

Force measurement — Strain gauge load cell systems — Calibration method

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Committees responsible for this British Standard

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- Association of Consulting Scientists
- British Civil Engineering Manufacturers' Association
- British Non-ferrous Metals Federation
- British Society for Strain Measurement
- GAMBICA Association Ltd.
- Lloyds Register
- National Physical Laboratory
- QinetiQ
- Society of British Aerospace Companies Ltd.
- United Kingdom Accreditation Service
- United Kingdom Steel Association
- Co-opted members

The following bodies were also represented in the drafting of the standard through Panel ISE/NFE/4/1/1, Strain gauge load cells.

- Institute of Measurement and Control
- MIRA Ltd.

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Foreword

This British Standard has been prepared by Subcommittee ISE/NFE/4/1, under the direction of Technical Committee ISE/NFE/4.

The initial draft of this standard was based on the Institute of Measurement and Control publication WGL9301 [1], but the standard has evolved significantly since that time.

Other standards and international recommendations exist for the calibration of load cells, but these are restricted to specific areas of load cell use. BS EN ISO 376 covers the calibration of force-proving instruments (including load cells) used for the verification of uniaxial testing machines, and the use of load cells classified to it is specified by various machine calibration standards. In the legal metrology area, OIML R60 [2] prescribes evaluation procedures for load cells used in the measurement of mass.

This British Standard does not replace the existing documents but is intended for use in those areas of industrial weighing and force measurement in which the existing procedures are not applicable.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

WARNING. This British Standard calls for the use of procedures (e.g. inclined and eccentric testing) that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 31 and a back cover.

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1 Scope

This British Standard describes a method of calibration for strain gauge load cell systems for use in various industrial weighing and force measurement applications.

NOTE The technical procedures covered in this British Standard are split into one “standard calibration” (Clause 7), which determines the basic response of the system in terms of non-linearity and reproducibility, and a number of “supplementary calibrations” (Clause 8 to Clause 22), each of which determines the response of the system to one specific input factor. It is envisaged that load cell systems calibrated in accordance with this standard will normally undergo the standard calibration, possibly together with a number of supplementary calibrations, but a system may also be calibrated solely in accordance with one or more of the supplementary calibrations.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE These are relevant only to supplementary calibrations P and Q.

BS EN 60068-2-30:1999 (IEC 60068-2-30:1980), *Environmental testing — Part 2-30: Test methods — Test Db and guidance: damp heat, cyclic (12 + 12 hour cycle)*.

BS EN 60068-3-4 (IEC 60068-3-4), *Environmental testing — Part 3-4: Guidance — Damp heat tests*.

BS EN 60529, *Specification for degrees of protection provided by enclosures (IP code)*.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this British Standard, the following terms apply.

3.1.1

axial force

force applied along the principal axis of a load cell

NOTE See Figure 2, Figure 3 and Figure 4.

3.1.2

calibration

3.1.2.1

standard calibration

procedure to determine the performance of a load cell system in terms of non-linearity and reproducibility

3.1.2.2

supplementary calibration

procedure to determine system response to a particular input factor, other than those responses determined in the standard calibration

3.1.3

calibration forces

3.1.3.1

maximum calibration force

maximum force applied during calibration

3.1.3.2

minimum calibration force

minimum force applied during calibration

3.1.4

compensated temperature range

range of temperature over which a load cell meets its stated specification

3.1.5

creep

change in output which occurs with time while a load cell is subjected to constant force and with all environmental conditions and other variables remaining constant

NOTE See Figure 1.

3.1.6

creep recovery

change in output which occurs with time after the force applied to a load cell has been removed, with all the environmental conditions and other variables remaining constant

NOTE See Figure 1.

3.1.7

deflections

3.1.7.1

deflection

difference between the load cell system output under force and the output at zero force

3.1.7.2

maximum deflection

difference between the load cell system output at maximum calibration force and the output at zero force

3.1.7.3

maximum mechanical deflection

displacement along the principal axis (3.1.18) for a change of force from zero to maximum calibration force

3.1.8

eccentric force

force applied parallel to the principal axis (3.1.18) at a specified orientation and eccentricity

NOTE See Figure 4.

3.1.9

excitation voltages

3.1.9.1

excitation voltages

voltage applied at the input terminals of a load cell

3.1.9.2

maximum excitation voltage

excitation voltage above which a load cell cannot be continuously operated without degradation of its performance

3.1.9.3

recommended excitation voltage

excitation voltage or range of voltages at which a load cell can be continuously operated and meet its stated specification

3.1.10

hysteresis

difference between measurements of load cell deflection for the same applied force, one measurement being obtained by increasing the force from zero, the other by decreasing the force from the maximum calibration force

3.1.11**inclined forces****3.1.11.1****concentric inclined force**

force applied through the principal axis (**3.1.18**) at the point of force application but inclined at an angle and at a defined direction with respect to the principal axis

NOTE See Figure 2.

3.1.11.2**eccentric inclined force**

force applied eccentric to the principal axis (**3.1.18**) at the point of force application and inclined at an angle at a defined direction with respect to the principal axis

NOTE See Figure 3.

3.1.12**load cell**

device which, when mechanically loaded and electrically energized, produces an electrical signal, derived from electrical resistance strain gauges, which is a function of the applied force

3.1.13**load cell system**

load cell together with its associated fittings and instrumentation

3.1.14**loading surface**

surface of a suitably shaped loading pad used to permit the application of force to a load cell

3.1.15**non-linearity**

maximum deviation of measured deflections, obtained for increasing forces only, from a best fit polynomial, calculated using the method of least squares

NOTE This covers any degree of polynomial, including straight line fits.

3.1.16**output stability**

maximum change in load cell system output, either at zero force or at maximum calibration force, over an extended period of time, with all the environmental conditions and other variables remaining constant

3.1.17**pre-load**

maximum calibration force applied prior to calibration

3.1.18**principal axis**

axis along which a load cell is designed to be loaded

NOTE See Figure 2, Figure 3 and Figure 4.

3.1.19**repeatability**

measure of agreement between the results of successive measurements of deflection for repeated applications of the same calibration force from zero, with all the environmental conditions and other variables remaining constant

3.1.20**reproducibility**

measure of agreement between the results of successive measurements of deflection for repeated applications of the same calibration force from zero, with the load cell rotated about its principal axis between each successive force applications

3.1.21**side force**

force acting at a 90° angle to the principal axis of a load cell on the specified loading surface and in a defined direction

3.1.22**supply voltage**

voltage used to energize a load cell system

3.1.23**warm-up period**

period of time during which a load cell system achieves and maintains a specified level of stability of its zero load output reading, with all environmental conditions and other variables remaining constant

3.1.24**zero force output**

output reading from a load cell at a stated excitation voltage and at zero force

NOTE This is obtained with the appropriate loading fittings located in the normal calibration position.

3.2 Symbols

NOTE Symbols that are used only in Annex B are defined separately in that annex.

- d_1 mean deflection at maximum calibration force with concentric inclined application of force, in millivolts per volt (mV/V)¹⁾
- d_2 mean deflection at maximum calibration force with eccentric inclined application of force, in millivolts per volt (mV/V)¹⁾
- d_3 mean deflection at maximum calibration force with eccentric application of force, in millivolts per volt (mV/V)¹⁾
- $d_{\max}$ maximum deflection with concentric application force along the principal axis, in millivolts per volt (mV/V)¹⁾
- E eccentricity, in millimetres (mm)
- NOTE This is the distance between the loading axis of the applied force, at the point of force application, and the principal axis of the load cell.
- e_1 effect of concentric inclined application of force, as a percentage of $d_{\max}$ (%)
- e_2 effect of eccentric inclined application of force, as a percentage of $d_{\max}$ (%)
- e_3 effect of eccentric application of force, as a percentage of $d_{\max}$ (%)

4 General**4.1 Calibration methods**

The standard calibration specified in Clause 7, and the supplementary calibrations specified in Clause 8 to Clause 22, shall be carried out only if requested by the customer.

4.2 Identification of connection details

All connection details for the load cell and any associated indicator shall be clearly identified and shall be recorded on the calibration certificate (see Clause 23).

4.3 Laboratory reference standards

The reference standards used by the laboratory shall be traceable to the SI system of units with a combined uncertainty appropriate to the customer's requirements.

¹⁾ The units of deflection will be those of the indicator, which will not necessarily be millivolts per volt (mV/V).

4.4 Environmental conditions

The calibration of the load cell shall be made at a temperature within the range 18 °C to 28 °C, unless otherwise specified within the relevant procedure or by the customer. To ensure stable conditions, the load cell system shall be kept at this temperature until thermal stability is achieved before the commencement of the calibration.

NOTE A temperature within the range 18 °C to 28 °C is normally used, but the customer may specify a different temperature if required for a specific application.

The temperature of the load cell shall be recorded and shall be maintained to within a range of 2 °C for each calibration performed. If the temperature is kept within this range for all calibrations, the overall range shall be recorded on the calibration certificate (see Clause 23). If this is not the case, the temperature range for each individual calibration shall be recorded separately on the calibration certificate.

4.5 Zero force output

The zero force output of the load cell shall be measured before and after each calibration and the maximum and minimum values for each loading mode shall be recorded on the calibration certificate (see Clause 23).

4.6 Deflection

NOTE This applies to both the standard calibration and the supplementary calibrations.

If the final zero output is different to the initial zero output, a uniform progressive change shall be assumed in order to calculate the deflection.

4.7 Pre-load procedure

If a pre-load is required, it shall be carried out by applying the maximum calibration force at least three times and returning to zero force after each force application. The duration of the application of each pre-load and each wait at zero force shall be between 60 s and 90 s.

5 Apparatus

5.1 Plane pad, the surfaces of which shall have parallelism not exceeding 1 part in 10 000 of radius. When a load cell is to be calibrated in the compression mode, it shall be placed on a plane pad of hardness not less than 400 HV 30 with a surface finish not exceeding 32 µm centre line average.

5.2 Wedge-shaped pads, with a hardness not less than 400 HV 30, an angle of $3.00^\circ \pm 0.05^\circ$ and a surface finish not exceeding 32 µm centre line average.

NOTE These pads are used when the load cell is subjected to inclined application of force.

5.3 Convex pad (conically raised), with a hardness not less than 400 HV 30 and a convexity of (1.0 ± 0.1) in 1 000 of the radius.

5.4 Concave pad (conically depressed), with a hardness not less than 400 HV 30 and a concavity of (1.0 ± 0.1) in 1 000 of the radius.

6 Preparation

NOTE When calibrating a load cell system, cognisance should be taken of guidance and recommendations from the manufacturer.

Before commencing any calibration, the supply voltage recommended by the manufacturer shall be applied for the minimum warm-up period recommended by the manufacturer. In the absence of manufacturer's recommendations, a supply voltage that is appropriate to the load cell system being calibrated shall be applied, and the value of this shall be recorded on the calibration certificate (see Clause 23).

If applicable, the excitation voltage shall be measured and recorded at the beginning and end of each calibration, and its maximum and minimum values shall be recorded on the calibration certificate (see Clause 23).

7 Standard calibration

7.1 Application of forces

7.1.1 Position the loading fittings to ensure axial force application.

7.1.2 Carry out a pre-load in accordance with **4.7**.

7.1.3 Record the zero force output.

7.1.4 Apply a series of at least five, substantially equally spaced, increasing forces from zero force up to and including the maximum calibration force.

7.1.5 At each force, record the output after a period of not less than 30 s.

7.1.6 Were decreasing forces are to be applied, reduce the applied force to zero force, pausing at the values of force which had been applied during the increasing series and recording the output as specified in **7.1.5**.

7.1.7 Record the final zero force output.

7.1.8 Repeat the operations specified in **7.1.3**, **7.1.4**, **7.1.5**, **7.1.6** and **7.1.7** twice to give three series. Between successive series, rotate the load cell and its associated fittings through 120° about its principal axis or, if this is not possible, through 180° . After each rotation, pre-load the load cell at least once to its maximum calibration force.

7.2 Shunt resistor output

NOTE If the load cell is provided with a built-in shunt calibration facility, this may be used to determine its effect on the output when activated.

7.2.1 If shunt resistor output measurement is required by the customer, carry out the operations specified in **7.2.2**, **7.2.3** and **7.2.4** immediately after carrying out the operations specified in **7.1**.

7.2.2 Record the zero force output.

7.2.3 Activate the shunt calibration facility and record the output.

7.2.4 Report the difference between the output with the shunt calibration activated and zero force output.

NOTE 1 This difference is sometimes known as the Calcheck figure.

NOTE 2 This difference may also be used to compute the force that would produce the output.

7.3 Calculation of non-linearity

7.3.1 Calculate the mean deflection (**3.1.7.1**) for each increasing calibration force and record these values on the calibration certificate (see **Clause 23**).

7.3.2 Using the method of least squares, compute the coefficients of a polynomial equation giving deflection as a function of applied force and record these values on the calibration certificate (see **Clause 23**).

NOTE 1 This is generally a second order equation, but higher orders are permitted if statistically supported by the data (e.g. by use of the F test; see ASTM E74). A linear fit may also be used if requested by the customer.

NOTE 2 Many customers will find the coefficients of an equation giving force as a function of measured deflection equally valuable, and it is recommended that these coefficients are also recorded on the calibration certificate.

7.3.3 For each calibration force, calculate the difference between the actual load cell deflection and the value computed from the equation.

7.3.4 The non-linearity shall be taken as the maximum of these differences, expressed as a percentage of maximum deflection, and shall be recorded on the calibration certificate (see **Clause 23**), together with information as to the order of fit and whether it has been forced through zero.

7.4 Calculation of reproducibility

7.4.1 Calculate the maximum difference between the three deflections at each increasing calibration force.

7.4.2 The reproducibility shall be taken as the maximum of these differences, expressed as a percentage of maximum deflection, and shall be recorded on the calibration certificate (see Clause 23).

NOTE If the load cell has previously been calibrated in accordance with this British Standard, it is permissible to carry out the three loading runs at the same orientation. The above calculation will therefore result in the maximum repeatability for the calibration forces (as specified in Clause 8), rather than the reproducibility, and this should be recorded on the calibration certificate, together with the previously obtained reproducibility figure.

8 Supplementary calibration A — Repeatability

8.1 Position the loading fittings to ensure axial force application.

8.2 Carry out a pre-load in accordance with 4.7.

8.3 Record the zero force output.

8.4 Apply the selected force to the load cell and maintain for a period of not less than 30 s. Record the output. Calculate the load cell deflection.

NOTE For the determination of repeatability, the selected force is normally the maximum calibration force, but the repeatability may also be determined at any other force.

8.5 Repeat 8.3 and 8.4 to give three applications of the selected force.

8.6 Calculate the maximum difference between the three load cell deflections obtained at the selected force.

8.7 The repeatability at this force shall be taken as this maximum difference, expressed as a percentage of maximum deflection. It shall be recorded on the calibration certificate (see Clause 23) together with the selected force value.

9 Supplementary calibration B — Hysteresis

9.1 Carry out the standard calibration procedure specified in 7.1, with the exception of the rotation of the load cell between calibration series as specified in 7.1.8 (see Note).

NOTE The rotation of the load cell between calibration series may be carried out but is not essential for the purposes of determining the hysteresis.

9.2 Calculate the average value of load cell deflection for each increasing and decreasing calibration force.

9.3 For each calibration force, subtract the load cell deflection for increasing force from the deflection for decreasing force.

9.4 The hysteresis shall be taken as the maximum of these differences (when expressed as absolute values), expressed as a percentage of maximum deflection, and this value shall be recorded on the calibration certificate (see Clause 23).

10 Supplementary calibrations C — Creep and D — Creep recovery

NOTE 1 A graphical representation of creep and creep recovery measurement is shown in Figure 1.

NOTE 2 In order to obtain reliable data from creep and creep recovery measurements, it is important to have determined the calibration machine loading characteristics and to take the outputs of the load cell at precisely defined time intervals. This is of paramount importance if the data is to be used for comparison purposes.

10.1 Position the loading fittings to ensure axial force application.

10.2 Carry out a pre-load in accordance with 4.7.

10.3 Wait at zero force for a period of between 30 min and 60 min. Record the zero force output.