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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

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

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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.

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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 376 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals.*

It cancels and replaces ISO Recommendation R 376 : 1964, of which it constitutes a technical revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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

1 Scope and field of application

This International Standard covers the calibration of force-proving instruments used for the static verification of uniaxial testing machines (e.g. tensile testing machine) and describes a procedure for classifying these instruments. The force-proving instrument is defined as being the whole assembly from the force transducer through 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 Principle

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

When an electrical measurement is made, the indicator may be replaced by an indicator that can be shown to have an equal uncertainty of measurement.

3 Characteristics of force-proving instruments

3.1 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, for example, by the name of the manufacturer, the model and the serial number. For the force transducer, the maximum working force shall be indicated.

3.2 Application of force

The force transducer shall be designed so as to permit axial application of force, whether tensile or compressive.

3.3 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 an 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 6).

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. In fact, the dial gauge is used over a long travel and can contain large localized periodic errors which produce an uncertainty too great to permit interpolation between calibration forces. Nevertheless, it may be used for interpolation if the characteristics of the dial gauge have been determined previously, and its periodic error has a negligible influence on the interpolation error of the force-proving instrument.

4 Symbols, units and definitions

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

Table 1 — Symbols, units and definitions

Symbol	Unit	Definition
F_N	N	Maximum capacity of the measuring range
F_f	N	Maximum capacity of the transducer
X	—	Reading[1)] on the indicator with increasing test force
$\overline{X}$	—	Average value of the readings[1)] on the indicator
X'	—	Reading[1)] on the indicator with decreasing test force
X_{max}	—	Maximum reading[1)] on the indicator
X_{min}	—	Minimum reading[1)] on the indicator
X_a	—	Computed value of deflection
X_{io}	—	Reading[1)] on the indicator before application of force
X_{if}	—	Reading[1)] on the indicator after removal of force
X_N	—	Reading[1)] on the indicator, corresponding to the maximum capacity
b	%	Relative repeatibility error of the force-proving instrument
f_o	%	Relative zero error
f_c	%	Relative interpolation error
r	—	Resolution of the indicator
u	%	Relative reversibility error of the force-proving instrument

1) Reading value corresponding to the deflection.

5 Verification of the force-proving instrument

5.1 General

Before undertaking the calibration of the force-proving instrument, it shall be ensured 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.

5.1.1 Overloading test

This optional test is described in the annex, clause A.1.

5.1.2 Verification relating to application of forces

It shall be ensured

- that the attachment system of the force-proving instrument allows axial application of the load where 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.

The method described in the annex, clause A.2, is an example of a method which can be used.

5.1.3 Variable voltage test

This test is left to the discretion of the calibration service. For the force-proving instruments requiring an electrical power supply for the electrical circuits connected, it shall be verified 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.

5.2 Resolution of the indicator

5.2.1 Analog 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 ratios 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.

5.2.2 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 when the instrument is unloaded.

5.2.3 Variation of readings

If the readings fluctuate by more than the value previously calculated for the resolution (with the instrument unloaded), the resolution shall be deemed to be equal to half the range of fluctuation.

5.2.4 Units

The resolution shall be converted to units of force.

5.3 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

2 000 × r for the class 0

1 000 × r for the class 1

500 × r for the class 2

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

5.4 Test procedure

5.4.1 Preloading

Before the calibration forces are applied, the maximum force shall be applied to the instrument three times. The duration of the application of each preload shall be between 1 and 1 1/2 min.

5.4.2 Procedure

The calibration shall be carried out by applying to the proving instrument at least three series of calibration forces with increasing values and, if necessary, with decreasing values. Between each series of forces, the proving instrument should be turned on its axis so as to occupy during the calibration at least three positions uniformly distributed over 360° (i.e. 0°, 120°, 240°). When this is not possible, it is permissible to adopt the following three positions: 0°, 180° and 360°.

For the determination of the interpolation curve, the number of forces shall be not less than 8, and these forces shall be distributed as uniformly as possible over the calibration range.

NOTE — If a periodic error is suspected, it is recommended to avoid intervals between the forces which correspond to the periodicity of this error.

For force-proving instruments intended to be used in two modes (in tension and in compression), the calibration sequence shall be as follows:

- two series of forces in compression;
- three series of forces in tension;
- one series of forces in compression.

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 and, in the same way, when the direction of loading is changed, the maximum force is applied three times in the new direction.

Between loadings, the readings corresponding to no load after waiting at least 30 s for the return to zero shall be noted.

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

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

5.4.3 Loading conditions

The time-interval between two successive loadings shall be as uniform as possible, and no reading shall be taken less than 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 to 28 °C and 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 not less than 30 min before calibration.

5.4.4 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 at readings in length units.

5.5 Assessment of the force-proving instrument

5.5.1 Relative repeatability error, b

The relative repeatability error is, for each calibration force, the difference between the highest and lowest values with respect to the average. This is calculated using the equation

$$b = \frac{X_{max} - X_{min}}{\bar{X}} \times 100$$

where

$$\bar{X} = \frac{X_1 + X_2 + X_3}{3}$$

5.5.2 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. The equation used shall be indicated in the calibration report:

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

5.5.3 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 is completely removed.

The relative zero error is calculated from the equation

$$f_o = \frac{X_{if} - X_{io}}{X_N} \times 100$$

5.5.4 Relative reversibility error, u

This determination is only carried out on request. The relative reversibility error is determined, at each calibration, by carrying out a verification with increasing forces and then with decreasing forces.

The difference between the values obtained with increasing force and with decreasing force enables the relative reversibility error to be calculated using the equation

$$u = \frac{X' - X}{X} \times 100$$

6 Classification of the force-proving instrument

6.1 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 from this 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.

6.2 Classification criteria

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

6.2.1 For instruments classified only for specific forces, the criteria which shall be taken into consideration are

- the relative repeatability error;
- the relative zero error;
- the relative reversibility error, when required.

6.2.2 For instruments classified for interpolation, the following criteria shall be taken into consideration:

- the relative repeatability error;
- the relative interpolation error;
- the relative zero error;
- the relative reversibility error, when required.

Table 2 gives the values of these different parameters in accordance with the class of the force-proving instrument as with the uncertainty of the calibration forces.

Table 2 — Characteristics of force-proving instruments

Class	Maximum permissibles values of the force-proving instrument, %				Calibration force
	Relative error				Uncertainty (%)
	of repeatability b	of interpolation f_c	of zero f_o	of reversibility[1)] u	
0	0,10	± 0,05	± 0,05	0,15	± 0,025
1	0,20	± 0,10	± 0,10	0,30	± 0,05
2	0,40	± 0,20	± 0,20	0,50	± 0,10

1) The verification of reversibility shall only be carried out on request.

6.3 Calibration certificate and duration of validity

6.3.1 If a force-proving intrument has satisfied the requirements of this International Standard at the time of calibration, the calibration authority shall draw up a certificate stating the following information:

a) identity of all the elements of the force-proving instrument and loading attachments and of the calibration machine;

b) the method of force application (tension-compression);

c) that the instrument is in accordance with the requirements of preliminary tests;

d) the class and the range (or forces) of validity;

e) the results of the calibration and, when required, the calibration curve;

f) the temperature at which the calibration was performed.

6.3.2 For the purposes of this International Standard, the maximum period of validity of the certificate shall not exceed 26 months.

A force-proving instrument shall be recalibrated when it sustains an overload higher than the test overload (see the annex, clause A.1) or after repair.

7 Use of calibrated force-proving instruments

Force-proving instruments shall be loaded in accordance with the conditions for which they were calibrated. Precautions shall be taken to prevent the instrument from being subjected to forces greater than the maximum calibration force.

Instruments classified only for specific forces shall be used only for these forces.

Instruments classified for interpolation may be used for any force in the interpolation range.

If a force-proving instrument is used at a temperature other than the calibration temperature, the deflection of the instrument shall be, if necessary, corrected for any temperature variation in accordance with the equation

$$D_t = D_e [1 + K(t - t_e)]$$

where

D_t is the deflection at the temperature t °C;

D_e is the deflection at the calibration temperature t_e °C;

K is the temperature coefficient of the instrument, in reciprocal degrees Celsius.

For instruments other than those having a force transducer with electrical outputs made of steel containing not more than 7 % of alloy elements, the value K = 0,000 27/°C may be used.

For instruments made of material other than steel or which include force transducers with electrical outputs, the value K shall be determined experimentally and shall be provided by the manufacturer. The value used shall be stated on the calibration certificate of the instrument.

Table 3 gives the deflection corrections for instruments of the first type. These corrections were obtained with K = 0,000 27/°C.

NOTE — When the instrument is made of steel and the deflection is measured in units of length, the temperature correction is equal to approximately 0,001 for each variation of 4 °C.

Most force transducers with electrical outputs are thermally compensated.

Generally, it is sufficient to measure the temperature of the device to 1 °C (see the note in 5.4.3).

Table 3 — Deflection correction for temperature variations of a steel force-proving instrument
(not including force transducer with electrical outputs)

Deflection corrections (divisions)	Temperature variation in relation to the calibration temperature							
	1 °C	2 °C	3 °C	4 °C	5 °C	6 °C	7 °C	8 °C
	Maximum deflections to which correction is applied (divisions)							
0,0	185	92	61	46	37	30	26	23
0,1	555	277	185	138	111	92	79	69
0,2	925	462	308	231	185	154	132	115
0,3	1 296	648	432	324	259	216	185	162
0,4	1 666	833	555	416	333	277	238	208
0,5	2 037	1 018	679	509	407	339	291	234
0,6		1 203	802	601	481	401	343	300
0,7		1 388	925	694	555	462	396	347
0,8		1 574	1 049	787	629	524	449	393
0,9		1 759	1 172	879	703	586	502	439
1,0		1 944	1 296	972	777	648	555	486
1,1		2 129	1 419	1 064	851	709	608	532
1,2			1 543	1 157	925	771	661	578
1,3			1 666	1 250	999	833	714	625
1,4			1 790	1 342	1 074	895	767	671
1,5			1 913	1 435	1 148	956	820	717
1,6			2 037	1 527	1 222	1 018	873	763
1,7			2 160	1 620	1 296	1 080	925	810
1,8				1 712	1 370	1 141	978	856
1,9				1 805	1 444	1 203	1 031	902
2,0				1 898	1 518	1 265	1 084	949
2,1				1 990	1 592	1 327	1 137	995
2,2				2 083	1 666	1 388	1 190	1 041
2,3					1 740	1 450	1 243	1 087
2,4					1 814	1 512	1 296	1 134
2,5					1 888	1 574	1 349	1 180

If a deflection has been measured with a force-proving instrument at a temperature greater than the calibration temperature and it is desired to obtain the deflection of the instrument for the calibration temperature, the deflection correction given in the table shall be deducted from the deflection measured.

When measurement is carried out with a force-proving instrument at a temperature lower than the calibration temperature, the correction shall be added.

EXAMPLE:

temperature of the force-proving instrument: 22 °C
deflection observed: 729,6 divisions
calibration temperature: 20 °C
temperature variation: 22 − 20 = + 2 °C

In the column corresponding to the variation of + 2 °C, the nearest deflection which exceeds 729,6 divisions is 833 divisions. For this value of deflection, table 3 gives a correction of 0,4 division.

The corrected deflection is 729,6 − 0,4 = 729,2 divisions.