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British Standard

Materials testing machines and force verification equipment

Part 2. Specification for the grading of equipment used for the verification of the forces applied by materials testing machines

Machines d'essai des matériaux et appareils de vérification des forces
Partie 2. Graduation des appareils de vérification des forces exercées par les machines d'essai des matériaux — Spécifications

Werkstoffprüfmaschinen und Kraftmeßeinrichtungen
Teil 2. Klasseneinteilung für Einrichtungen zur Messung der von Werkstoffprüfmaschinen angebrachten Kräfte

British Standards Institution

Foreword

This Part of BS 1610 has been prepared under the direction of the Iron and Steel Standards Committee and the Non-ferrous Metals Standards Committee. Parts 1 and 2 together supersede BS 1610 : 1964 which is withdrawn.

An extensive revision has been necessary due to the development of materials testing machines incorporating strain-gauge load cells and electronic force indication and the more varied types of test that can be made using such machines. Account has also been taken of developments in the force verification equipment, in particular, modern electronic indication.

Part 1 of BS 1610 specifies requirements for the grading of the forces applied by a materials testing machine and the method of verification; Part 2 specifies requirements for the grading of force verification equipment and the method of calibration of proving devices.

Cognizance has been taken of discussions in the International Organization for Standardization (ISO) and the International Organization for Legal Metrology (OIML). A numerical system of grading is specified which relates to that being adopted internationally and is also conceptually similar to the system for testing machines specified in the previous edition of BS 1610. For each grade of the verification equipment, the numerical value of repeatability has been defined as five times better than that required for the corresponding grade of the test machine.

Some parameters adopted in this revision differ slightly from international views because they have been chosen as a result of national experience and to maintain conformity with a wide range of commercial interests.

Although this Part is mainly intended to apply to proving devices, requirements are also included for verification masses, for use when small forces are being measured, and for proving levers for special applications. A requirement is also included that calibration forces be traceable to national standards held at the National Physical Laboratory (NPL) either directly or indirectly through a hierarchical chain such as that provided by a calibration laboratory accredited by the National Measurement Accreditation Service. Traceability to national standards of other countries is acceptable, provided these standards are recognized by NPL.'

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Contents

Section one. General

1.1 Scope

This Part of BS 1610 specifies requirements for the grading of proving devices, verification masses and proving levers used for the force verification of materials testing machines and describes the method of calibration for proving devices.

NOTE. The title of the publication referred to in this standard is given on the inside back cover.

1.2 Definitions

For the purposes of this Part of BS 1610 the following definitions apply.

1.2.1 SI unit of force. The force that, when applied to a mass of 1 kg, gives the mass an acceleration of 1 m/s^2, i.e. the newton (N).

1.2.2 verification equipment. Equipment consisting of proving devices, verification masses and proving levers.

1.2.3 calibration forces. Forces of specified repeatability and error applied to the verification equipment.

1.2.4 proving device. A device that determines force by the measurement of the elastic deflection of a loaded member.

NOTE. Proving devices may be proving rings, electrical resistance strain-gauge load cells or other devices in which the deflection of the loaded member is measured by means of a transducer. The transducer may be a mechanical, electrical or optical system and is considered to be an integral part of the device.

1.2.5 limited force device. A device that satisfies the requirements specified for repeatability but not the requirements for interpolation and is therefore limited in use to forces corresponding to the calibration forces.

1.2.6 deflection. A value obtained by subtracting the reading of the deflection-measuring indicator at zero force from the reading with a force applied.

1.2.7 resolution. The smallest specified measurement interval on the deflection-measuring indicator (see **3.2.1**).

1.2.8 lower limit of calibration. The force below which a proving device cannot be calibrated to comply with a given grading.

1.2.9 repeatability. The difference between the maximum and minimum values of deflection obtained from the repeated application of any given calibration force.

1.2.10 interpolation. A procedure for the calculation of the values of deflections of a proving device, for values of force between the measured values, using a mathematically fitted curve.

1.2.11 bearing pad. A steel pad provided for the purpose of applying force and having a known loading surface form and a specified hardness.

1.2.12 verification masses. Masses that are of determined values.

1.2.13 proving lever. A system of mechanical levers of a fixed ratio that, when loaded with verification masses, can be used to generate specific forces.

1.2.14 loading mode. The direction of an increasing force, either tensile or compressive.

Section two. Grading of verification equipment

2.1 Proving devices

2.1.1 Preliminary requirements for grading

2.1.1.1 *General.* Prior to the grading of proving devices for repeatability and interpolation, the results of the tests, made in accordance with section three, shall be assessed and a range of forces determined for each specific grading in accordance with **2.1.1.2** to **2.1.1.4** and the maximum permissible values given in table 1. An optimum range of forces shall be determined for each specific grade from the individual assessments made in accordance with **2.1.1.2** to **2.1.1.4.**

Devices shall not be given a grading below the lower limit of calibration for any specific grade (see **3.2.2**).

2.1.1.2 *Change of reading at zero force during overload test and calibration.* When tested in accordance with **3.4.3**, the change of reading at zero force, before and after the first overload, shall be ignored. Thereafter, the change of reading at zero force produced by each subsequent overload shall not exceed the values given in column 2 of table 1 for a specific grade.

When calibrated in accordance with **3.5**, the change of reading at zero force shall not exceed the values given in column 2 of table 1 for a specific grade.

2.1.1.3 *Change of deflection during bearing pad test.* When tested in accordance with **3.4.4**, the departure of the average deflections on the depressed and raised surfaces, from the average deflection on the flat surface, shall be expressed as a percentage of the average deflection on the flat surface and shall not exceed the values given in columns 3 and 4 of table 1 for a specific grade.

If the proving device complies with the requirements at the maximum force but fails to comply with the requirements at the minimum force, the lowest force at which the device complies with the requirements shall be determined.

2.1.1.4 *Change of deflection during variable voltage test.* When tested in accordance with **3.4.5**, the departure from average deflection above and below nominal mains voltage shall be expressed as a percentage of the average deflection at nominal mains voltage and shall not exceed the values given in column 5 of table 1 for a specific grade.

2.1.2 Grading for repeatability and interpolation

2.1.2.1 *General.* Proving devices shall be graded in accordance with the maximum permissible values given in table 2 for repeatability of the deflection of the device for each calibration force and, where applicable, for interpolation between calibration forces as specified in **2.1.2.2** and **2.1.2.3**, when calibrated in accordance with section three.

2.1.2.2 *Repeatability.* At each calibration force from the maximum force to be calibrated downwards, the values of repeatability calculated in accordance with **3.6.2** shall not exceed the values given in table 2 for any specific grade. The particular grading shall cease to apply at the first calibration force where the limit for that grade is exceeded and the range of forces for any specific grading shall not exceed the corresponding optimum range of forces determined in the preliminary grading (see **2.1.1.1**).

2.1.2.3 *Interpolation.* To grade the ability to interpolate between the deflections of a proving device obtained from calibration forces, the residuals, calculated in accordance with **3.6.3**, shall not exceed the values given in table 2 for a specific grade for a minimum of five consecutive calibration forces from the maximum calibration force downwards. The range of forces graded for interpolation shall not exceed the corresponding range of forces graded for repeatability.

Table 1. Preliminary requirements for grading of proving devices

Grade of proving device	Change of reading at zero force during overload and calibration as percentage of deflection at maximum calibration force	Bearing pad test		Variable voltage test
		Maximum permissible difference		Maximum permissible difference at maximum force as percentage of deflection
		At maximum force as percentage of deflection	At minimum force as percentage of deflection	
	%	%	%	%
0.5	0.05	0.1	0.2	0.1
1.0	0.10	0.2	0.4	0.2
2.0	0.20	0.4	0.8	0.4

Table 2. Grading of proving devices for repeatability and interpolation

Grade of proving device	Maximum permissible repeatability as percentage of deflection	Maximum permissible residual for interpolation as percentage of calibration factor
	%	%
0.5	0.1	± 0.05
1.0	0.2	± 0.10
2.0	0.4	± 0.20

NOTE. The upper limit to which a device may be calibrated to comply with a specific grade will be restricted by the availability of calibration forces in accordance with **3.3**.

2.1.3 Certificate of grading

When a proving device has been calibrated and graded in accordance with this Part of BS 1610, the calibration authority shall issue a certificate stating the following.

(a) The date of issue of the certificate, which shall also be identified by a unique reference.

(b) The serial numbers of the proving device, the transducer and readout instrument.

(c) The identity of the calibration equipment and the grades of its calibration forces.

(d) Where appropriate, the date that the proving device complied with the requirements of the bearing pad test and the variable voltage test for the grading given.

In the case of the variable voltage test, it is sufficient for the calibration authority to state that a successful test has been undertaken on an indicator of the same type, used with a proving device giving the same electrical loading.'

(e) The range and mode (compression or tension or both) of forces over which the proving device complies with the requirements for the repeatability grading given. Where applicable, the corresponding range and mode of forces over which the proving device complies with the requirements for the interpolation grading given, together with any other information to enable the user of the device to obtain the deflection for any force within the range calibrated.

(f) The range of temperature of the proving device during the calibration.

(g) The forces applied during the calibration, together with the deflections after correction for any departure of the temperature of the proving device from 20 °C, and the value of the temperature coefficient used.

2.1.4 Frequency of recalibration

A proving device shall be recalibrated every two years or if it suffers any damage or has been subjected to any adjustment.

2.2 Verification masses

2.2.1 Identification

Verification masses shall be identified with the serial number and the nominal mass value.

2.2.2 Grading

Masses shall be graded as 0.5 if their mass is within ± 1 part in 2000 (± 0.05 %) of their nominal value.

NOTE. The vertical force that a mass exerts on a materials testing machine, when directly attached to the loading shackles, is the 'gravity' force less the air-buoyancy force acting on the mass. The air-buoyancy force acting on steel or cast-iron masses is about 1 part in 7000 of the gravity force and for the verification of materials testing machines may be ignored. Therefore the following equation for the force applied F, in newtons, is sufficiently accurate:

$$F = m \times g_1$$

where

m is the mass (in kg);

g_1 is the local value of acceleration due to gravity (in m/s^2).

For the verification of materials testing machines in the UK, a value of $g_1 = 9.815\ m/s^2$ may be used. It is unlikely that at the site of any materials testing machine in the UK the actual value of g will depart from this typical value by more than 0.05 %.

2.2.3 Certificate of grading

When masses have been calibrated and graded in accordance with this Part of BS 1610, the calibration authority shall issue a certificate to this effect. The certificate shall refer to the identification of the masses.

2.2.4 Frequency of recalibration

Recalibration of masses shall be carried out every five years or if they suffer any damage or have been subjected to any adjustment.

2.3 Proving levers

2.3.1 Identification

Proving levers shall be identified with the serial number and the maximum working force.

2.3.2 Grading

Proving levers shall be graded 0.5 if the measured force at the loading position is repeatable to within 0.1 %, when the same force, as generated by the verification masses, is applied to the end of the lever (effort) and the average measured force does not depart by more than ± 0.1 % from its nominal value. When the proving lever is to be used to apply a range of forces, a minimum of five calibration forces spread at approximately equal intervals over the range shall be measured.

2.3.3 Certificate of grading

When a proving lever has been calibrated and graded in accordance with this standard, the calibration authority shall issue a certificate to this effect. The certificate shall refer to the identification of the lever and the verification masses associated with the lever.

Section three. Method of calibration of proving devices

3.1 General

The proving device shall be calibrated according to the procedures described, using calibration forces over the range of the device from its maximum force down to the lower limit of calibration as determined. The repeatability and, where appropriate, the interpolation values required for grading shall be calculated from the calibration results.

3.2 Proving device

3.2.1 Resolution

3.2.1.1 *Analogue scale.* When the deflection is measured by devices with an analogue scale, i.e. a dial gauge or micrometer, the resolution (r) shall be determined as follows:

(a) when the scale interval is at least 1.25 mm wide, the resolution shall be one-tenth of a scale interval;

(b) when the scale interval is less than 1.25 mm wide, the resolution shall be one-fifth of a scale interval.

When the deflection is measured by means of a micrometer fitted with a vernier scale, the resolution shall be one division of the vernier scale.

3.2.1.2 *Digital scale.* The resolution shall be determined when there is no force applied to the proving device and shall be equal to one-half of the range of fluctuation on the digital read-out but shall be not less than one increment of count.

3.2.2 Lower limit of calibration

Calibration shall not be performed below the force corresponding to the deflection d determined as follows:

$$d = a \times r$$

where

a has the following values:

2000 for a grade 0.5 device;
1000 for a grade 1.0 device;
500 for a grade 2.0 device;

r is the resolution determined in accordance with 3.2.1.

3.2.3 Condition and identification of proving device

Calibration shall not be commenced unless the proving device is in good working order and is identified with the serial number and the maximum working force.

1 Electrical indication equipment used with a proving device shall be identified with a serial number. The indicator may be replaced by another one and the proving device need not be recalibrated provided the following conditions are met.

(a) The original indicator has a calibration certificate, traceable to national standards, which gives the results of a calibration made in terms of the electrical base unit (volt) or derived units (e.g. ampere, ohm, millivolt/volt). The indicator shall have been calibrated over a range equal to or greater than the range over which it is used with the proving device and the resolution of the indicator when calibrated shall be equal to or better than when used with the proving device.

(b) The replacement indicator shall have a resolution equal to or better than the indicator it is replacing and shall have a calibration certificate, traceable to national standards, in terms of the same electrical units and covering the range over which it will be used with the proving device.

(c) The date on the certificate for the original indicator shall not precede that on the certificate for the replacement indicator by more than 12 months.

(d) The certificates for the two indicators show that the deflections of the proving device, as measured by the two indicators, shall agree within ± 0.1 % over the range of the grading of the device.'

3.3 Calibration forces

Values for the repeatability and error of the calibration forces used for different grades shall not exceed the values given in table 3. 'The calibration forces shall be traceable to national standards held at the National Physical Laboratory (NPL) either directly or indirectly through a hierarchical chain such as that provided by a calibration laboratory accredited by the National Measurement Accreditation Service*. Traceability to national standards of other countries is acceptable, provided these standards are recognized by NPL.'

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Table 3. Calibration forces

Grade of proving device	Maximum permissible repeatability of calibration force	Maximum permissible error of calibration force
	%	%
0.5	0.02	± 0.02
1.0	0.05	± 0.05
2.0	0.10	± 0.10

3.4 Preliminary procedure

3.4.1. Alignment

Mount the proving device in the calibration machine so that the forces are applied along the loading axis of the device. Where the device has compression-loading attachments or tension shackles, ensure that these are in place at the time of calibration.

3.4.2 Conditions of loading

Calibrate the proving device at a temperature in the range 15 °C to 25 °C. Allow the device and all relevant parts of the equipment to attain a stable temperature and record the temperature at the beginning and end of each test. Maintain the temperature to within 1 °C throughout the test.

Keep the time interval between successive loadings as uniform as possible. Do not take any readings less than 30 s after a change of force.

3.4.3 Overload test

Before any calibration or recalibration, overload the proving device four times in the mode (compression, tension or both) in which it is intended to be used, to a force not less than 9 % and not more than 11 % above the maximum force of the device. Maintain each overload for a period of between 1 min and 1.5 min. Record the readings at zero force of the device, before and after each application of overload.

3.4.4 Bearing pad test (for compression devices)

At the time of the first calibration and after any major overhaul, load the proving device through bearing pads with flat, conically raised and conically depressed surfaces in contact with the base of the proving device.

The bearing pads shall be of steel of hardness not less than 400 HV30. The conically raised and depressed

1 *Information about the National Measurement Accreditation Service may be obtained from: the National Measurement Accreditation Service, National Physical Laboratory, Teddington, Middlesex TW11 0LW.'

surfaces shall be respectively raised and depressed 1.0 ± 0.1 in 1000 of the radius.

If a proving device is submitted for calibration with associated loading pads which will subsequently always be used with the device, the device shall be considered to be a combination of the force-measuring instrument plus the associated loading pads; load this combination in turn through the flat, conically raised and conically depressed surfaces.

Apply two forces to the device: the first shall be equal to the maximum specified force for the device, the second shall be the lower limit of calibration as determined in accordance with **3.2.2.**

Repeat the tests to give three applications of the forces for each condition of support of the device. Calculate the average deflection for each loading on the depressed, raised and flat surfaces.

3.4.5 Variable voltage test (for devices dependent upon mains electrical supply)

At the first calibration apply the maximum force of the proving device three times with the supply voltage at 10 % below nominal, three times with the supply voltage at 10 % above nominal and three times at the nominal supply voltage. Allow a minimum of 15 min after a change of voltage before taking any readings. Calculate the average deflection for each test voltage.

1 *This test need not be undertaken if a successful test has already been undertaken on an indicator of the same type, used with a proving device giving the same electrical loading.'

3.5 Calibration procedure

3.5.1 General

1 *First load the proving device through a steel pad of hardness not less than 400 HV30 in contact with the base of the proving device.'

Before commencing the calibration procedure, load the device three times to the maximum calibration force in the proposed loading mode. Where a device is to be used in both compression and tension, repeat this procedure in the opposite direction before the device is used in the alternative loading mode.

3.5.2 Selection of calibration forces

When a proving device is to be calibrated for repeatability only, use the calibration forces at which it will subsequently be used. Where the device is to be additionally calibrated for interpolation, use not less than eight forces distributed as evenly as possible over the calibration range.

3.5.3 Application of calibration forces

3.5.3.1 *Devices to be used in compression only.* First load the proving device through a steel pad of hardness not less than 500 HV30 in contact with the base of the proving device. Apply two series of calibration forces in ascending order of magnitude. Remove the pad and replace it by a steel pad of hardness of not greater than 300 HV30 and apply a further series of calibration forces to give a total of three series of forces.

3.5.3.2 *Devices to be used in tension only.* Apply two series of calibration forces in ascending order of magnitude. Then disturb the device and, after repositioning in the machine, apply a further series of calibration forces to give a total of three series of forces.

3.5.3.3 *Devices for use in both compression and tension.* Apply three series of calibration forces in ascending order of magnitude in each mode, so that not more than two series in succession are applied in the same direction of loading.

3.6 Calculation of results

3.6.1 Determination of deflection

Calculate deflection by subtracting the mean of the readings at zero force, before and after the application of the force, from the reading with the force applied. If more than one reading is interposed between the two readings at zero force and there is a change in the readings at zero force, a uniform progressive change shall be assumed in order to calculate deflection.

Correct the deflection for any departure of the temperature of the device from 20 °C, as given in appendix A.

3.6.2 Determination of repeatability

At each calibration force, calculate the difference between the maximum and minimum of the three temperature-corrected values for deflection as a percentage of the average value of deflection for that force.

3.6.3 Determination of interpolation

Calculate a calibration factor of deflection per unit force from the average of the three temperature-corrected deflections for each given calibration force.

Then compute a 'best fit' second-order polynomial equation relating the calibration factors to the calibration forces. Give all the points equal weighting and compute a second-order polynomial series such that the sum of the squares of the residuals, i.e. the departures of the actual calibration factors from the computed values given by the equation, is a minimum.

At each calibration force, calculate the residual as a percentage of the average calibration factor for that force.

Appendix

Appendix A. Correction applied to the deflection of a proving device when calibrated at a temperature other than 20 °C

When a proving device is calibrated at a temperature other than 20 °C, use the following equation to correct the deflection for the effect of a change of temperature of the loaded member:

$$d_{20} = d_t\,[1 - K\,(t - 20)]$$

where

d_{20} is the deflection of the proving device at 20 °C for a given force;

d_t is the observed deflection of the proving device at t °C;

t is the temperature in °C of the proving device during calibration;

K is the temperature coefficient of the proving device per °C.

NOTE. For proving devices, other than strain-gauge load cells, made of steel of not more than 7 % alloy content, the value of $K = 0.000\,27/°C$ should be used.

For proving devices made of other materials, the value of K should be provided by the manufacturer.

For strain-gauge load cells that are not compensated for temperature changes, the value of K should be provided by the manufacturer.

Publication referred to

BS 1610 Materials testing machines and force verification equipment
*Part 1 Specification for the grading of the forces applied by materials testing machines

*Referred to in the foreword only.

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Committees responsible for this British Standard

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Aluminium Federation
British Civil Engineering Test Equipment Manufacturers' Association
British Gas Corporation
British Non-ferrous Metals Federation
British Railways Board
British Steel Industry
British Steel Industry (Wire Section)
Copper Development Association
Department of Industry (British Calibration Service)
Department of Industry (National Engineering Laboratory)
Department of Industry (National Physical Laboratory)
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Ministry of Defence
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Materials testing machines and force verification equipment
Part 2. Specification for the grading of equipment used for the verification of the forces applied by materials testing machines

Revised text

AMD 6174
October 1989

Foreword

Delete the final sentence of the sixth paragraph and insert the following.

'A requirement is also included that calibration forces be traceable to national standards held at the National Physical Laboratory (NPL) either directly or indirectly through a hierarchical chain such as that provided by a calibration laboratory accredited by the National Measurement Accreditation Service. Traceability to national standards of other countries is acceptable, provided these standards are recognized by NPL.'

AMD 6174
October 1989

Table 1. Preliminary requirements for grading of proving devices

Delete both headings in column 2 and substitute 'Change of reading at zero force during overload and calibration as percentage of deflection at maximum calibration force'.

AMD 6174
October 1989

Clause 2.1.3 Certificate of grading

In item (d) of the list, after the existing sentence, insert the following.

'In the case of the variable voltage test, it is sufficient for the calibration authority to state that a successful test has been undertaken on an indicator of the same type, used with a proving device giving the same electrical loading.'

AMD 6174
October 1989

Clause 2.2.2 Grading

In line 7 of the note delete 'kilonewtons' and substitute 'newtons'.

AMD 6174
October 1989

Clause 3.2.3 Condition and identification of proving device

Delete the second paragraph and substitute the following.

'Electrical indication equipment used with a proving device shall be identified with a serial number. The indicator may be replaced by another one and the proving device need not be recalibrated provided the following conditions are met.

(a) The original indicator has a calibration certificate, traceable to national standards, which gives the results of a calibration made in terms of the electrical base unit (volt) or derived units (e.g. ampere, ohm, millivolt/volt). The indicator shall have been calibrated over a range equal to or greater than the range over which it is used with the proving device and the resolution of the indicator when calibrated shall be equal to or better than when used with the proving device.

(b) The replacement indicator shall have a resolution equal to or better than the indicator it is replacing and shall have a calibration certificate, traceable to national standards, in terms of the same electrical units and covering the range over which it will be used with the proving device.

(c) The date on the certificate for the original indicator shall not precede that on the certificate for the replacement indicator by more than 12 months.

(d) The certificates for the two indicators show that the deflections of the proving device, as measured by the two indicators, shall agree within ± 0.1 % over the range of the grading of the device.'

AMD 6174
October 1989

Clause 3.3 Calibration forces

Delete the second sentence of the first paragraph and insert the following.

'The calibration forces shall be traceable to national standards held at the National Physical Laboratory (NPL) either directly or indirectly through a hierarchical chain such as that provided by a calibration laboratory accredited by the National Measurement Accreditation Service*. Traceability to national standards of other countries is acceptable, provided these standards are recognized by NPL.'

Delete the associated footnote and insert the following.

'*Information about the National Measurement Accreditation Service may be obtained from: the National Measurement Accreditation Service, National Physical Laboratory, Teddington, Middlesex TW11 0LW.'

AMD 6174
October 1989

Clause 3.4.5 Variable voltage test (for devices dependent upon mains electrical supply)

In the first sentence delete 'and after any overhaul of the electrical circuits,'.

After the existing text insert the following new paragraph.

'This test need not be undertaken if a successful test has already been undertaken on an indicator of the same type, used with a proving device giving the same electrical loading.'

AMD 6174
October 1989

Clause 3.5.3.1 Devices to be used in compression only

Delete the first sentence and substitute the following.

'First load the proving device through a steel pad of hardness not less than 400 HV30 in contact with the base of the proving device.'