BRITISH STANDARD

BS 1610 : Part 1 : 1992

Materials testing machines and force verification equipment

Part 1. Specification for the grading of the forces applied by materials testing machines when used in the compression mode

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Foreword

This new edition of BS 1610 : Part 1 has been prepared under the direction of the Iron and Steel and Non-ferrous Standards Policy Committees. It, together with BS EN 10002-2, replaces BS 1610 : Part 1 : 1985 which is withdrawn.

This edition introduces technical changes to bring the standard up-to-date but it does not reflect a full review of the standard, which will be undertaken in due course. The opportunity has been taken, when preparing this new edition, to incorporate Amendment No. 1, published in 1989, to BS 1610 : Part 1 : 1985.

It is important to note the limitation to the scope introduced in this edition of BS 1610 : Part 1, which now specifies the grading of the forces applied by a materials testing machine, and the method of verification, when the machine is used in the compression mode only. BS EN 10002-2 specifies the grading of the forces applied by a materials testing machine, and the method of verification, when the machine is used in tension. BS 1610 : Part 2 specifies 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). The numerical system of grading specified relates to that adopted internationally and is also conceptually similar to the system for testing machines specified in BS 1610 : 1964. 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.

This Part of BS 1610 does not restrict the type of equipment used for verification but, by reference to BS 1610 : Part 2, requires that the 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.

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Section 1. General

1.1 Scope

This Part of BS 1610 specifies requirements for the grading of the forces applied by uniaxial materials testing machines, and describes the method of verification, when the machine is used in the compression mode only.

Verification of the dynamic forces applied by materials testing machines is excluded.

NOTE 1. BS EN 10002-2 specifies the grading of the forces applied by a materials testing machine, and the method of verification, when the machine is used in tension.

NOTE 2. The titles of the publications referred to in this standard are listed 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 force-measuring system

A system for measuring force by means of an analogue or digital display or a chart recorder. Each form of display and each range in a multi-range machine is an independent force-measuring system.

1.2.3 loading mode

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

1.2.4 repeatability

Depending on the method of verification adopted (see **3.5.1**), one of the following definitions applies.

(a) When the true force method is used, the repeatability is the greatest difference between the indicated forces corresponding to repeated applications of the true force.

(b) When the indicated force method is used, the repeatability is the greatest difference between the true forces corresponding to repeated applications of the indicated force.

1.2.5 error

Depending on the method of verification adopted (see **3.5.1**), one of the following definitions applies.

(a) When the true force method is used, the error is the mean indicated force corresponding to repeated applications of the true force minus the true force.

(b) When the indicated force method is used, the error is the indicated force minus the mean true force, corresponding to repeated applications of the indicated force.

1.2.6 resolution

The smallest specified measurement interval on a given force-measuring range (see **3.2.1**).

1.2.7 lower limit of verification

The lowest specified force on a given measurement range to which a materials testing machine can be verified.

1.2.8 error of zero force

The residual force indicated after applying and removing a series of forces.

1.2.9 verification equipment

Equipment consisting of proving devices, verification masses and proving levers (see BS 1610 : Part 2).

1.2.10 proving device

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

1.2.11 deflection

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

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Section 2. Grading of materials testing machines

2.1 General

Uniaxial materials testing machines shall be graded in accordance with the maximum permissible values given in table 1 for the repeatability and error of the forces specified in **2.2** to **2.4** and for the error of zero force, when verified in accordance with section three.

If the machine fails to comply with a given grading with the maximum-reading facility connected, but does comply with the facility disconnected, then grading shall be given providing this condition is stated in the certificate of grading (see **2.5**(f)).

NOTE 1. The number of forces specified is dependent on the number of ranges over which the machine is constructed to operate (see **3.5.2**).

NOTE 2. Machines which have a digital indicator with a zero-track facility should be verified, and subsequently used, with the facility in use. The requirement of table 1 for the error of zero force is not appropriate.

NOTE 3. For machines where it is not possible to determine the error of zero force, e.g. because a zero mark does not exist or because the pointer rests against a stop at zero force, the requirement of table 1 for the error of zero force does not apply. These machines can only be assessed in accordance with the grade 2.0 requirements of table 1 for repeatability and error. The force (in newtons) due to the mass of the proving device, if applied along the loading axis of the machine, should be calculated by multiplying the mass (in kilograms) by 9.815 and should be recorded on the certificate of grading. The force due to the mass of an item subsequently tested in the machine should not differ from this value by more than ± 0.4 % of the lowest force verified.

2.2 Single-range materials testing machines

At least five consecutive forces, from the maximum to be verified downwards, shall not exceed the values given in table 1 for a specific grade.

The grading shall cease to apply below the last force that complies with these requirements.

It is possible for a range to be given more than one grading, but for each such grading all forces from the maximum downwards shall be considered. Thus a more exacting grade shall not be introduced to cover some intermediate part of the range.

Table 1. Grading of materials testing machines

Grade of machine	Maximum permissible repeatability of forces as percentage of nominal force	Maximum permissible error of forces as percentage of nominal force	Maximum permissible error of zero force as percentage of maximum force of range
	%	%	%
0.5	0.5	± 0.5	± 0.1
1.0	1.0	± 1.0	± 0.2
2.0	2.0	± 2.0	± 0.4

2.3 Multi-range materials testing machines

Each range shall be graded as described in **2.2**.

NOTE. The resolution and hence the lower limit of verification may change when a new range is selected.

A machine with an auto-ranging digital indicator, i.e. an indicator where the increment of count of the indicated force changes automatically at given points between zero and the maximum reading, shall be graded as a single-range machine as described in **2.2**. However, a grading can only apply if, throughout the range graded, the ratio of the indicated force to the increment of count at that force is not less than the following values:

400 for grade 0.5 machine;

200 for grade 1.0 machine;

100 for grade 2.0 machine.

2.4 Discrete-force materials testing machines

For machines applying not more than five discrete forces each force shall not exceed the values given in table 1 for a specific grade. For machines applying more than five discrete forces, at least five forces, spread at approximately equal intervals over the range of the machine, shall not exceed the values given in table 1 for a specific grade.

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2.5 Certificate of grading

When a materials testing machine has been graded and verified in accordance with this Part of BS 1610, the verifier shall issue a certificate stating the following.

(a) The identity and location of the materials testing machine and the date of verification.

(b) The resolution, grade, mode and range of forces on each force-measuring system verified.

(c) Where appropriate, any force-measuring systems that were not verified.

(d) For discrete-force materials testing machines, the grade of each force verified.

(e) The method of verification used (see **3.5.1**) and the identity, grading and date of the certificate of grading of the verification equipment used.

(f) Whether or not a maximum-reading facility was used (see **3.5.3.2**).

(g) The average temperature of the verification equipment at the time of verification.

(h) Where appropriate, the force due to the mass of the proving device (see note 3 to **2.1**).

(i) Where appropriate, the type of chart paper used during the verification and an accurate measurement of the width of the paper (see **3.2.1.1**).

2.6 Frequency of reverification

A materials testing machine shall be reverified annually or if it has been dismantled for moving or subjected to major repair or adjustment.

NOTE. A machine designed to be portable need not be reverified if it is moved to a new site.

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Section 3. Method of verification

3.1 General

The forces applied by uniaxial materials testing machines shall be verified according to the procedures described so as to permit a determination of grading for repeatability and error of force. To ensure that the grading is consistent with the resolution of the force indication, a lower limit of verification is determined.

3.2 Materials testing machine

3.2.1 Resolution

3.2.1.1 *Analogue scale*

The width of the graduation marks defining the smallest scale interval on the scale shall be uniform and approximately equal to the width of the pointer. If the force indication is made by means of a chart recorder, then the width of the lines defining the smallest scale interval on the chart shall be uniform and approximately equal to the width of the trace.

NOTE. Widths of graduations and pointer should be in accordance with BS 3693.

A scale interval shall be subdivided by estimation to determine the resolution (r) as follows.

(a) When the scale interval is at least 2.5 mm wide, the resolution shall be one-tenth of a scale interval.

(b) When the scale interval is at least 1.25 mm wide and less than 2.5 mm wide the resolution shall be one-fifth of a scale interval.

(c) When the scale interval is less than 1.25 mm wide, the resolution shall be one-half of a scale interval.

The resolution shall be expressed in SI units of force in newtons.

If the force indication is by means of a chart recorder, the nominal width and the graduation interval of the chart paper used shall be recorded. The grading of the machine is applicable only when chart paper of the same type is used. If there is no facility for generating an electrical calibration input to a chart recorder so that small changes in the width of the chart paper may be accommodated, then the overall width of the chart used during the verification shall be measured to an accuracy equivalent to the resolution and shall be recorded. The width of chart paper subsequently used shall be within $\pm 2r$ of this width.

3.2.1.2 *Digital scale*

The resolution shall be determined when there is no force applied by the materials testing machine 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.

The resolution shall be expressed in SI units of force in newtons.

3.2.2 Verification

Verification shall be carried out for each force-measuring system and in each loading mode for which a grade is sought.

3.2.3 Lower limit of verification

Verification shall not be performed below the lower limit F_v on any force-measuring system determined as follows:

$$F_v = a \times r$$

where

a has the following values:

400 for grade 0.5 machine;

200 for grade 1.0 machine;

100 for grade 2.0 machine;

r is the resolution determined in accordance with **3.2.1**.

3.2.4 Condition

Verification shall not be commenced unless the materials testing machine is in good working order.

3.3 Verification equipment

Verification equipment shall be in accordance with BS 1610 : Part 2. The grade of the verification equipment shall be equal or superior to the grade determined for the materials testing machine.

3.4 Preliminary procedure

3.4.1 Alignment

Mount the verification equipment in the machine so that the forces are applied along the loading axis of the machine. Mount tension proving devices in the machine using fittings for alignment at each end of the device. For the alignment of a proving device in a compression mode, mount a spherical seating on to the device.

NOTE. This may be achieved by means of a soft-steel loading pad placed on the domed boss of the proving device or, where the upper boss is plane, by means of a spherical seating unit placed on the boss or by using the spherically-seated platen of the machine loading directly on to the device.

3.4.2 Temperature compensation

Allow sufficient time for the verification equipment to attain a stable temperature. Record the temperature at the beginning and end of the application of each series of forces. Where necessary, apply temperature corrections to the deflections of proving devices using the equations given in appendix A.

3.4.3 Machine conditioning

Exercise the materials testing machine and verification equipment three times between zero force and the maximum force to be measured. Then reset the machine's force indicator to zero.

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3.5 Verification procedure

3.5.1 Method

Use one of the following verification methods.

(a) *True force.* Operate the machine to balance a given true force as determined by the verification equipment. Then record the machine's indicated force.

(b) *Indicated force.* Operate the machine to apply a given indicated force and record the true force measured by the verification equipment.

3.5.2 Selection of test forces

3.5.2.1 ***General***

As the total number of forces required to verify a materials testing machine depends on the number of ranges over which the machine is constructed to operate, use the appropriate number of forces as given in **3.5.2.2** to **3.5.2.4**.

3.5.2.2 ***Single-range materials testing machines***

Apply a series of at least five approximately equispaced forces upwards from 20 % of the scale maximum or the lower limit of verification, whichever is greater.

When the lower limit of verification is below 20 % of the scale maximum, additional forces may be applied below 20 % of the scale maximum down to and including the lower limit of verification. Working downwards from 20 % of the scale maximum, consecutive forces shall not differ by more than 6 % of the scale maximum.

3.5.2.3 ***Multi-range materials testing machines***

Verify each range as described in **3.5.2.2**.

3.5.2.4 ***Materials testing machines with auto ranging digital indicators***

Apply a series of at least five approximately equispaced forces upwards from 20 % of the maximum reading of the digital indicator. Apply at least one additional force for each 6 % of the maximum reading, working downwards from the 20 % point to the lower limit of verification (see **3.2.3**). At least two forces shall be verified on each part of the range where the increment of count does not change.

3.5.2.5 ***Discrete-force materials testing machines***

For machines applying not more than five discrete forces verify each force. For machines applying more than five discrete forces, verify at least five forces spread at approximately equal intervals over the range of the machine.

3.5.3 Application of test forces

3.5.3.1 ***Procedure***

For each range, apply the series of forces in ascending order and repeat each series to give three series of such forces. Completely remove the force after each series of applications. Record the zero reading not less than 30 s and not more than 2 min after removing the force.

Make the zero reading of the force indicator recorded after removing the force with the machine in the same mechanical condition as it was in before applying the series of forces.

If necessary, reset the force indicator to zero at the commencement of each series of readings but do not apply a correction to readings already taken.

NOTE. In some testing machines difficulty may be experienced in maintaining a steady force; in such circumstances measurements may then be made under conditions of slowly increasing force.

3.5.3.2 ***Maximum-reading facility***

When the force indicator is fitted with a maximum-reading facility which could introduce friction, e.g. a pointer-arresting mechanism or slave pointer, apply one of the series of forces with the facility in operation for each range of the machine. Make the zero reading of the force indicator with the facility disengaged.

3.5.3.3 ***Force indication by hydraulic pressure***

For machines employing a hydraulic ram and a method of force measurement derived from the hydraulic pressure, apply each series of forces with the ram at a significantly different position within its available stroke. Where this is not practicable, apply the series of forces three times with the ram in the normal working position.

3.6 Calculation of results

At each nominal force, calculate the repeatability and error from the results of all the applications of forces and express these as a percentage of the nominal force.

Calculate the error of zero force for each series of forces and express it as a percentage of the maximum force of the machine range.

Do not correct the forces indicated by the materials testing machine for the error of zero force.

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Appendix

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

A.1 General

The deflections of a proving device at 20 °C are given for each force in the certificate of grading for the proving device (see **2.1.3** of BS 1610 : Part 2 : 1985). When a proving device is used at a temperature other than 20 °C, correct the deflection for the effect of the change in temperature using the appropriate equation given in **A.2** and **A.3**.

A.2 True force method

For the true force method (see **3.5.1**(a)), use the following equation:

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

where

- d_{20} is the calibrated deflection of the proving device at 20 °C for a given calibration force;
- d_t is the deflection of the proving device that has to be maintained by the machine in order to apply the true value of force;
- t is the temperature in °C of the proving device during verification;
- 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.

Typical deflection corrections are given in table 2.

For proving devices made of other materials and for all strain gauge load cells, the value of K given in the certificate of grading should be used.

A.3 Indicated force method

For the indicated force method (see **3.5.1**(b)), use one of the following equations:

$$D_{20} = D_t\,[1 - K\,(t - 20)] \qquad (2)$$

where

- D_{20} is the observed deflection of the proving device, corrected for the departure of the temperature from 20 °C, for comparison with the calibrated deflection d_{20};
- D_t is the observed deflection of the proving device when the machine indicates a given nominal force;

t and K are as defined in **A.2**.

$$d_t = d_{20}\,[1 + K\,(t - 20)] \qquad (3)$$

where

- d_{20} is the calibrated deflection of the proving device at 20 °C for a given calibration force;
- d_t is the equivalent calibrated deflection of the proving device at t °C, for comparison with observed deflection D_t;

t and K are as defined in **A.2**.

A.4 Examples

A.4.1 *Example 1*

True force method (see **3.5.1**(a)):

temperature of device, t	= 22 °C
change of temperature, $(t - 20)$	= +2 °C
required true force	= 300 kN
equivalent calibrated deflection at 20 °C, d_{20}	= 802.6 divisions

In table 2, in the column headed 2 °C, the nearest entry exceeding 802.6 divisions is 833 divisions which corresponds to 0.4 division correction.

Hence, deflection to be maintained by machine, d_t	= 802.6 + 0.4
	= 803.0 divisions

A.4.2 *Example 2*

Indicated force method (see **3.5.1**(b)):

temperature of device, t	= 23 °C
change in temperature, $(t - 20)$	= +3 °C
observed deflection, D_t	= 1220.7 divisions

In table 2, in the column headed 3 °C, the nearest entry exceeding 1220.7 divisions is 1296 divisions which corresponds to 1.0 division correction.

Hence,

corrected deflection, D_{20}	= 1220.7 − 1.0
	= 1219.7 divisions
indicated force	= 500 kN
equivalent calibrated deflection at 20 °C, d_{20}	= 1224.6 divisions
Hence, true force applied by machine	= 498 kN

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Table 2. Deflection corrections for temperature variations of a steel proving device with K = 0.000 27/°C

Correction to deflection (division)	Departures of temperature from 20 °C							
	1 °C	2 °C	3 °C	4 °C	5 °C	6 °C	7 °C	8 °C
	Maximum deflection (divisions) to which stated correction applies							
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	1296	648	432	324	259	216	185	162
0.4	1666	833	555	416	333	277	238	208
0.5	2037	1018	679	509	407	339	291	234
0.6		1203	802	601	481	401	343	300
0.7		1388	925	694	555	462	396	347
0.8		1574	1049	787	629	524	449	393
0.9		1759	1172	879	703	586	502	439
1.0		1944	1296	972	777	648	555	486
1.1		2129	1419	1064	851	709	608	532
1.2			1543	1157	925	771	661	578
1.3			1666	1250	999	833	714	625
1.4			1790	1342	1074	895	767	671
1.5			1913	1435	1148	956	820	717
1.6			2037	1527	1222	1018	873	763
1.7			2160	1620	1296	1080	925	810
1.8				1712	1370	1141	978	856
1.9				1805	1444	1203	1031	902
2.0				1898	1518	1265	1084	949
2.1				1990	1592	1327	1137	995
2.2				2083	1666	1388	1190	1041
2.3					1740	1450	1243	1087
2.4					1814	1512	1296	1134
2.5					1888	1574	1349	1180

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Publication(s) referred to

BS 1610	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
BS 3693	Recommendations for design of scales and indexes on analogue indicating instruments
BS EN 10002-2	Tensile testing of metallic materials Part 2 Verification of the force measuring system of the tensile testing machine

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