

Australian Standard[®]

Calibration and classification of force-measuring systems



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- Australasian Railway Association
 - Bureau of Steel Manufacturers of Australia
 - Institute of Materials Engineering Australasia
 - National Association of Testing Authorities
 - National Measurement Institute
-

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STANDARDS AUSTRALIA

RECONFIRMATION

OF

AS 2193—2005

Calibration and classification of force-measuring systems

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NOTES

Australian Standard[®]

Calibration and classification of force-measuring systems

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PREFACE

This Standard was prepared by the Standards Australia Committee MT-006, Mechanical Testing of Metals, to supersede AS 2193—2002, *Calibration and classification of force-measuring systems*.

This Standard incorporates Amendment No. 1 (August 2006). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

The objective of this revision is to introduce a specification for calibrating load rings and similar force measuring devices.

During the preparation of this edition, cognizance was taken of the following Standards:

ISO

376 Metallic materials—Calibration of force-proving instruments used for the verification of uniaxial testing machines

7500 Metallic materials—Verification of static uniaxial testing machines

7500-1 Part 1: Tension/compression testing machines—Verification and calibration of the force-measuring system

ASTM

E74 Standard practice of calibration of working force standards for verifying the load indication of testing machines

AS ISO/IEC

17025 General requirements for the competence of testing and calibration laboratories

ISO

GUM Guide to the Expression of Uncertainty in Measurement

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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FOREWORD

Calibration of working force standards is performed in either primary or secondary force standardizing machines by applying forces of known magnitude and uncertainty and deriving a mathematical relationship between applied force and instrument readings. The estimation of the uncertainty associated with this mathematical relationship is included in the procedure.

Calibration of force-measuring systems comprises a comparison between indicated and applied forces of known magnitude and uncertainty by means of suitable working force standards.

Calibration includes an assessment of readability, repeatability and accuracy of the indicated force, the assignment of class or classes and the issue of a report.

Force-measuring systems referred to in this Standard are those associated with force-testing machines or any other machinery or instruments where force application is measured. In the case of testing machines, they may be classified as tension or compression machines depending on the mode of straining applied to the test piece. Some machines have provision for more than one mode of straining.

It is necessary for machines and force-measuring systems to be maintained in good working order and condition. Regular servicing is recommended, the frequency of the servicing being dependent on the frequency and conditions of use. All force-measuring systems should be calibrated periodically so that their results are reliable and consistent with those obtained from other force-measuring systems. However, the test data obtained depend also on the testing techniques used. It is important for users of this Standard to make reference to the specified method of test and also to printed literature provided by manufacturers of testing equipment.

Calibration authorities and force-measuring system users should note that the calibration procedures specified in this Standard apply only to statically applied forces.

Special procedures, which are outside the scope of this Standard, should be followed for dynamic calibration of force-measuring systems employing high rates of force application.

STANDARDS AUSTRALIA

Australian Standard**Calibration and classification of force-measuring systems**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for the static calibration of force-measuring instruments and their classification as working force standards. It also specifies the requirements for the static calibration of force-measuring systems of uniaxial testing machines and other force-measuring systems used for measuring the strength and other properties of materials, components, products and assemblies.

The Standard covers the following subjects:

- (a) Classification requirements for force-measuring systems of testing machines and other force-measuring systems.
- (b) Procedures for the calibration of force-measuring systems.
- (c) Requirements for the calibration and the classification of working force standards used for the verification of force-measuring systems.

NOTES:

- 1 Requirements for extensometers used in conjunction with tension and compression testing machines are given in AS 1545.
- 2 Advice and recommendations on information necessary for the performance of calibration are contained in the purchasing guidelines set out in Appendix A.

This Standard applies to testing machines and force-measuring systems which indicate in terms of the SI unit of force, the newton (N), or in arbitrary units.

NOTE: Reference should be made to AS/NZS 1376 for the relationship between the newton and technical units of force.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1545 Methods for the calibration and grading of extensometers

2103 Dial gauges and dial test indicators (metric series)

2706 Numerical values—Rounding and interpretation of limiting values

3807 Vocabulary of basic and general terms in metrology

AS ISO/IEC

17025 General requirements for the competence of testing and calibration laboratories

AS/NZS

1376 Conversion factors

ISO

3534 Statistics—Vocabulary and symbols

3534-1 Part 1: Probability and general statistical terms

Guide to the Expression of Uncertainty in Measurement (ISO GUM)

1.3 DEFINITIONS

For the purpose of this Standard, the definitions given in AS 3807, ISO 3534-1 and those below apply. The term, ‘force-measuring system’, applies to testing machines and other force-measuring systems.

1.3.1 Terms relating to testing machine and force-measuring system calibration

1.3.1.1 *Applied force*

A value of force as measured by a working force standard.

1.3.1.2 *Calibrating authority*

An organization recognized as being qualified and equipped to perform tests specified in this Standard.

NOTE: There are organizations accredited with the National Association of Testing Authorities, Australia, for performing calibrations in accordance with this Standard.

1.3.1.3 *Calibration*

All the operations for the purpose of determining the compliance of the machine with the requirements of this Standard.

1.3.1.4 *Calibration factor (see ‘Scale factor’)*

See Clause 1.3.1.16.

1.3.1.5 *Calibration range*

A portion of a machine range, or operating range, selected for calibration.

1.3.1.6 *Error in indicated force*

The value obtained by subtracting the applied force from the indicated force. It may be expressed as a percentage of the applied force.

1.3.1.7 *Force scale*

The form of display used to indicate the magnitude of the force, whether directly or indirectly. The display may be in the form of a graduated scale, a digital readout, an oscillogram or a computer printout.

1.3.1.8 *Class*

The category into which the force-measuring system (or an operating range or part thereof) is placed by virtue of its compliance with the specified limits of readability, repeatability and mean error of indicated force.

1.3.1.9 *Indicated force*

A value of force as indicated by a force-measuring system.

1.3.1.10 *Machine capacity*

The maximum force which a machine or force-measuring system is designed to apply and measure.

1.3.1.11 *Machine range*

The range of forces which the testing machine or force-measuring system can measure without substitution of any key element in the force-measuring system.

1.3.1.12 *Operating range*

The range of forces which the testing machine or force-measuring system can measure for any chosen setting of the force-measuring system.

1.3.1.13 *Resolution multiplier*

The value by which the readability is multiplied to determine the minimum reading at which the force scale may be used or calibrated for a particular Class.

1.3.1.14 *Resolution*

The smallest value which can be estimated with assurance from the scale.

1.3.1.15 *Repeatability of indicated force*

The difference between the highest and lowest values indicated for the same applied force during repeated sets of calibration readings. Alternatively, the repeatability is the difference between the highest and lowest values of applied force for the same indicated force during repeated sets of calibration readings, (see Appendix G).

1.3.1.16 *Scale factor (calibration factor)*

A factor by which the reading of an arbitrary machine scale is multiplied to obtain the corresponding value of indicated force.

NOTE: A scale factor applies to machines indicating in units other than force and to machines using a single force scale for more than one operating range. This factor may not be constant over the calibration range.

1.3.1.17 *Testing machine*

A device for applying forces to a test piece, or a test specimen, and then measuring the forces during testing either over a range or as discrete values.

NOTE: Testing machines may apply forces in tension, in compression, or in both modes. In the latter case they are known as universal testing machines.

1.3.2 Terms relating to force standardizing machines and to working force standards

1.3.2.1 *Calibration equation*

A mathematical equation which relates the accepted true values of force to the values indicated by an instrument.

1.3.2.2 *Calibration forces*

Those forces of known magnitude and uncertainty that are applied to the working force standard during calibration.

1.3.2.3 *Calibrated range*

The range of forces within which the uncertainty of measurement does not exceed the maximum uncertainty specified for the Class or Classes of the instrument.

1.3.2.4 *Continuous class*

A classification which permits interpolation between calibration forces using a calibration equation.

1.3.2.5 *Count of a digital display*

The smallest incremental change that can be induced on the display. For some automatic ranging digital displays this may vary according to the magnitude of the output signal from the working force standard.

1.3.2.6 Deflection

The difference between a reading after the application of an applied force and the reading at zero, or tare force. Temperature corrections are also applied to the deflections of working force standards that are not temperature compensated. Temperature compensation is made for the differences between the temperature at which the working force standard is used and the temperature at which it was calibrated, or to which the calibration of the working force standard is referred (normally 20°C), as applicable.

1.3.2.7 Force standards

Force standards are categorized as follows:

- (a) *National force standard*—the force standard for a particular magnitude range recognized by the *National Measurement Act* as the basis for assigning the values of all other force standards in that range.
- (b) *Primary force standard*—a dead weight force standardizing machine whose value is accepted without reference to other standards of the same quantity.
- (c) *Secondary force standard*—a force standardizing machine whose value is determined by direct or indirect comparison with a primary force standardizing machine.
- (d) *Working force standard*—a transportable force standard which is used for the calibration of force-measuring systems of testing machines and for other force-measuring systems. Working force standards are calibrated against primary or secondary force standardizing machines.

1.3.2.8 Minimum continuous class force

The lowest force in the Continuous Class range at which the working force standard complies with the requirements of this Standard for a particular Continuous Class.

NOTE: This force does not necessarily coincide with a calibration force used to determine the uncertainty of the working force standard, however it is equal to, or greater than, the lowest calibration force included in calculations for Continuous Class.

1.3.2.9 Minimum point class force

The lowest specific force at which the working force standard complies with the requirements of this Standard for a particular point class.

1.3.2.10 Nominal deflection

That deflection associated with a given force as determined from the calibration data.

1.3.2.11 Point class

A classification permitting the use of the instrument only at the forces used during its calibration.

1.3.2.12 Programmable instruments

Microprocessor-based instruments which can store performance characteristics of one or more working force standards and use internally-stored programs to produce a linearized output in selectable units of force.

NOTE: Programmable instruments can include instrument/computer combinations.

1.3.2.13 Reading

A numerical value indicated on the scale, dial or digital display of a working force standard.

1.3.2.14 Resolution of a working force standard

The smallest numerical value that can be estimated with confidence from the scale or read-out.

NOTE: This value is established by the calibrating authority.

1.3.2.15 *SI unit of force (the newton)*

That force which, when applied to a mass of one kilogram (1 kg), gives that mass an acceleration of one metre per second per second (1 ms^{-2}).

1.3.2.16 *Zero deviation*

The maximum difference between zero-load readings at the beginning and end of each series of applied calibration forces.

1.3.3 Terms relating to the expression of uncertainty**1.3.3.1** *Uncertainty of measurement*

A parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

1.3.3.2 *Standard uncertainty*

The uncertainty of the result of a measurement expressed as a standard deviation.

1.3.3.3 *Type A uncertainty*

The standard uncertainty evaluated by the statistical analysis of a series of observations.

1.3.3.4 *Type B uncertainty*

The standard uncertainty evaluated by means other than by the statistical analysis of a series of observations.

1.3.3.5 *Combined standard uncertainty*

The standard uncertainty of the result of a measurement. In the case where all input quantities are uncorrelated, the combined standard uncertainty is the positive square root of the sum of the squares of the standard uncertainty associated with each of the input quantities.

1.3.3.6 *Expanded uncertainty*

A quantity defining an interval about the result of a measurement within which the value of the measurand may be expected to lie with a specified level of confidence.

1.3.3.7 *Coverage factor (k)*

A numerical value used as a multiplier of the combined uncertainty in order to obtain an expanded uncertainty.

SECTION 2 REQUIREMENTS FOR THE CLASSIFICATION OF TESTING MACHINES AND FORCE-MEASURING SYSTEMS

2.1 SCOPE OF SECTION

This Section specifies requirements for four Classes of testing machines or force-measuring systems, designated AA, A, B and C.

2.2 REQUIREMENTS FOR CLASSIFICATION

Unless otherwise specified, the force-measuring system of a testing machine shall be classified for the following properties—

- (a) resolution;
- (b) repeatability of indicated force; and
- (c) mean error of indicated force.

Requirements for Classes AA, A, B and C force-measuring systems are set out in Table 2.1.

2.3 ASSESSMENT OF CALIBRATION

Compliance of a force-measuring system with the classification requirements of Table 2.1 shall be determined in accordance with Clause 3.5 on the basis of the calibration results obtained.

2.4 ASSIGNMENT OF CLASS

The assigned Class shall be the lowest Class allocated for any of the three properties listed in Clause 2.2.

A testing machine or force-measuring system may have allocated to it more than one Class for different operating ranges, or part thereof, within its total range of calibration. In all cases, the portion of an operating range that has been allocated a Class shall comply with the requirements of Table 2.1 for at least the number of consecutive forces specified in Clause 3.5.

The assigned Class shall be the lowest Class allocated for the three properties listed in Table 2.1. The uncertainty of measurement shall not be considered in the assignment of class. In assigning Classes for repeatability and mean error of indicated force the calculated values shall be rounded to 0.1%, according to AS 2706.

TABLE 2.1
REQUIREMENTS FOR CLASSIFYING FORCE-
MEASURING SYSTEMS

Class	Resolution multiplier	Repeatability of indicated force (maximum permissible value) percent	Maximum permissible mean error of indicated forces percent
AA	400	0.5	± 0.5
A	200	1.0	± 1.0
B	100	2.0	± 2.0
C	40	5.0	± 5.0

SECTION 3 CALIBRATION OF TESTING MACHINES AND FORCE - MEASURING SYSTEMS

3.1 GENERAL

Force measurement systems that are not calibrated in-situ and that do not read out force units shall be calibrated according to Clause 3.3. The assessment of results and classification of the force scale shall be carried out in accordance with Appendix H.

NOTE: Certain force measuring systems, such as load rings, require initial calibration procedures similar to those described in Section 4, working force standards. The read out is in arbitrary units and in practice the relationship between force and deflection is found by a first-order equation, allowing interpolation. However, they do not conform to the classification criteria of Clause 1.3.2.7(d). Calibration and classification requirements are described in Appendix H.

3.2 METHODS OF FORCE CALIBRATION

3.2.1 General

The calibration of force-measuring systems shall be carried out using either of the following types of standards:

- (a) Weights.
- (b) Working force standards.

The requirements for the calibration and classification of working force standards are given in Section 4.

The Class of the working force standard to be used shall be in accordance with the Class required for the force scale, as given in Table 3.1.

TABLE 3.1
CLASSES OF WORKING FORCE STANDARDS

Class required for force scale of force- measuring system	Class of weights to be used (see Clause 4.2.2)	Class of working force standards to be used (see Clause 4.3.5)
AA	0	0 or 1
A	0	0, 1 or 2
B	0	0, 1, 2 or 3
C	0	0, 1, 2 or 3

3.2.2 Calibration by weights

Where a force scale is to be calibrated at a given force using weights, the appropriate weights shall be applied to the machine or force-measuring system without shock and with the force acting along the straining axis. Unless otherwise specified, the application of the weights shall be controlled to ensure that equilibrium is obtained after each increment of force.

Where it is necessary to provide a carrier for attaching weights to a machine or force measuring system, the carrier itself shall be considered as a weight, unless the scale zero of the machine or force-measuring system has been reset with the carrier attached.

The force exerted by a weight is dependent on the value of acceleration due to gravity at the place of use, and may be calculated from the following equation:

$$F_L = \frac{F_N g_L}{g_N} \quad \dots 3.1$$

where

- F_L = force exerted by a weight at place of use
- F_N = the nominal value of force exerted by a weight
- g_L = the value of acceleration due to gravity at the place of use
- g_N = the value of acceleration due to gravity at which a weight is nominally correct (marked in accordance with Clause 4.2.1)

NOTE: A list of values of acceleration due to gravity at selected locations in Australia is given in Appendix C.

3.2.3 Calibration by elastic working force standards

Where a force scale is to be calibrated at a given force by an elastic working force standard, the machine or force-measuring system shall be operated to apply the force to the instrument so that the reaction is along the straining axis of the machine or force-measuring system. Multiple working force standards may be used in parallel, thereby providing a convenient means of measuring greater ranges of force. When used in this mode, the working force standards shall be arranged so that the resultant reaction is along the straining axis of the machine or force-measuring system.

Unless otherwise specified, the application of each force shall be controlled to ensure that stability is achieved.

If the force scale is to be calibrated for decreasing force, the working force standard shall have been calibrated under conditions of decreasing force, unless it has been established that the effects of hysteresis in the working force standard are insignificant in relation to the required accuracy of the testing machine or force-measuring system.

Working force standards may have been classified either for use at any force within a given range, or for use only at selected forces. Instruments that have been allocated a Continuous Class, in addition to Point Class, may be used to measure any forces in that part of the range which has the required Class. However, instruments that have been allocated a Point Classification shall only be used to measure the nominal values of force at which they were calibrated.

It is necessary to allow the calibrating instrument to reach a stable temperature before the calibration is commenced. Where the instrument is not temperature compensated, the effects of temperature shall be taken into consideration (see Clause 3.9).

In order to stabilize the zero reading of the instrument, it is necessary, immediately before use, to apply a force to the instrument in the direction in which it is to be used, equal to the maximum force to be measured, and to repeat the procedure as necessary to produce a stable zero reading.

3.3 FORCE CALIBRATION PROCEDURE

3.3.1 General

Where practicable, the procedure for calibration shall be similar to the conditions of normal operation, e.g. where the straining mechanism is not used to apply the forces, as occurs when weights are used, the straining mechanism shall, where practicable, be operated to provide similar conditions to those present during testing.

NOTE: See Appendix B.

During the calibration, the testing machine or force-measuring system and the working force standard shall, where practicable, be operated in accordance with the instructions for their use.

All external adjustment settings that may affect the performance of the force-measuring system shall be capable of being reset to the values used during the calibration.

NOTE: The calibration procedure used by the calibrating authority will, to some extent, depend on the information supplied by the user.

3.3.2 Calibration range

For a given Class, the calibration range will depend on the resolution of indicated force and the use to which the machine is to be put. Calibration ranges shall be determined by the calibrating authority in consultation with the user. An operating range shall not be calibrated for classification purposes at readings below a value which is dependent on the resolution and the Class. This value is determined by multiplying the resolution of the machine scale by the resolution multiplier given in Table 2.1.

3.3.3 Preliminary inspection

Before applying the procedure described in Clauses 3.3.4 to 3.3.6, it shall be ascertained that—

- (a) the testing machine or force-measuring system is in good working order and condition;
- (b) the control of application of the forces is adequate for the method of calibration to be used;
- (c) tension holders or compression platens to be used with the working force standard are satisfactorily aligned and function correctly;
- (d) the maximum reading device, e.g. a friction pointer or pawls and ratchet, functions satisfactorily over the range of the scale to be calibrated (where applicable); and
- (e) the recorder paper is suitable for the machine (where applicable).

NOTES:

- 1 Other aspects of machine function such as reliable operation of software, ongoing calibration stability, etc., as well as possible safety concerns should be considered before proceeding with calibration.
- 2 The decision to proceed with the calibration will depend on the result of the preliminary inspection and on agreement between the customer and the calibrating authority.

3.3.4 Setting up

The indicator of the testing machine or force-measuring system shall be set to zero before the first series of readings is commenced. If the design of the machine or force-measuring system is such that the gravity force exerted by the weight carrier or working force standard is applied to the force-measuring system, the zero shall be set with the working force standard set up in the machine. If the provision for zero adjustment of the machine or force-measuring system is inadequate for this, the weight carrier or working force standard shall be considered as a weight and due allowance made for the gravity force it applies. If a maximum reading device is to be used during the calibration, the zero setting shall be made with the device disengaged.

It is essential that the working force standard set up in the machine ensures that the forces are applied along the straining axis, as specified in Clause 3.2.

Where a working force standard is used, sufficient time shall be allowed for the instrument to attain a stable temperature. The temperature of the instrument shall be recorded at appropriate intervals (usually at the end of each series of calibration forces).