BS 5214 : Part 2 : 1978
UDC 678.01 : 620.172.05

Specification for

Testing machines for rubbers and plastics

Part 2. Constant rate of force application machines

Spécification des machines d'essai des caoutchoucs et matières plastiques
Partie 2. Machines à vitesse d'application constante de force

Spezifikation für Prüfmaschinen für Kautschuke und Kunststoffe
Teil 2. Maschinen mit gleichmäßiger Belastungssteigerung

British Standards Institution Gr 5

Contents

Foreword

This part of this British Standard has been produced under the direction of the Plastics and Rubber Standards Committees. It covers machines used for measuring the tensile, flexural and compression properties of adhesive joints, rubbers and plastics under constant rate of force application. This standard is therefore complementary to BS 5214 : Part 1 which covers machines operating at constant rate of traverse. An explanatory appendix on aspects of testing at a constant rate of force application is provided.

BSI

Amendment Slip No. 1
published and effective from 31 August 1981
to BS 5214 : Part 2 : 1978

Testing machines for rubbers and plastics
Part 2. Constant rate of force application machines

Revised text

AMD 3556
August 1981

Foreword

Add the following second paragraph:

'It is intended to produce further Parts of this standard, dealing with other equipment used for testing plastics and rubber. It is the intention that the various Parts of this standard will be quoted in the corresponding British Standards covering methods of test, e.g. BS 903, BS 2782, BS 4370 and BS 4443.'

AMD 3556
August 1981

Clause 3.1 tensile testing system

At the end of the existing text insert the following note:

'NOTE. According to the arrangement of grips or jigs, the test specimen will be in tension, shear, compression or flexure. If the machine is used for tests other than in tension, the term 'grip' should be taken to include a platen or other member for the application of force to the test specimen.'

AMD 3556
August 1981

Clause 3.2 force

Delete the existing term and definition and substitute the following:

'Text deleted'.

AMD 3556
August 1981

Clause 3.5 repeatability of force, elongation and deflection measurement

In the title insert an asterisk after the word 'force'.

Insert the following footnote:

'*The term force throughout this standard refers to the force acting along the straining axis of the machine.'.

AMD 3556
August 1981

Clause 4. Designation of machine accuracy

In item (b) delete 'or D' and substitute ', D or E'.

AMD 3556
August 1981

Clause 8. Measurement of elongation (deflection)

In the second line of the fifth paragraph delete 'and D' and substitute ', D and E'.

In the first line of item (2) delete 'and D' and substitute ', D and E'.

Delete the existing last paragraph and substitute:

'The values in table 2 for grades B, C, D and E are given in percent of scale reading. The manufacturer shall state the lowest elongation at which the specified accuracy can be achieved.'

AMD 3556
August 1981

Table 2. Grades of accuracy for displacement measurement

Delete the existing entries for Grades B, C and D and substitute the following:

'B	10 % on 25 mm (ΔL = 2.5 mm)	± 2 %	± 0.5 %	In accordance with BS 3846 (error only)	Rig with micrometer head to BS 870
C	50 % on 25 mm (ΔL = 12.5 mm)	± 2 %	± 0.5 %	In accordance with BS 3846 (error only)	Rig with scale to BS 4372 Rig with micrometer head to BS 870
D	1200 % on 20 mm (ΔL = 240 mm)	± 2 %	± 0.5 %	Rig with scale to BS 4372	Rig with scale to BS 4372
E	1200 % on 10 mm (ΔL = 120 mm)	± 2 %	± 0.5 %	Rig with scale to BS 4372	Rig with scale to BS 4372

In the second line of the asterisked footnote under table 2 delete 'and D' and substitute ', D and E'.

AMD 3556
August 1981

Standards publications referred to

Insert the following publications in the correct numerical order.

BS 903* Methods of testing vulcanized rubber
BS 2782* Methods of testing plastics
BS 4370* Methods of test for rigid cellular materials
BS 4443* Methods of test for flexible cellular materials

Insert the following footnote as follows:

*Referred to in the foreword only.

British Standard Specification for

Testing machines for rubbers and plastics

Part 2. Constant rate of force application machines

1. Scope

This Part of this British Standard specifies the requirements for tensile testing systems suitable for testing rubbers, plastics and adhesive joints under the condition of a constant rate of application of force although any one system may only be applicable to a narrower range of materials. It also covers such systems when used for flexural, shear and compression tests.

2. References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. Definitions

For the purposes of this Part of this British Standard the following definitions apply.

3.1 tensile testing system. A machine composed of a nominally fixed and a movable member to which may be attached suitable grips or jigs for holding the test specimen. The machine is equipped with a force measuring system and is capable of controlling the rate of application of force applied to the test specimen. The force measuring system is complete with indicator and/or recorder. In addition there may be included a system for measuring the displacement (extension or deflection) of the test specimen.

3.2 force. The force measured is that acting along the straining axis of the machine. According to the arrangement of grips or jigs, the test specimen will be in tension, shear, compression or flexure.

NOTE. For the purpose of this definition, 'grip' is taken to mean 'platen' or other member for application of force to the test specimen when the machine is used for tests other than in tension.

3.3 elongation. The increase in the test length of a tensile test specimen.

3.4 deflection. The distortion in the direction of the applied force of a test specimen in compression, shear or flexure.

3.5 repeatability of force, elongation and deflection measurement. The greatest difference, at a given true value, between the indicated values corresponding to repeated applications of the true value.

3.6 error. The mean indicated value, at a given true value, corresponding to repeated applications of the true value, less the true value.

NOTE. The definitions of repeatability and error assume verification by observing the variation in indicated values obtained with repeated application of known values.

3.7 accuracy of force control. The maximum permitted positive or negative deviation of the value of the actual force from the value of the required force at any instant of time during the test. The commencement of the test is defined as the instant of the initial increment of force from zero.

The accuracy is expressed as a percentage of the required force or as the same percentage of 1/5 of the maximum demanded force, whichever is the greater. This is illustrated in figure 1.

NOTE. The accuracy of force control is the sum of the control system accuracy and a proportion of the force measuring system accuracy.

3.8 accuracy of control of rate of force application. The maximum permitted positive or negative deviation of the actual rate of application of force from that required, up to the point where the change of rate of strain relative to that in the initial linear zone exceeds 10 : 1 (see figures 2 and 3) or there is a peak of force.

The value is expressed as the percentage deviation from the rate of application of force required. This is illustrated in figure 1.

4. Designation of machine accuracy

Machines shall be designated according to accuracy in respect of the following parameters:

(a) measurement of force (grade A or B);

(b) measurement of elongation or deflection (grade A, B, C or D).

For example, a machine of the highest accuracy shall be designated as 'force: grade A, elongation (deflection): grade A'.

If for any application it is not considered necessary to specify accuracy limits for either of these parameters, then no grade letters shall be quoted.

It is not practicable to specify the machine accuracy in respect of force control. Instead the required accuracy of the machine and test specimen combination shall be specified as described in clause **10**. For example, force control: grade A on material ABC of dimensions XYZ.

5. Design features

5.1 Size and construction. The size and construction shall be such that the machine is able to test all materials for which it is intended to be used and shall have no features which may adversely affect test results.

The traverse of the moving grip shall be able to accommodate the maximum elongation of the test specimen. In the case of the more highly extensible materials a traverse in excess of 1 m may be necessary.

5.2 Machine axial alignment. The coupling between the force measuring system, the grips or test specimen jig and the correctly installed test specimen shall be accurately aligned with the straining axis of the machine and the test axis of the test specimen shall coincide with the direction of the applied force.

NOTE. Non-axial alignment of a test specimen in the grips and lack of test specimen symmetry are particularly important causes of variation in test results.

5.3 Specimen grips. For testing dumb-bell, parallel strip and similar tensile test specimens, the machine shall be provided with a type of grip which closes automatically as the tension increases (e.g. wedge or pneumatic) and which exerts a uniform pressure across the width of the test specimen. The test specimen shall be held in such a manner that slip relative to the grips is prevented as far as possible. For testing lap joints of rigid materials other types of grip may be suitable.

5.4 Drive characteristics. The drive of the machine shall be without significant backlash and the machine shall be fitted with an automatic cut-out which stops the drive when the test specimen fails.

5.5 Jigs for use in compression, shear and flexure. Such jigs or fixtures shall conform to the relevant method of test or material specification. They shall not significantly affect the accuracy of the machine by the introduction of friction, backlash or non-alignment.

6. Force measuring system

A continuous indication of the force applied to the test specimen, preferably recorded automatically with a permanent indication of the maximum force, shall be provided. Machines with low inertia in their force measuring system shall be provided for constant rate of force application testing, where the control response of the machine as well as the force measuring system response is very much influenced by inertia effects.

7. Force measuring system accuracy

7.1 Static force. For all scale ranges, two grades, A and B, shall be specified, as defined in BS 1610. The designation of each scale of a machine depends upon the values of repeatability and error found when it is verified in accordance with the methods described in section one of BS 1610 : 1964 except that calibration shall be made with both increasing and decreasing force. In general, method 1 is suitable only for verifying scales with a maximum force up to approximately 1500 N, whilst methods 2 and 3 are suitable for verifying all scales with a maximum force reading greater than 500 N.

The maximum permissible values for repeatability for grades A and B are given in table 1 and are based on BS 1610; the corresponding limits of error are illustrated in figure 4.
If separate scales for use in compression or other modes of operation are provided, these shall be verified separately.

7.2 Dynamic force. Tensile testing machines fitted with electronic force measuring devices may be regarded as sufficiently free of inertia for the speeds of testing given in clause **9**. This does not necessarily apply to the electronic recorders normally used with them and, in many cases, the dynamic inaccuracy of these recorders considerably exceeds their static inaccuracy.

All electro-mechanical recorders suffer dynamic errors which are usually made up of acceleration errors stemming

Table 1. Grades of accuracy for force measurement

1	2	3	4	5	6	7
Grade	**Accuracy of verification devices**		**Certified range**			
	Force applied by weights or proving levers correct to within	Grading of elastic proving device	One-fifth force to full force of machine scale and all forces of a machine applying fixed forces		Below one-fifth of machine scale range	
			Requirement for repeatability	**Requirement for accuracy**	**Requirement for repeatability**	**Requirement for accuracy**
			At each verification force, maximum permissible difference between highest and lowest readings expressed as a percentage of the verification force	At each verification force, maximum permissible error expressed as a percentage of the verification force	At each verification force, maximum permissible difference between highest and lowest readings, expressed as a percentage of the full force reading of the scale	At each verification force, maximum permissible error expressed as a percentage of the full force reading of the scale
A	% ± 0.2	1	% 1.0	% ± 1.0	% 0.2	% ± 0.2
B	± 0.3	2	2.0	± 2.0	0.4	± 0.4

NOTE. The requirement for accuracy is a percentage of the true force within the range one-fifth force to full force of the machine scale but is a constant force error for forces below one-fifth of the scale. Thus at one-fifth scale on a 500 kN grade A machine scale, the maximum percentage error of applied force permitted is ± 1 % and the force error is ± 1 kN. The permitted force error from zero to one-fifth of the scale, (100 kN) accordingly remains constant at ± 1 kN.

from the inertia of the device and velocity lag errors due to viscous and coulomb friction. Measurement of recorder dynamic accuracy is best achieved by recording the error signal level during the test. This can be done without affecting the instrument performance but is usually technically difficult. It is, therefore, not considered practicable at present to specify limits and a calibration procedure for dynamic accuracy in this standard. Consequently the user is advised to obtain, from the testing machine manufacturer, dynamic accuracy figures for the recorder in order to calculate the probable measurement error and assess whether or not it is significant. In cases where it is significant, either the testing rate may be reduced, or the full scale range of the output device may be increased in order to reduce the acceleration and velocity levels.

As a guide to recorder requirements, the response time for full scale travel should be considerably less than the rise time of the force, if the dynamic errors are to be comparable with the static inaccuracy. It is recommended, therefore, that the maximum demanded pen velocity (V_D) should be less than the maximum possible pen velocity (V_{max}) by a factor dependent on the machine grade as follows:

(a) $V_D \leqslant \frac{V_{max}}{10}$ for grade A machines,

(b) $V_D \leqslant \frac{V_{max}}{5}$ for grade B machines.

If only the recorder response time T is known, then V_{max} may be calculated approximately by means of the following equation:

$$V_{max} = \frac{R}{T}$$

where

R is the recorder full scale movement

If the recommendations above are not followed, recorder errors arising from dynamic operation should be obtained from the manufacturer.

8. Measurement of elongation (deflection)

The elongation (deflection) of test specimens shall be measured by a method of test utilizing one of the following techniques:

(a) grip separation;

(b) extensometers attached to the test specimen;

(c) optical or other non-attached extensometers.

During the process of measurement, a continuous indication of the elongation (deflection) and a permanent indication of the maximum elongation (deflection) shall be given. Preferably the elongation (deflection) should be recorded autographically in the form of a force/elongation (deflection) curve.

For some purposes, particularly for tests in flexure, shear or compression, the measurement of grip separation is the most convenient method. In such cases it is essential that there shall be no play in the elongation (deflection) measuring system nor any slippage between the grips and the test specimen which would significantly affect the accuracy of the test results.

If an extensometer attached to the test specimen is used, there shall be no sign of distortion or damage to the test specimen nor any slippage between the extensometer grips and the test specimen which would significantly affect the test results.

When extensometer accuracy is specified, four grades, A, B, C and D are recognized. The grading of each range of each measuring device depends on the following:

(1) for grade A the values of gauge length error, discrimination, repeatability and error found when it is verified in accordance with BS 3846;

(2) for grades B, C and D the values of error found when it is verified in accordance with the method given in table 2.

The values in table 2 for grades B, C and D are given in millimetres and the corresponding errors in strain units therefore depend upon the gauge length used. For all grades, the gauge length and its accuracy shall be specified in the relevant method of test or material specification.

9. Rate of application of force

The testing machine shall preferably be capable of operating at one or more of the following rates of application of force:

0.5 kN/min, 1 kN/min, 2 kN/min, 5 kN/min,
10 kN/min, 20 kN/min, 50 kN/min

Care should be taken to ensure that an appropriate size of test specimen is used in each case.

Other rates, outside these limits, following the R10 (1, 2, 5) series given in BS 2045 : 1965 may be used if given in a material specification.

10. Accuracy of force control

The accuracy of force control and the accuracy of the rate of application of force is dependent upon the following:

(a) the maximum straining rate;

(b) the change of straining rate;

(c) the rate of change of straining rate;

(d) the machine drive and other characteristics.

Therefore, since the first three factors are dependent on the specimen being tested, the accuracy of force control of the machine alone cannot be specified. The user is advised to carry out some preliminary tests to establish whether the accuracy required is attainable on the machine.

The accuracy grades shown in table 3 shall be used as a means of quantifying the performance of a constant rate of force machine when testing a particular material and specimen shape.

Table 2. Grades of accuracy for displacement measurement

Grade	Approximate maximum elongation (deflection) % on given gauge length, mm	Accuracy of measurement, mm	Accuracy of verification device, mm	Method of verification*	
				For extensometer measurement, mm	For crosshead displacement measurement, mm
A	Complying with the requirements of grade C of BS 3846:1970				
B	10 on 25 ($\Delta L = 2.5$)	± 0.05	± 0.01	Complying with the requirements of BS 3846 (error only)	Rig with micrometer head complying with the requirements of BS 870, i.e. ± 0.0015†
C	50 on 25 ($\Delta L = 12.5$)	± 0.5	± 0.1	Complying with the requirements of BS 3846 (error only)	Rig with scale complying with the requirements of BS 4372, i.e. ± 0.1‡ Rig with micrometer head complying with the requirements of BS 870, i.e. ± 0.0015†
D	1200 on 25 ($\Delta L = 300$)	± 1.0	± 0.25	Rig with scale complying with the requirements of BS 4372, i.e. ± 0.25	Rig with scale complying with the requirements of BS 4372, i.e. ± 0.25‡

*It is probable that, for tensile measurements, extensometers attached to the test specimen will be used. However, for measurements to grades B, C and D, crosshead displacement will sometimes be suitable and this may consist of a direct reading scale or a magnifying device. Alternative methods of verification are therefore proposed for extensometer and crosshead measurement.

Furthermore, where crosshead displacement is a satisfactory measurement, it is assumed that the deflection of the load measuring head of the machine is insignificant in relation to the deflection being measured.

†In this case, the verification device should comprise a micrometer head to the required accuracy. The micrometer head should be attached to the fixed part of the machine, e.g. adjacent to the load measuring crosshead. The axis of the verification device should be as near as possible to the loading axis of the machine.

‡The verification device should comprise a scale and vernier to the required accuracy. One end is attached to the fixed part of the machine, e.g. the load measuring head, and the other to the moving crosshead. The attachment of the scale and vernier should be as near as possible to the loading axis of the machine, e.g. utilizing the machine grips.

Table 3. Accuracy of force control

Accuracy grade	Accuracy of rate of application of force, %	Accuracy of force control, %
A	1	1
B	2	2
C	5	5
D	10	10
E	50	50

11. Machine stiffness

Machine stiffness (also referred to as hardness) is the force required to produce unit deflection of the testing system. This includes the framework of the machine, the straining mechanism, the force measuring device and the grips and attachments by which the test specimen is held.

For a 'soft' machine the traverse of the driven element is not necessarily the same as the rate of separation of the grips. Consequently, the uncorrected crosshead movement cannot be used as a measure of sample deflection. The accuracy of control of rate of application of force will generally be better with a stiff machine. Preference shall, therefore, be given to a machine which is stiff in comparison with the test specimen.

NOTE. A method of determining the *K*-value of a test machine, i.e. its apparent elastic compliance (deflection per unit force) is given in BS 4759.

12. Stability

The long term stability of electronic testing machines is influenced by a number of factors, the most important of which are temperature, mechanical hysteresis in the force sensing element, sensitivity to mains supply voltage and change in electronic component value.

The manufacturer shall, therefore, state in his specification and in any instruction manual, such of the following requirements as may be necessary to maintain the stated accuracy of the machine:

(a) the maximum permissible temperature variation from standard conditions;

(b) the maximum permissible variation of supply voltage;

(c) the frequency at which it is necessary to adjust any manual control, e.g. for zero or span.

13. Operational aspects

Slack in the grips and/or couplings shall be avoided whenever possible and change in the straining rate during the test shall be minimized where possible.

The maximum straining rate shall be as low as possible in relation to the maximum velocity of the testing machine.

Stringent specifications regarding test machine accuracy are of little value unless testing technique is closely controlled. Correlation of test data from different laboratories depends as much upon testing techniques as upon machine specifications. Operator errors, test specimen installation technique and test specimen variability are major sources of error.

Care shall be taken to avoid exposure of the machine to draughts or to radiant heat.

14. Certificate of verification

When a testing machine has been verified in accordance with this standard, the verifying authority shall issue a certificate stating the following:

(a) the identity of the machine and date of verification;

(b) the certified range and grade of each force or extension scale;

(c) the method of verification used and the identity of any calibrating devices employed;

(d) the ambient temperature at the time of verification;

(e) if required, the accuracy of control of the rate of force application;

NOTE. This can only be certified in terms of a given test specimen.

(f) the number of this British Standard, i.e. BS 5214: Part 2.

The testing machine shall be re-verified periodically to ensure that it continues to meet the grade(s) specified in this standard. The frequency of re-verification depends on the type of machine, the standard of maintenance, and the amount of usage. Normally, it is recommended that re-verification should be carried out at intervals not exceeding 12 months. However, a machine shall be re-verified if, in moving to a new location, it is dismantled, or if it is subject to major repairs or adjustments.

Appendix A

Testing at a constant rate of force application

A constant rate of traverse test requires the controlled element of the testing machine to travel at a pre-determined velocity. The machine will drive at this speed whether or not a specimen is fitted because the drive performance is nominally independent of the specimen characteristics.

Testing at a constant rate of application of force, however, requires the specimen, the grips and the force transducer to become part of the control loop. This means that the characteristics of these elements such as backlash in the grip, stiffness change in the specimen and non-linearity of the transducer may affect both the accuracy and the dynamic stability of the system. Figures 2 and 3 respectively illustrate the variations of force and strain during such a test on a specimen which exhibits a sudden change of stiffness (points D′ and D). The lines OA and OF′ represent the desired and the actual specimen loading during the test. The error in the value of force at any instant is shown typically as *e* and the error of the rate of force application at any instant is shown typically by the change of slope relative to the desired line OA. The loading line OF′ may be considered hypothetically as comprising five zones as shown in figure 2; these are as follows:

OB′ is the backlash originating usually from slack in the couplings;

B′C′ is the bedding zone originating from grips or couplings which require a certain force before they bed down and start to deform linearly;

C′D′ is the linear force application zone in which all machine elements, as well as the specimen, deform elastically;

D′E′ is a further linear force application zone following a sudden change of straining rate;

E′F′ is the non-linear zone in which the rate of change of force varies owing to the sensitivity of the control system to the increasing strain rate. This normally originates from the specimen when plastic deformation occurs.

The corresponding variation of strain during these five zones is shown in figure 3.

In some cases the initial backlash and bedding zones and the zone in which the rate of straining changes significantly are of limited interest. However, if the errors encountered in the important zone are excessive, it may be possible to reduce them by one or more of the following:

(a) altering the shape of the test specimens;

(b) reducing the rate at which force is applied;

(c) improving the machine performance by adjustment or machine change.

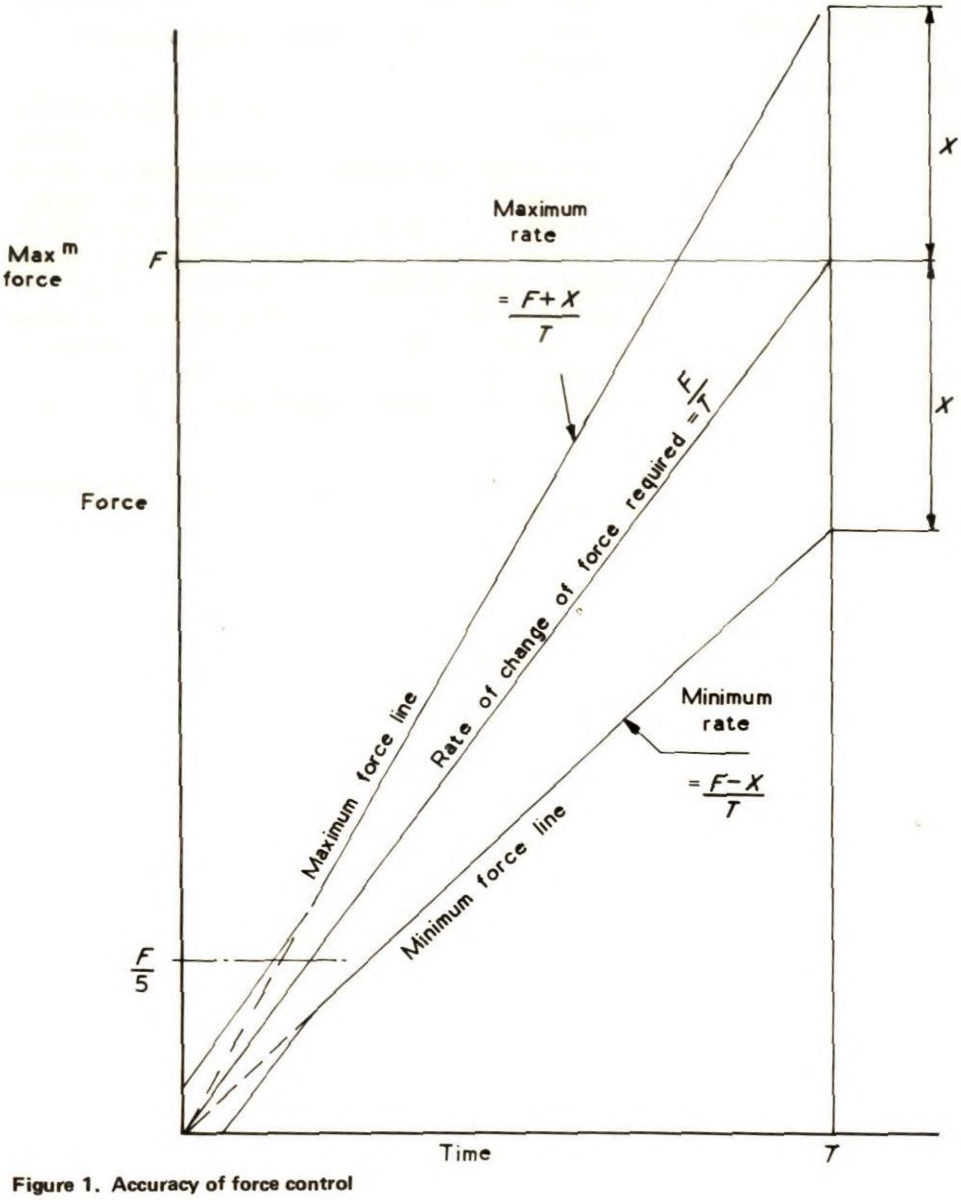

Figure 1. Accuracy of force control

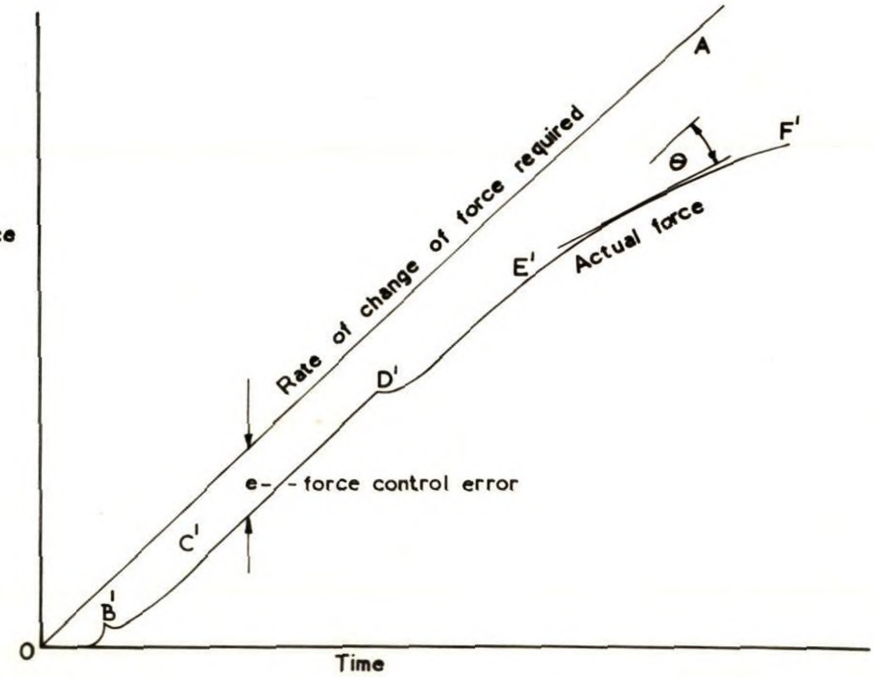

Figure 2. Typical actual force/time curve obtained during a test compared with the required curve

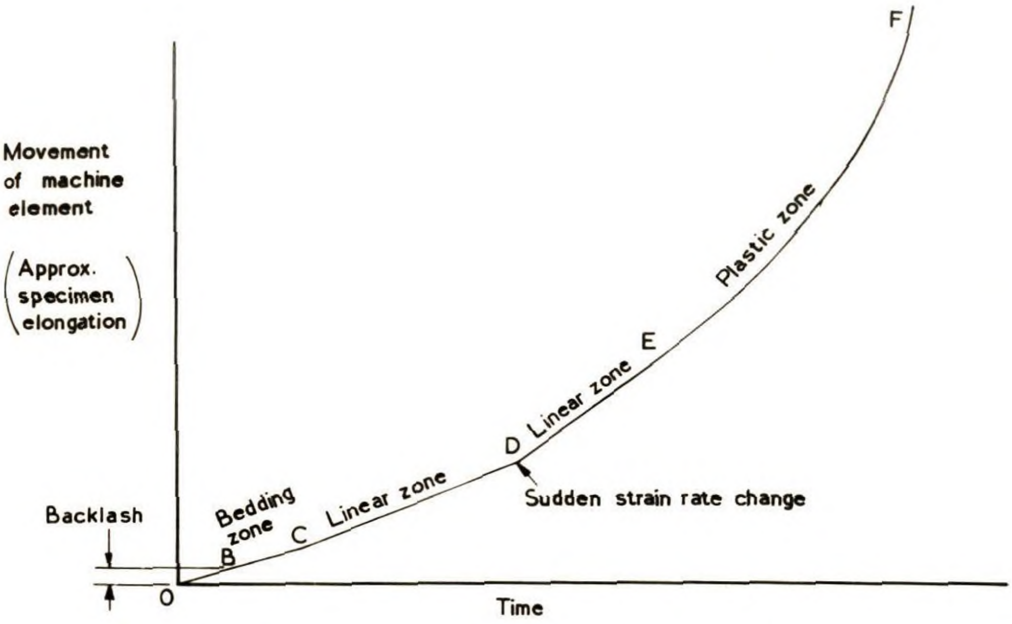

Figure 3. Machine element displacement/time curve corresponding to the actual force curve shown in figure 2

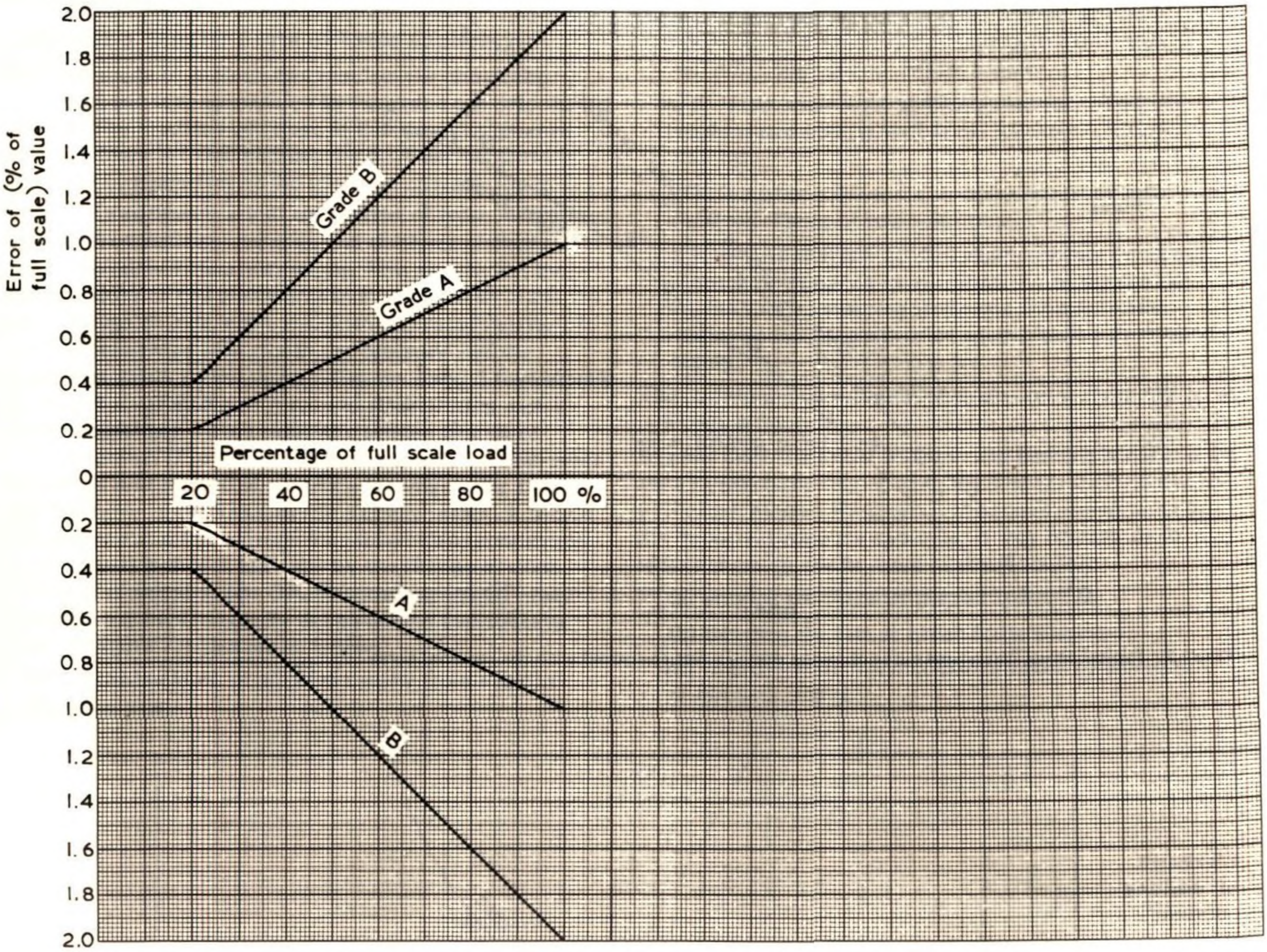

Figure 4. Machine accuracy gradings from BS 1610

Standards publications referred to

BS 870	External micrometers
BS 1610	Methods for the load verification of testing machines
BS 2045	Preferred numbers
BS 3846	Methods for the calibration and grading of extensometers for testing of metals
BS 4372	Engineers' steel measuring rules
BS 4759	Method for determination of *K*-values of a tensile testing system
BS 5214	Testing machines for rubbers and plastics
	Part 1 Tensile, flexural and compression machines

This British Standard, having been prepared under the direction of the Plastics and Rubber Standards Committee, was published under the authority of the Executive Board on **30 September 1978**

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Contract requirements
Attention is drawn to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

Revision of British Standards
British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. **It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.**

The following BSI references relate to the work on this standard:
Committee reference PLC/RUC/6 Draft for comment 75/52157 DC

Cooperating organizations

The Plastics Standards Committee and Rubber Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations

British Plastics Federation
*British Rubber Manufacturers' Association
Chemical Industries Association
Department of Industry (Chemicals and Textiles)
Department of Industry (National Physical Laboratory)
Department of the Environment (Building Research Establishment)
Electrical and Electronic and Insulation Association (BEAMA)
Electrical Installation Equipment Manufacturers' Association (BEAMA)
Electrical Research Association
Engineering Equipment Users' Association
Institution of Production Engineers
Malaysian Rubber Producers' Research Association
*Ministry of Defence
Plastics and Rubber Institute
*Post Office
Royal Institute of British Architects
*Rubber and Plastics Research Association of Great Britain
Rubber Growers' Association
Society of Chemical Industry
Society of Motor Manufacturers and Traders Limited

The organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Individual experts

Amendments issued since publication

Amd. No.	Date of issue	Text affected