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Indian Standard

METHOD FOR CALIBRATION OF FORCE-PROVING INSTRUMENTS USED FOR THE VERIFICATION OF UNIAXIAL TESTING MACHINES

(First Revision)

Methods of Physical Tests Sectional Committee, SMDC 3 [Ref : Doc : SMDC 3 (3244)]

1. Scope — This standard covers the method for calibration of force-proving instruments used for the static verification of uniaxial testing machines (for example, 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 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.

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

3. Characteristics of Force-Proving Instruments

3.1 *Identification of the Force-Proving Instruments* — 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 as to permit axial application of force, whether tensile or compressive.

3.3 *Measurement of Deflection*

3.3.1 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.

3.3.2 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* **6**).

3.3.3 Generally the use of force-proving instruments with dial gauges as a means of measuring the deflection is limited to the force 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 and Definitions — For the purpose of this standard, the symbols and definitions as given in Table 1 shall apply.

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 example:

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TABLE 1 SYMBOLS AND DEFINITIONS

(*Clause* 4)

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

*Reading value corresponding to the deflection.

5.1.1 *Overloading test* — This optional test is described in **A-1**.

5.1.2 *Verification relating to application of forces* — It shall be ensured:

a) that the attachment system of the force-proving instrument allows axial application of the load where the instrument is used for tensile testing, and

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

The method described in **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 cricuits connected, it shall be verified that a variation of ± 10 percent 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 *Analogue scale*

5.2.1.1 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.

5.2.1.2 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 are 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 ot fluctuation.

5.2.4 *Units* — The resolution (*r*) shall be expressed in 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 following conditions:

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

2 000 × r for class 0

1 000 × r for class 1

500 × r for 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 1½ minutes.

5.4.2 *Procedure*

5.4.2.1 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° (that is, 0°, 120° and 240°). When this is not possible, it is permissible to adopt the following three positions: 0°, 180° and 360°.

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

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

a) two series of forces in compression,

b) three series of forces in tension, and

c) one series of forces in compression.

5.4.2.4 The force-proving instrument shall be preloaded 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.

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

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

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

5.4.3 *Loading conditions*

5.4.3.1 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.

5.4.3.2 Strain gauge transducers shall be energized for not less than 30 minutes 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 applied to output readings in electrical units as well as to output 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 from the formula:

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

where

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

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:

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

5.5.3 *Relative zero error* (f_0) — 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 formula:

$$f_0 = \frac{X_{1f} - X_{10}}{X_N} \times 100$$

5.5.4 *Relative reversibility error* (u)

5.5.4.1 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.

5.5.4.2 The difference between the values obtained with increasing force and with decreasing force enables the relative reversibility error to be calculated from the formula:

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

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:

a) Either for specific forces, or

b) For interpolation.

6.2 *Classification Criteria* — The range of classification of a force-proving instrument shall at least cover the range 50 to 100 percent of F_N.

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

a) relative repeatability error;

b) relative zero error; and

c) relative reversibility error, when required.

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

a) relative repeatability error;

b) relative interpolation error;

c) relative zero error; and

d) relative reversibility error, when required.

6.2.2.1 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 Permissible Values of the Force-Proving Instrument, Percent				Calibration Force
	Relative Error of				
	Repeatability (b)	Interpolation (f_c)	Zero (f_0)	Reversibility* (u)	Uncertainty Percent
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

*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 instrument has satisfied the requirements of this 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) 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; and

f) The temperature at which the calibration was performed.

6.3.2 For the purpose of this standard, the maximum period of validity of the certificate shall not exceed 26 months.

6.3.2.1 A force-proving instrument shall be recalibrated when it sustains an overload higher than the test overload (*see* **A-1**).

7. Use of Calibrated Force-Proving Instruments

7.1 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.

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

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

7.4 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 formula:

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

where

D_t = deflection at the temperature t °C;

D_e = deflection at the calibration temperature t_e °C; and

K = temperature coefficient of the instrument, in reciprocal degree Celcius.

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

7.6 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.

7.7 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.

7.8 Most force transducers with electrical output are thermally compensated.

7.9 Generally, it is sufficient to measure the temperature of the device to 1°C (*see* Note under **5.4.3.1**).

TABLE 3 DEFLECTION CORRECTION FOR TEMPERATURE VARIATIONS OF A STEEL FORCE PROVING INSTRUMENT

(*Clause* 7.7)

Deflection Correction (In 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 (In 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	258	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

7.10 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 Table 3 shall be deducted from the deflection measured.

7.11 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

7.12 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.

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

APPENDIX A

(*Clauses* 5.1.1, 5.1.2 *and* 5.4.2.7)

ADDITIONAL INFORMATION

A-1. Overloading Test

A-1.1 The force-proving instrument is subjected four times in succession to an overload which shall exceed the maximum force by a minimum of 8 percent and a maximum of 12 percent. Overloading is maintained for a period of 1 to 1½ minutes.

A-2. Example of Method of Verification that there is no Interaction Between the Force Transducer of an Instrument Used in Compression and its Support on the Calibration Machine

A-2.1 The force-proving instrument is loaded by means of intermediate bearing pads having a cylindrical shape and plane, convex and concave surfaces, and which are in contact with the base of device.

A-2.2 The concave and convex surfaces are considered as representing the limits of the absence of flatness and of variations in hardness of the bearing pads on which the instrument may be used, when in operation.

A-2.3 The intermediate bearing pads are made of steel having a hardness between 400 and 650 HV 30. The convexity and concavity of the surfaces are 1·0 ± 0·1 in 1 000 of the radius [(0 1 ± 0·01) percent of the radius].

A-2.4 If a force-proving instrument is submitted for calibration with associated loading pads which will subsequently always be used with the force-proving instrument, the test device is considered to be a combination of the force-proving instrument plus the associated loading pads. This combination is loaded, in turn, through the plane and conical bearing pads.

A-2.5 Two test forces are applied to the force-proving instrument, the first being the maximum force of the instrument and the second the minimum calibration force for which deflection of the instrument is sufficient from the point of view of repeatability.

A-2.6 The tests are repeated so as to have three force applications for each of the three types of intermediate bearing pads. For each force, the difference between the mean deflection using concave and plane bearing pads and the difference between the mean deflection using convex and plane bearing pads should not exceed the limits given in Table 4 as indicated in relation with the class of the force-proving instrument.

TABLE 4 PERMISSIBLE DIFFERENCES

Class	Maximum Permissible Difference, Percent	
	At Maximum Force	At Minimum Force
0	0·1	0·2
1	0·2	0·4
2	0·4	0·8

A-2.7 If the force-proving instrument satisfies the requirement relating to the maximum force but does not fulfil that for the minimum force, the smallest force for which the instrument fulfils the conditions shall be determined.

A-2.8 The smallest increase in the force used to determine the smallest force satisfying the condition is left to the discretion of the authority qualified to carry out the calibration.

A-2.9 Generally, there is no need to repeat these tests with intermediate bearing pads each time the instrument is calibrated but only after an overhaul of the force-proving instrument.

A-3. Comments on the Record of the Zero Signal of Unloaded Force Transducer

A-3.1 A change of zero of unloaded force transducer indicates plastic deformations due to overloading of the force transducer, whereas a permanent long time drifting indicates the moisture influence of the strain gauges ground or a bonding defect of the strain gauges.

A-4. Example of Calibration Procedure for Dial Gauges

A-4.1 The calibration procedure described concerns dial gauges used for interpolation.

A-4.2 The calibration procedure is made only in the increasing direction and in the utilization range (for example, 3·000 to 8·000 mm).

A-4.3 The calibration points are closer in the beginning of the utilization range.

A-4.4 According to the utilization range, the calibration can be made as follows:

a) Move the plunger until the totalization needle (small dial) indicates 3·000 mm and rotate the bezel so that the zero coincides with the indicating needle in the vertical position.

b) Over the range 3·000 to 3 400 mm (corresponding to the range not used by the force-proving instrument), no readings are taken.

c) Over the range 3·400 to 4·500 mm, one reading per 0·05 mm is taken.

d) Over the range 4·500 to 8·000 mm, one reading per 0·1 mm is taken.

EXPLANATORY NOTE

This standard was first published in 1967. In this revision, the standard has been brought in line with International Standard ISO : 376-1987 Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines, issued by the International Organization for Standardization (ISO).

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