INTERNATIONAL STANDARD

ISO 376

Second edition
1999-08-15

Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines

Matériaux métalliques — Étalonnage des instruments de mesure de force utilisés pour la vérification des machines d'essais uniaxiaux

Reference number
ISO 376:1999(E)

Contents

Page

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 376 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This second edition cancels and replaces the first edition (ISO 376:1987) which has been technically revised.

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

Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines

1 Scope

This International Standard covers the calibration of force-proving instruments used for the static verification of uniaxial testing machines (e.g. tension/compression testing machines) and describes a procedure for classifying these instruments. A force-proving instrument is defined as being the whole assembly from the force transducer through to and including the indicator. This International Standard generally applies to force-proving instruments in which the force is determined by measuring the elastic deformation of a loaded member or a quantity which is proportional to it.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system.*

3 Principle

Calibration consists of applying precisely-known forces to the loaded member and recording the data from the deflection measuring system, which is considered an integral part of the force-proving instrument.

When an electrical measurement is made, the indicator may be replaced by another indicator and the force-proving instrument need not be recalibrated provided the following conditions are fulfilled.

a) The original and replacement indicators have calibration certificates traceable to national standards which give the results of calibration in terms of electrical base units (volt, ampere). The replacement indicator shall be calibrated over a range equal to or greater than the range for which it is used with the force-proving instrument and the resolution of the indicator shall be at least equal to the resolution of the indicator when it is used with the force-proving instrument.

b) The units and excitation source of the replacement indicator should be respectively of the same quantity (e.g. 5 V, 10 V) and type (e.g. AC or DC carrier frequency).

c) The uncertainty of each indicator (both the original and the replacement indicators) shall not influence the uncertainty of the whole assembly of the force-proving instrument. It is recommended that the uncertainty of the replacement indicator should be no greater than 1/3 of the uncertainty of the entire system.

4 Characteristics of force-proving instruments

4.1 Identification of the force-proving instrument

All the elements of the force-proving instrument (including the cables for electrical connection) shall be individually and uniquely identified, e.g. by the name of the manufacturer, the model and the serial number. For the force transducer, the maximum working force shall be indicated.

4.2 Application of force

The force transducer and its loading fittings shall be designed so as to ensure axial application of force, whether in tension or compression.

Examples of loading fittings are given in annex A.

4.3 Measurement of deflection

Measurement of the deflection of the loaded member of the force transducer may be carried out by mechanical, electrical, optical or other means with adequate accuracy and stability.

The type and the quality of the deflection measuring system determine whether the force-proving instrument is classified only for specific calibration forces or for interpolation (see clause 7).

Generally, the use of force-proving instruments with dial gauges as a means of measuring the deflection is limited to the forces for which the instruments have been calibrated. The dial gauge, if used over a long travel, may contain large localised periodic errors which produce an uncertainty too great to permit interpolation between calibration forces. The dial gauge may be used for interpolation if its periodic error has a negligible influence on the interpolation error of the force-proving instrument.

5 Symbols, units and designations

For the purpose of this International Standard, the symbols, units and designations given in Table 1 shall apply.

Table 1 — Symbols, units and designations

Symbol	Unit	Designation
F_N	N	Maximum capacity of the measuring range
F_f	N	Maximum capacity of the transducer
i_o	–	Reading[a] on the indicator before application of force
i_f	–	Reading[a] on the indicator after removal of force
X	–	Deflection with increasing test force
X'	–	Deflection with decreasing test force
$\bar{X}_r$	–	Average value of the deflections with rotation
$\bar{X}_{wr}$	–	Average value of deflections without rotation
X_{max}	–	Maximum deflection
X_{min}	–	Minimum deflection
X_a	–	Computed value of deflection
X_N	–	Deflection corresponding to the maximum capacity
b	%	Relative reproducibility error with rotation
b'	%	Relative repeatability without rotation
f_o	%	Relative zero error
f_c	%	Relative interpolation error
r	–	Resolution of the indicator
v	%	Relative reversibility error of the force-proving instrument

a Reading value corresponding to the deflection.

6 Calibration of the force-proving instrument

6.1 General

Before undertaking the calibration of the force-proving instrument, ensure that this instrument is able to be calibrated. This can be done by means of preliminary tests such as those defined below and given as examples.

6.1.1 Overloading test

This optional test is described in clause B.1.

6.1.2 Verification relating to application of forces

Ensure

— that the attachment system of the force-proving instrument allows axial application of the force when the instrument is used for tensile testing;

— that there is no interaction between the force transducer and its support on the calibration machine when the instrument is used for compression testing.

Clause B.2 gives an example of a method which can be used.

NOTE Other methods can be used, e.g. a method using a flat-based transducer with a spherical button or upper bearing surface.

6.1.3 Variable voltage test

This test is left to the discretion of the calibration service. For force-proving instruments requiring an electrical supply, verify that a variation of ± 10 % of the line voltage has no significant effect. This verification can be carried out by means of a force transducer simulator or by another appropriate method.

6.2 Resolution of the indicator

6.2.1 Analogue scale

The thickness of the graduation marks on the scale shall be uniform and the width of the pointer shall be approximately equal to the width of a graduation mark.

The resolution (r) of the indicator shall be obtained from the ratio between the width of the pointer and the centre-to-centre distance between two adjacent scale graduation marks (scale interval), the recommended ratios being 1/2, 1/5 or 1/10, a spacing of 1,25 mm or greater being required for the estimation of a tenth of the division on the scale.

A vernier scale of dimensions appropriate to the analogue scale may be used to allow direct fractional reading of the instrument scale division.

6.2.2 Digital scale

The resolution is considered to be one increment of the last active number on the numerical indicator, provided that the indication does not fluctuate by more than one increment with no force applied to the instrument.

6.2.3 Variation of readings

If the readings fluctuate by more than the value previously calculated for the resolution (with no force applied to the instrument), the resolution shall be deemed to be equal to half the range of fluctuation.

6.2.4 Units

The resolution (r) shall be converted to units of force.

6.3 Minimum force

Taking into consideration the accuracy with which the deflection of the instrument may be read during calibration or during its subsequent use for verifying machines, the minimum force applied to a force-proving instrument shall comply with the two following conditions:

a) the minimum force shall be greater than or equal to:

- $4\,000 \times r$ for class 00
- $2\,000 \times r$ for class 0,5
- $1\,000 \times r$ for class 1
- $500 \times r$ for class 2

b) the minimum force shall be greater than or equal to 0,02 F_f.

6.4 Calibration procedure

6.4.1 Preloading

Before the calibration forces are applied, in a given mode (tension or compression), the maximum force shall be applied to the instrument three times. The duration of the application of each preload shall be between 1 min and 1,5 min.

6.4.2 Procedure

The calibration shall be carried out by applying two series of calibration forces to the force-proving instrument with increasing values only, without disturbing the device.

Then apply at least two further series of increasing and decreasing values. Between each of the further series of forces, the force-proving instrument shall be rotated symmetrically on its axis to positions uniformly distributed over 360° (i.e. 0°, 120°, 240°). If this is not possible, it is permissible to adopt the following positions: 0°, 180° and 360° (see Figure 1).

For the determination of the interpolation curve, the number of forces shall be not less than eight, and these forces shall be distributed as uniformly as possible over the calibration range.

NOTE 1 If a periodic error is suspected, it is recommended that intervals between the forces which correspond to the periodicity of this error should be avoided.

NOTE 2 This procedure determines only the maximum hysteresis of the device. Accurate determination of the hysteresis can only be performed on dead-weight machines.

The force-proving instrument shall be pre-loaded three times to the maximum force in the direction in which the subsequent forces are to be applied. When the direction of loading is changed, the maximum force shall be applied three times in the new direction.

The readings corresponding to no force shall be noted after waiting at least 30 s after the force has been totally removed.

NOTE 3 There should be a wait of at least 3 min between subsequent measurement series.

Instruments with detachable parts shall be dismantled, as for packaging and transport, at least once during calibration. In general, this dismantling shall be carried out between the second and third series of calibration forces. The maximum force shall be applied to the force-proving instrument at least three times before the next series of forces is applied.

Before starting the calibration of an electrical force-proving instrument, the zero signal may be noted (see clause B.3).

6.4.3 Loading conditions

The time interval between two successive loadings shall be as uniform as possible, and no reading shall be taken at least 30 s after the start of the force change. The calibration shall be performed at a temperature stable to ± 1 °C, this temperature shall be within the range 18 °C to 28 °C and shall be recorded. Sufficient time shall be allowed for the force-proving instrument to attain a stable temperature.

NOTE When it is known that the force-proving instrument is not temperature compensated, care should be taken to ensure that temperature variations do not affect the calibration.

Strain gauge transducers shall be energized for at least 30 min before calibration.

6.4.4 Determination of deflection

A deflection is defined as the difference between a reading under force and a reading without force.

NOTE This definition of deflection applies to output readings in electrical units as well as to output readings in length units.

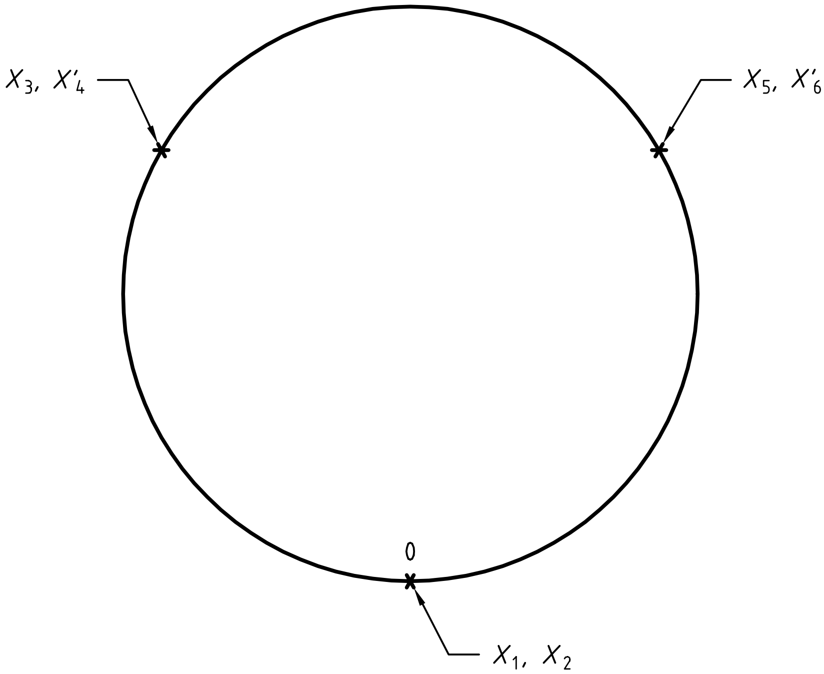

Figure 1 — Positions of the force-proving instrument

6.5 Assessment of the force-proving instrument

6.5.1 Relative reproducibility and repeatability errors, b and b'

These errors are calculated for each calibration force and in the two cases: with rotation of the proving instrument (b) and without rotation (b'), using the following equations:

$$b = \left| \frac{X_{\text{max}} - X_{\text{min}}}{\bar{X}_{\text{r}}} \right| \times 100$$

where

$$\bar{X}_{\text{r}} = \frac{X_1 + X_3 + X_5}{3}$$

$$b' = \left| \frac{X_2 - X_1}{\bar{X}_{\text{wr}}} \right| \times 100$$

where

$$\bar{X}_{\text{wr}} = \frac{X_1 + X_2}{2}$$

6.5.2 Relative interpolation error, f_c

This error is determined using a first-, second-, or third-degree equation giving the deflection as a function of the calibration force.

NOTE For other methods of determining this error, see the Bibliography.

The equation used shall be indicated in the calibration report. The relative interpolation error shall be calculated from the equation:

$$f_c = \frac{\overline{X}_r - X_a}{X_a} \times 100$$

6.5.3 Relative zero error, f_o

The zero shall be adjusted before and recorded after each series of tests. The zero reading shall be taken approximately 30 s after the force has been completely removed.

The relative zero error is calculated from the equation:

$$f_o = \frac{i_f - i_o}{X_N} \times 100$$

6.5.4 Relative reversibility error, v

The relative reversibility error is determined at each calibration, by carrying out a verification with increasing forces and then with decreasing forces.

NOTE If determination of the relative reversibility error is not practical, a note in the calibration certificate should state that the device has been calibrated with increasing forces only.

The difference between the values obtained for both series with increasing force and with decreasing force enables the relative reversibility error to be calculated using the following equations:

$$v_1 = \left| \frac{X_4' - X_3}{X_3} \right|$$

$$v_2 = \left| \frac{X_6' - X_5}{X_5} \right|$$

v is calculated as the mean value of v_1 and v_2:

$$v = \frac{v_1 + v_2}{2}$$

7 Classification of the force-proving instrument

7.1 Principle of classification

The range for which the force-proving instrument is classified is determined by considering each calibration force, one after the other, starting with the maximum force and decreasing to the lowest calibration force. The classification range ceases at the last force for which the classification requirements are satisfied.

The force-proving instrument can be classified either for specific forces or for interpolation.

7.2 Classification criteria

The range of classification of a force-proving instrument shall at least cover the range 50 % to 100 % of F_N.

7.2.1 For instruments classified only for specific forces, the criteria which shall be considered are:

— the relative reproducibility and repeatability errors;

— the relative zero error;