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CALIBRATION OF ELASTIC PROVING DEVICES

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BRIEF HISTORY

The ISO Recommendation R 376, *Calibration of Elastic Proving Devices*, was drawn up by Technical Committee ISO/TC 17, *Steel*, the Secretariat of which is held by the British Standards Institution (BSI).

Work on this question by the Technical Committee began in 1957 and led, in 1962, to the adoption of a Draft ISO Recommendation.

In November 1962, this Draft ISO Recommendation (No. 521) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies:

Australia	France	Spain
Austria	Germany	Sweden
Belgium	Hungary	Switzerland
Brazil	India	Turkey
Burma	Ireland	United Kingdom
Canada	Italy	U.S.A.
Chile	Japan	U.S.S.R.
Czechoslovakia	Netherlands	Yugoslavia
Denmark	Portugal	
Finland	Romania	

No Member Body opposed the approval of the Draft.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in August 1964, to accept it as an ISO RECOMMENDATION.

ISO Recommendation | R 376 | August 1964

CALIBRATION OF ELASTIC PROVING DEVICES

1. SCOPE

This ISO Recommendation applies to elastic proving devices for the static verification of testing machines. It is intended to cover only those devices in which the load is determined by measurement of the elastic deflection of a loaded member. The measurement of the deflection may be made by mechanical, electrical, optical or other means of sufficient precision and stability.

2. DESIGN REQUIREMENTS FOR ELASTIC PROVING DEVICES

It is recommended that proving devices should be provided with means permitting axial application of load, whether tension or compression. (In other cases, it is essential that the self-aligning device of the machine should be used in conjunction with the proving device).

When the deflection of the device is measured on a scale, the width of the graduation marks on the scale should be uniform, and the width of the index mark or of the pointer should be approximately equal to the width of a graduation mark.

No upper limit is set to the number of scale divisions which may be provided on the deflection, measuring apparatus for the reading corresponding to the full load on the device, but a lower limit is set to the number of divisions corresponding to the minimum load at which the device may be used (see clause 4.2). In general, the lower limit for the number of divisions of deflection will control the minimum load at which the device will be calibrated.

Further, for the purpose of assessing the minimum load at which a device may be used, it will be assumed, for the purposes of this ISO Recommendation, that a scale division may not be subdivided by estimation into more than a specified number of sub-divisions, depending on the type of deflection-measuring apparatus used and the scale spacing.*

In the case of devices incorporating a dial gauge or a micrometer screw, it will be assumed for this purpose that a division may be subdivided with assurance as follows:

- to one half of a scale interval, when the scale spacing is less than 1 mm (0.04 in);
- to one fifth of a scale interval, when the scale spacing is 1 mm (0.04 in) or more.

The reading limit so defined should be regarded as the smallest interval of scale reading of the device for the purpose of defining the minimum load.

For devices incorporating other forms of deflection measuring apparatus, i.e. microscopes, electrical circuits, etc., the calibrating authority should determine the smallest interval of scale reading which should be used for this purpose, having regard to both the setting and reading of the deflection-measuring apparatus.

The readings of deflection of the proving device should not be subject to variation by outside causes, e.g. by normal variations in power supply required, such as changes in line voltage or frequency.

The device should be suitably identified by the maker's name, serial number and maximum load.

* This does not, of course, impose any restriction on the calibrating authority or the user when reading the device.

3. CALIBRATION

3.1 **Determination of deflection.** A deflection is defined as the difference between a reading under load and the mean of the no-load readings before and after loading. If more than one reading is interposed between the actual no-load readings, and a change of the latter has taken place, a uniformly progressive change in no-load readings should be assumed in order to determine the no-load reading applicable to each load reading. If a uniformly progressive change cannot be assumed, but the change is small (see Table below, column 7), the deflection should not be corrected. However, the second no-load reading will be taken as the basis of the following readings.

The maximum change of no-load reading must not exceed the percentage of the deflection under full load as specified in the Table, column 7. The calibrating authority can use its discretion as to whether to return to zero load after each deflection.

Table. — **Grading of elastic proving devices**

1	2	3	4	5	6	7	8
Grade	**Maximum load of device**	**Requirements for calibrating loads**		**Requirements for elastic proving devices (These requirements include permissible inaccuracies of the calibrating loads)**			
				For repeatability			For linearity (optional)
		Lack of repeatability of calibrating load applied to device, expressed as percentage of applied load.	Maximum permissible error of load applied to device, expressed as percentage of applied load.	At each calibration load, difference between maximum and minimum of the deflections expressed, as percentage of average deflection.	Change of no-load reading in overload test, expressed as percentage of deflection under full load.	Change of no-load reading during calibration, expressed as percentage of deflection under full load.	Departure of linearity indicated by calibration curve, expressed as percentage of calibration factor of curve.
Maximum permissible							
1	Up to and including 50 000 kgf (50 tons-force)	0.01	± 0.02	0.2	0.1	0.1	± 0.1
	Over 50 000 kgf (50 tons-force), up to and including 500 000 kgf (500 tons-force)	0.10	± 0.2	0.4	0.1	0.1	± 0.3
2	Up to and including 50 000 kgf (50 tons-force)	0.01	± 0.02	0.4	0.2	0.2	± 0.2
	Over 50 000 kgf (50 tons-force), up to and including 500 000 kgf (500 tons-force)	0.10	± 0.2	0.6	0.2	0.2	± 0.4

NOTES

1. An elastic proving device of maximum load above 50 000 kgf (50 tons-force) is not inherently less accurate than a device of 50 000 kgf (50 tons-force) or less, maximum load. For loads

up to 50 000 kgf (50 tons-force), dead weights are generally available for the calibration of elastic proving devices, but for loads above 50 000 kgf (50 tons-force) secondary standards which are less accurate are usually employed. The requirements for the proving devices are therefore made less stringent so as to allow for the less accurate calibration loads.

2. When an elastic proving device of maximum load above 50 000 kgf (50 tons-force) is being calibrated, and the requirements of clause 4.2 allow grade 1 repeatability to be given for a load of 40 000 kgf (40 tons-force) or less, then all calibration loads of 50 000 kgf (50 tons-force) and less should be of the greater accuracy, i.e. having repeatability within 0.01 per cent and maximum permissible errors of ± 0.02 per cent.

3.2 **Overload test.** Before any calibration or re-calibration, the device should be overloaded four times in the manner (tension or compression or both) in which it is intended to be used, to a load of not less than 8 per cent and not more than 10 per cent in excess of the full load. The overload should be maintained for a period of 1 to 1½ minute. The difference between the no-load readings before and after the first overload should be ignored, but the change in no-load reading produced by any one subsequent overload should not exceed the percentage of the deflection under full load, as specified in the Table, column 6.

3.3 **Accuracy of applied loads.** The repeatability and the accuracy of the loads applied for calibration should be within the limits specified in the Table, columns 3 and 4.
It is recommended that elastic proving devices should be calibrated in terms of technical units * of force based on the kilogramme-mass or the pound-mass (or the multiple units, the metric tonne-mass equal to 1000 kilogrammes-mass and the (long) ton-mass equal to 2240 pounds-mass). The kilogramme-force (kgf) is that force which, acting on one kilogramme-mass, will give it an acceleration of 980.665 cm/s^2 (32.174 ft/s^2); the pound-force (lbf) is that force which, acting on one pound-mass will give to it an acceleration of 980.665 cm/s^2. If local gravitational units of force are used during the calibration, it is recommended that the results are converted to be in terms of technical units of force.

NOTE. — The newton (N) is that force which, acting on one kilogramme-mass, will give it an acceleration of 1 m/s^2.

3.4 **Conditions of loading.** The time interval between any two successive loadings should be as uniform as possible, and no reading should be taken less than 30 seconds after a change of load. Calibration of an elastic proving device should generally be carried out at a temperature of 20 ± 1 °C for temperature climates, and at 27 ± 1 °C for tropical climates. The parts of the device used to carry out the tests should be kept at the test temperature for sufficient time before the tests are started, to ensure stable conditions.
A device should be supported in accordance with the instruction issued by the maker and loaded in ascending order of loads.

3.5 **Minimum load.** The minimum calibration load normally applied to a device should be not less than the load corresponding to 250 times the smallest interval of scale reading of the device as defined in section 2 (see also clause 4.2).

3.6 **Calibration procedure.** The device should be preloaded three times to the maximum test load before the application of the test loads.
When the device is to be graded for linearity, the number of test loads should be not less than eight, and these should be distributed as evenly as possible over the calibration range.
For devices to be used only in one direction of loading, i.e. in tension only or in compression only, this procedure should be repeated to give three series of loadings.
For devices which are to be used in both tension and compression, three series of loadings should be made in each direction, of which not more than two series in succession are to be

* See ISO Recommendation R 31, *Fundamental quantities and units of the MKSA system and quantities and units of space and time, Part III, Quantities and units of mechanics.*

in the same direction. The device should be preloaded three times to the maximum test load in the direction in which the subsequent test loads are to be applied, and pre-loading should be similarly carried out in the new direction, when a change in the direction of loading is made.

At least once during calibration, the device should be dismantled to such an extent as is necessary for packing and transport. In general, this should be carried out between the second and third series of calibration loads.

If the deflection-measuring device is to be mechanically detached from the loaded member for packing and transport, the series of loadings should be increased from three to six.

4. GRADING

4.1 **Minimum requirements.** Devices should be graded for repeatability i.e. reproducibility of readings when repeated tests are made on a single occasion as defined in clause 4.3 below.

NOTE. — The grading for linearity, as defined in clause 4.4, is optional, but in no part of its range may a device be given a grading for linearity better than it receives for repeatability.

4.2 **Lower limit of calibration range.** Having regard to the accuracy with which the deflection of the device may be read during its calibration and during its subsequent use in verifying testing machines, a device may not be given Grade 1 repeatability for loads corresponding to less than 500 times the smallest interval of reading of the device as defined in section 2. Likewise, a device may not be given Grade 2 repeatability for loads corresponding to less than 250 times the smallest interval of reading of the device, as defined in section 2.

4.3 **Repeatability grading.** At each calibration load, the difference between the maximum and the minimum of the three or six deflections, each deflection having been corrected for any variation in the temperature of the device from the reference temperature 20 °C (or 27 °C), in accordance with formula 1, given in section 5, should not exceed the percentage of the average deflection for that load, as specified in the Table, column 5.

The repeatability may alternatively be calculated from the calibration factor, when this has been obtained for the purpose of grading for linearity (see clause 4.4).

After correcting the calibration factor for any variation in the temperature of the device from the reference temperature 20 °C (or 27 °C), in accordance with formula 2 or 3 given in section 5, the difference between the maximum and the minimum calibration factor for the same applied load, expressed as a percentage of the average calibration factor, should not exceed the percentage of the average deflection for that load, as specified in the Table, column 5.

The range of loads over which a given repeatability grade applies should be obtained by considering each calibration load in turn, starting at the maximum calibration load and working downwards. A given repeatability grade should cease to apply at the first calibration load at which the maximum permissible percentage difference is exceeded and that grade may not be re-introduced for lower calibration loads.

4.4 **Linearity grading (this is an optional requirement).** A calibration factor of load per unit deflection should be calculated from each of the three or six deflections observed at each value of applied load; the calibration factors should be corrected for any variations in the temperature of the device from the reference temperature 20 °C (or 27 °C), in accordance with formula 3, given in section 5.

The mean value of the three or six calibration factors for each applied load should be plotted against the corresponding mean deflection, and the best smooth curve, without any point of inflexion within the calibration range, should be drawn. This curve should be taken as the calibration of the device from which the load corresponding to any observed deflection may be obtained.

The deviation of each plotted point from the curve should not exceed the percentage of the calibration factor, as specified in the Table, column 8.

Alternatively, a calibration factor of deflection per unit of load may also be calculated from each of the three or six deflections observed at each value of applied load; these calibration factors should be corrected, where necessary, for any variation in the temperature of the device from the reference temperature 20 °C (or 27 °C), in accordance with formula 2, given in section 5.

The mean value of the three or six calibration factors for each applied load should be plotted against the applied load, and the best smooth curve without any point of inflexion within the calibration range, should be drawn. This curve should be taken as the calibration of the device from which the deflection corresponding to any given load may be obtained.

The deviation of each plotted point from the curve should not exceed the percentage of the calibration factor, as specified in the Table, column 8.

The range of loads over which a given linearity grade applies should be obtained by considering the deviation of the points from the curve, starting at the point corresponding to the maximum calibration load and working downwards.

To obtain linearity grading, a minimum number of four points should not exceed the maximum permissible departure of linearity, as indicated by the calibration curve, and the grade should cease to apply at the first calibration load at which the maximum permissible departure of linearity is exceeded. The grade may not be re-introduced for lower calibration loads.

NOTE. — It is intended that devices which receive repeatability grading only should be restricted in use to measure loads corresponding to the loads at which the device was calibrated. Devices which receive the additional (optional) linearity grading may be used to measure any load within the limits of the grading.

5. TEMPERATURE CORRECTION FORMULAE

When a device is calibrated (or subsequently used) at a temperature other than 20 °C (or 27 °C) the following formulae should be used to correct the deflection or the calibration factor, for variation in temperature. The temperature correction factor is only applied if it exceeds 0.0006. This allows a deviation of 2 °C from the reference temperature without correction.

$$D_n = D_t\,[l - K(t - n)] \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where D_n = deflection at n °C
D_t = deflection at t °C
K = temperature coefficient of the device
n = 20 °C for temperate climates and 27 °C for tropical climates.

$$f_n = f_t\,[l - K(t - n)] \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where f_n = calibration factor (deflection per unit load) at n °C
f_t = calibration factor (deflection per unit load) at t °C
K = temperature coefficient of the device
n = 20 °C for temperate climates and 27 °C for tropical climates.

$$F_n = F_t\,[l + K(t - n)] \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where F_n = calibration factor (load per unit deflection) at n °C
F_t = calibration factor (load per unit deflection) at t °C
K = temperature coefficient of the device
n = 20 °C for temperate climates and 27 °C for tropical climates.

For elastic proving devices, made of steel or not more than 7 per cent alloy content, the value $K = 0.000\,27$ per degree Celsius may be used.

For elastic proving devices made of other materials, the value of K should be found experimentally and this information should be furnished by the manufacturer. The value used should be stated on the certificate of calibration.

6. CERTIFICATE OF CALIBRATION AND TIME INTERVAL BETWEEN CALIBRATIONS

When, on calibration, an elastic proving device is found to comply with the requirements of this ISO Recommendation, the calibrating authority should issue a certificate to this effect. The certificate should refer to the device by suitable identification, and should state over what part of its range the device complies with each of the two grades of calibration for repeatability. The method of calibration and the actual loads applied, together with the corresponding deflection, should be stated, and also the unit of force used and the temperature of the device at the time of calibration. Where a device has been submitted for the optional linearity grading, the certificate should state over what part of its range the device complies with each of the two grades of calibration for linearity, and a copy of the calibration curve should be attached to the certificate.

Recalibration of elastic proving devices should normally be carried out every two years; in order to allow a short period of grace, a certificate issued according to this ISO Recommendation should not to be considered valid for more than 26 months and this should be stated on the certificate.

If an elastic proving device has been subjected to major repairs or adjustments, or if there is any reason to doubt the accuracy of its performance, it should be submitted for recalibration.

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