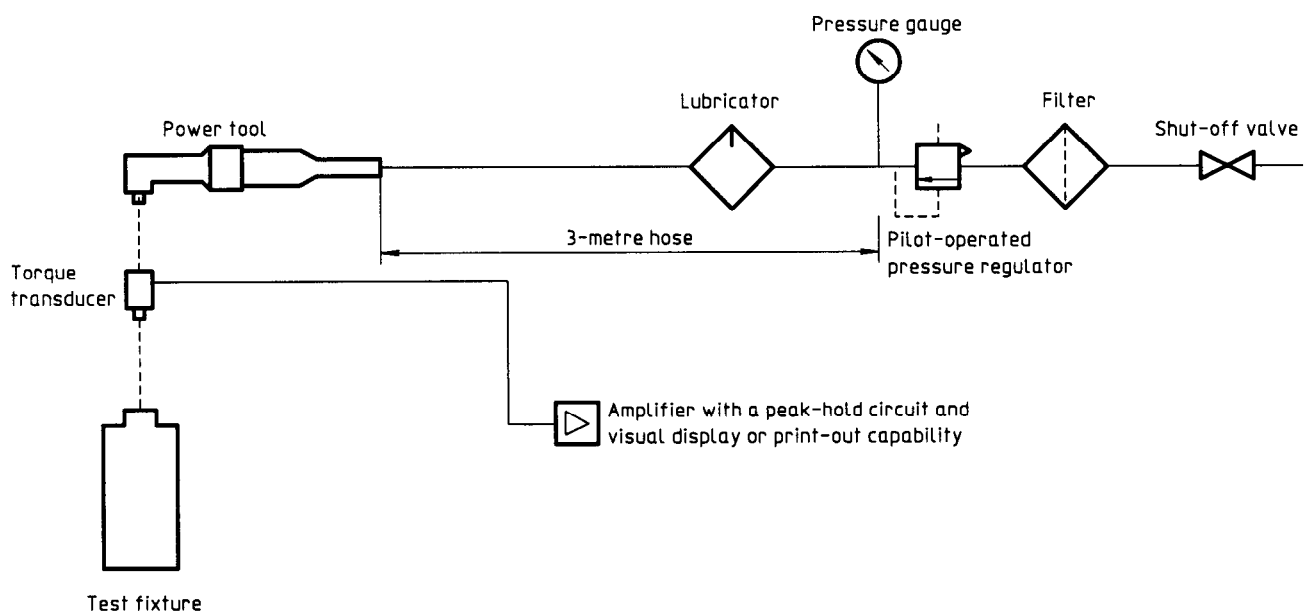


Figure 1 — Typical test installation

5.2.3 When the torque rate of a test joint is measured, the joint shall be tightened continuously (slowly and evenly) through a transducer-encoder. The encoder shall have a resolution of at least 0,5°. There shall be no rotational movement of the angle-sensing element during the measurement. The torque rate shall be independent of the applied rotational speed.

5.2.4 Each power assembly tool shall be tested on both a high (designated H) and a low (designated L) torque-rate joint, for which the following requirements are applicable.

- a) The test joint shall be such that the frictional load during run-down shall not exceed 5% of the test torque level.
- b) The high torque-rate joint (H) shall be such that the torque increase from 10 % to 100 % of the test torque level corresponds to an angular displacement of 27° (see figure 2).

NOTE 4 An angular displacement of 27° corresponds to a total angle of 30° at a test torque level between 0 and 100 %.

The transition angle from the 5 % to the 10 % test torque level shall not exceed 10° (see figure 2).

- c) The low torque-rate joint (L) shall be such that the torque increase from 10 % to 100 % of the test torque level shall not exceed 650° (see figure 2).

torque level corresponds to an angular displacement of not less than 650° (see figure 2).

NOTE 5 An angular displacement of 650° corresponds to a total angle of 720° at a test torque level between 0 and 100 %.

5.3 Test method

5.3.1 This International Standard recognizes that static, residual torque measurements give poor correlation to joint condition (tension). Therefore, all performance measurements made in accordance with this International Standard shall be taken dynamically during the tightening process.

Torque measurements shall be made by means of a rotary torque transducer and an amplifier with a peak hold circuit and visual display or print-out capability. The transducer shall be mounted in line between the tool drive and the test joint (see figure 1). The frequency response of the transducer and amplifier shall be -3 dB at 500 Hz, with a roll-off of at least 50 dB/decade.

The accuracy of the transducer and amplifier shall be within ± 1 % of the test torque level. The transducer shall be of the correct capacity for the test torque levels measured.

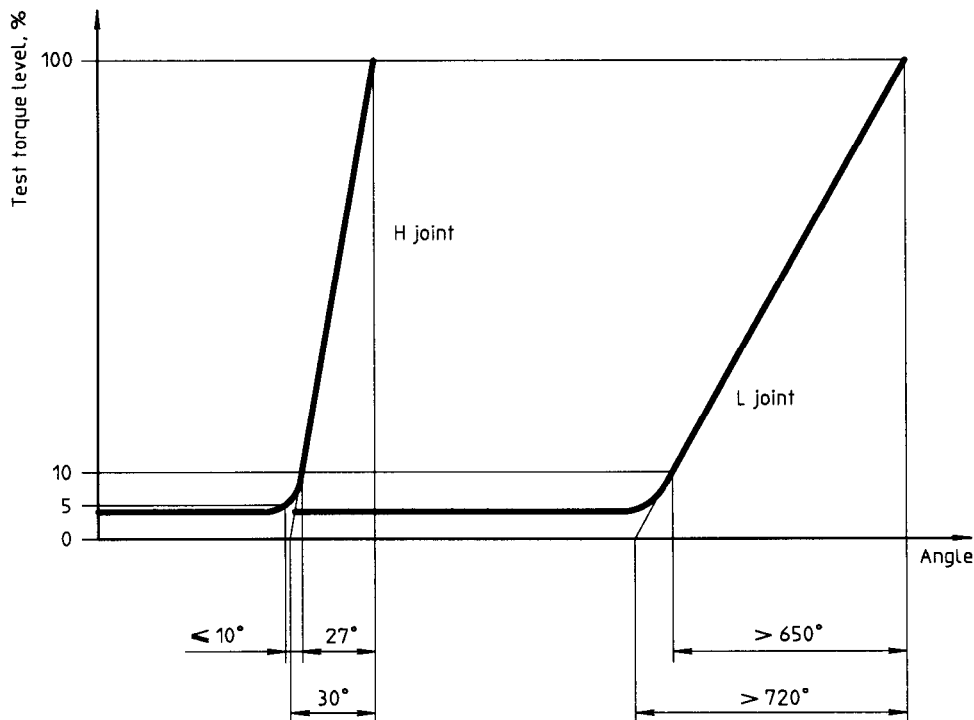


Figure 2 — Diagram showing torque versus angle curves for high (H) and low (L) torque-rate joints

The tool shall be rigidly fixed in the test stand to prevent any influence by the operator.

5.3.2 A tool performance test shall consist of 25 readings on each of the H and L joints.

5.3.3 In all test runs, the tool shall be allowed at least three full turns of free-running before reaching the torque rate of the test joint.

6 Evaluation of test results

6.1 For evaluating tool performance on each of the H and L joints, the following shall be calculated from the test results:

- mean torque, \bar{T} ;
- range;
- standard deviation, s ;
- $6s$ torque scatter (as an estimator of the 6 sigma torque scatter);
- $6s$ torque scatter as a percentage of the mean torque.

The mean torque \bar{T} is calculated as follows:

$$\bar{T} = \frac{1}{n} \sum_{i=1}^n T_i$$

where

- n is the number of readings;
- T_i is the torque measured on the i th reading.

The range is calculated by subtracting the lowest torque reading from the highest torque reading.

The standard deviation is calculated as follows:

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (T_i - \bar{T})^2}$$

The $6s$ torque scatter as a percentage of the mean torque is given by the formula

$$100 \times \frac{6s}{\bar{T}}$$

6.2 Since joints of uniform torque rate are very rarely used in practical applications, the tool performance on a single torque-rate joint such as H or L is of limited use in evaluating how a tool will perform in actual use. However, since joints H and L straddle the range of torque rates found in actual applications, an analysis combining tool performance on the two test joints will yield an evaluation of the tool performance on all actual applications within that range.

For evaluating tool performance over the range of practical torque rates from H through L, the following shall be calculated and listed:

- combined mean torque;
- mean shift;
- combined torque scatter;
- combined torque scatter as a percentage of the combined mean torque.

For use in the calculations given below, the following values are defined:

$$a = \bar{T}_H + 3s_H$$

$$b = \bar{T}_L + 3s_L$$

$$c = \bar{T}_H - 3s_H$$

$$d = \bar{T}_L - 3s_L$$

The combined mean torque \bar{T}_{comb} is calculated as the higher of a and b plus the lower of c and d , divided by 2.

The mean shift is calculated as $\bar{T}_H - \bar{T}_L$.

The combined torque scatter ΔT_{comb} is calculated as the higher of a and b minus the lower of c and d .

The combined torque scatter as a percentage of the combined mean torque is given by the following formula:

$$100 \times \frac{\Delta T_{\text{comb}}}{\bar{T}_{\text{comb}}}$$

6.3 Tool torque scatter capability (as defined in 3.4 to 3.13) may be identified over all or part of a tool's torque adjustment range. To find a tool's torque scatter capability over a defined range of torque, two tool performance tests shall be carried out on both the high torque-rate joint (H) and the low torque-rate joint (L), one test being at the test torque level of the upper limit of the defined torque range, and the other test being at the test torque level of the lower limit.

The tool capability over a defined range of torque shall be reported as shown in clause 7.

If a single tool torque scatter capability value (combined torque scatter as a percentage of the combined mean torque) is to be presented for the defined range of torques, the larger capability value at either test torque level shall be chosen.

7 Presentation of data

The performance test data shall be presented as shown below.

Performance test form

Manufacturer: Date:
 Serial number: Model:
 Type of tool:

I. Upper test torque level N·m

high torque rate (H) N·m/rev, corresponding to a tightening angle °
 low torque rate (L) N·m/rev, corresponding to a tightening angle °
 idle speed rev/min; air pressure bar; voltage V

	H	L
mean torque	..... N·m	..... N·m
range	..... N·m	..... N·m
standard deviation, <i>s</i>	..... N·m	..... N·m
6 <i>s</i> torque scatter	..... N·m	..... N·m
6 <i>s</i> scatter % of mean torque % %

	H + L
combined mean torque	..... N·m
mean shift	..... N·m
combined torque scatter	..... N·m
combined torque scatter % of combined mean torque %

II. Lower test torque level N·m

high torque rate (H) N·m/rev, corresponding to a tightening angle °
 low torque rate (L) N·m/rev, corresponding to a tightening angle °
 idle speed rev/min; air pressure bar; voltage V

	H	L
mean torque	..... N·m	..... N·m
range	..... N·m	..... N·m
standard deviation, <i>s</i>	..... N·m	..... N·m
6 <i>s</i> torque scatter	..... N·m	..... N·m
6 <i>s</i> scatter % of mean torque % %

	H + L
combined mean torque	..... N·m
mean shift	..... N·m
combined torque scatter	..... N·m
combined torque scatter % of combined mean torque %

III. Tool torque scatter capability

If a single tool torque scatter capability value (combined torque scatter as a percentage of the combined mean torque) is to be presented for the defined range of torques, the larger capability value at either test torque level shall be chosen.

Tool torque scatter capability over the defined torque range %

Tested in accordance with ISO 5393:1994

Tested by

Annex A (informative)

Rotary tools for threaded fasteners — Performance test method

A.1 Background

The development of power assembly tools during the 1980s has been rapid and their performance has been improved. On a specified joint, torque scatters (6σ) of less than 15 % are obtainable. This calls for precise specifications of the test requirements. These are reflected in this new edition of ISO 5393. The precise specifications refer to the requirements of the linearity of the high torque rate test joint and the frequency response of the transducer and amplifier connected to the in-line torque transducer used. Furthermore, the high torque rate joint of this second edition of ISO 5393 has its torque rate doubled compared to the first edition. This is because many joints in reality have torque rates corresponding to tightening angles of 30° .

We hope that this report will explain to the user of the standard why the new rigorous demands for test joint linearity are necessary. Furthermore, it has been commented that the test method has become a "laboratory test method". This may be the consequence of the standard, but with today's development of accurate power tools, test requirements have to be accurate to reflect the capability of the tools. A producer of power assembly tools would have this type of test equipment as part of his development laboratory.

A.2 Test joint (see 5.2)

A.2.1 High torque rate test joint

It is important that the test joint used is precisely specified to obtain consistent results when tools are tested on different joints with the same specification. The tightening process from the rundown to the test torque level is greatly affected by the linearity of the test joints.

A process such as (a) in figure A.1 would retard the tool at the beginning of the tightening. Thereby, the kinetic energy stored in the rotating parts is reduced when the test torque level is reached. A torque overshoot is then not likely to occur. A process such as (b), however, would be the opposite. The speed of the rotating parts would be high when the test torque level is reached. Thereby, the torque overshoot, i.e.

the additional torque obtained due to the kinetic energy conversion, would be high. Mathematical simulations have proven that a linearity demand of $\pm 2\%$ of the test torque level above the 5 % level of the test torque is adequate (see figure A.2).

A linearity of this order of magnitude is obtainable with steel torsion bar test joints. In view of the friction in the test joint, the linearity demand starts at the 5 % level.

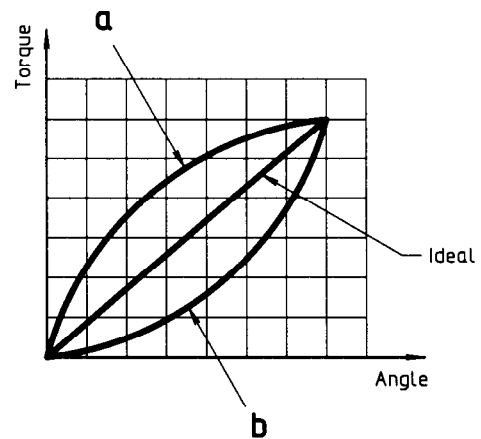


Figure A.1

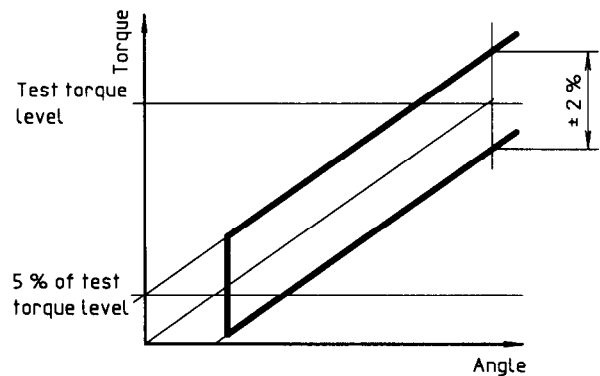


Figure A.2

When the torque rate of the test joint is measured, it shall be tightened continuously (slowly and evenly) to avoid introduction of dynamic effects. The measurements shall be carried out with a torque/angle encoder with a resolution of $0,5^\circ$ or better ($0,5^\circ$ corresponds to 60 sampled points to reach the test torque level). This means a resolution of $1/60 = 1,7\%$. An encoder with 1° resolution would not be sufficient ($1/30 = 3,3\%$ which is larger than the required 2%). The linearity of the test joints is calculated by a regression analysis of the sampled torque/angle measurement values.

A.2.2 Low torque rate test joint

The low torque rate joint shall be such that the rotational speeds of the moving parts are so small that torque overshoots do not occur when reaching the test torque level. In practice, this is readily achieved with tightening angles corresponding to two or three turns of the fastener.

A.2.3 Rundown phase

It is important that the rundown torque of the power tool is low enough that its speed is not significantly reduced. Otherwise the kinetic energy of its rotating parts would be reduced too much when the test torque level is reached. Therefore, it has been specified that the torque level of the rundown phase must not exceed 5% of the test torque level (see figure A.3).

A.3 Test method (see 5.3)

The frequency response of the amplifier of the torque transducer shall be -3 dB at 500 Hz with roll-off of at least 50 dB/decade. This is accomplished with a third-order filter of Butterworth type. This filter improves the method considerably, as the first edition of this International Standard did not require the roll-off. The choice of the frequency of 500 Hz is based on a series of tightening experiments. Fourier analysis of torque signals has proven that the energy content of the signal above 500 Hz does not contribute to the

energy transmitted to the joint. A 500 Hz third-order filter decreases or eliminates spurious signals that may originate from the clutch mechanism of certain tools. The combined accuracy of the transducer-amplifier shall be within $\pm 1\%$ of the test torque level. This is accomplished using commercially available products. It is important to use transducers with a capacity as close as possible to the test torque level in order to obtain maximum accuracy.

A.4 Lubrication of the pneumatic tool

It is important that pneumatic tools are adequately lubricated during tests. Experiments have shown that insufficient lubrication may affect the tool scatter, especially on the low torque rate joint.

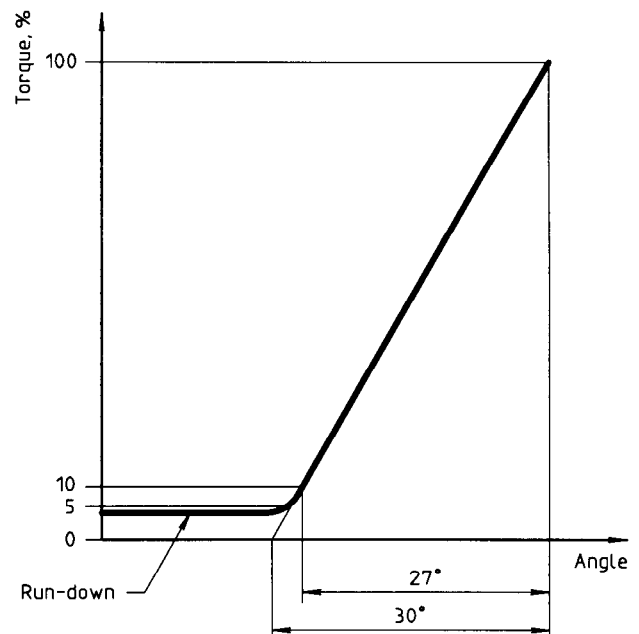


Figure A.3

Annex B (informative)

Bibliography

- [1] ISO 31-0:1992, *Quantities and units — Part 0: General principles*, plus all other parts of ISO 31.
- [2] ISO 1000:1992, *SI units and recommendations for the use of their multiples and of certain other units*.
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