BRITISH STANDARD

BS 8422:2003

Force measurement — Strain gauge load cell systems — Calibration method

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ICS 17.100; 19.060

British Standards

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee ISE/NFE/4, Mechanical testing of metals, to Subcommittee ISE/NFE/4/1, Uniaxial testing of metals, upon which the following bodies were represented:

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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Contents

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° ± 0.05° 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.

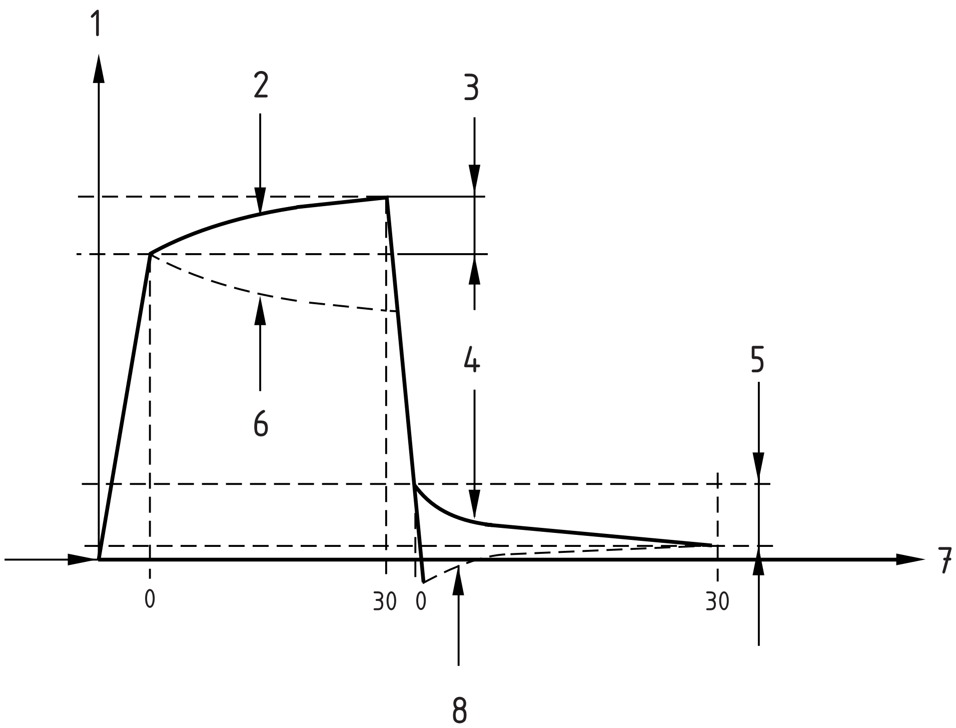
10.1 Position the loading fittings to ensure axial force application.

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.

10.4 Apply the maximum calibration force, immediately record the initial force output, and record the reading thereafter at intervals not exceeding 5 min, over a period of not less than 30 min. Subtract the initial force output from each subsequent output. Express these differences as percentages of maximum deflection and record them on the calibration certificate (see Clause **23**). The creep shall be taken as the maximum difference (when expressed as absolute values) obtained within the first 30 min.

10.5 Remove the force, immediately record the initial zero force output, and record the reading thereafter at intervals not exceeding 5 min, over a period of not less than 30 min. Subtract the initial zero force output from each subsequent output. Express these differences as percentages of maximum deflection and record them on the calibration certificate (see Clause **23**). The creep recovery shall be taken as the maximum difference (when expressed as absolute values) obtained within the first 30 min.



Key

1	Output	5	Creep recovery
2	Positive creep	6	Negative creep
3	Creep	7	Time, in minutes (min)
4	Positive creep recovery	8	Negative creep recovery

Figure 1 — Representation of creep and creep recovery measurement

11 Supplementary calibration E — Overload effect

11.1 Position the loading fittings to ensure axial force application.

11.2 Apply the maximum calibration force three times, recording the zero force output and the maximum calibration force output for each force application. Calculate the mean zero force output and the mean deflection.

11.3 Apply an overload of approximately 10 % of the maximum calibration force three times, recording the zero force output and the overload force output for each application

11.4 Repeat **11.2**.

11.5 Calculate the difference between the mean zero force output obtained in **11.2** and the mean zero force output obtained in **11.4**. Express this difference as a percentage of maximum deflection and record it on the calibration certificate (see Clause **23**).

11.6 Calculate the difference between the mean deflection obtained in **11.2** and the mean deflection obtained in **11.4**. Express this difference as a percentage of maximum deflection and record it on the calibration certificate (see Clause **23**).

12 Supplementary calibration F — Temperature sensitivity at zero force

NOTE If the temperature sensitivity at maximum calibration force is also to be determined, the results obtained at zero force during supplementary calibration G (see Clause **13**) may be used to determine the temperature sensitivity at zero force.

12.1 Unless specified otherwise by the customer, arrange the load cell and its cable in an environmental chamber such that the minimum cable length is outside the chamber. Attach the temperature sensors at agreed positions around the body of the load cell. Apply the recommended excitation voltage and allow the system to stabilize.

12.2 Set the temperature of the chamber to 20 °C. Ensure that the load cell has obtained a stable temperature before commencing the tests.

12.3 Record the zero force output.

12.4 Change the temperature setting of the environmental chamber to the lower limit of the compensated temperature range. Keep the environmental chamber at this temperature until thermal stabilization is achieved.

12.5 Record the zero force output.

12.6 Change the temperature setting of the environmental chamber to the upper limit of the compensated temperature range. Keep the environmental chamber at this temperature until thermal stabilization is achieved.

12.7 Record the zero force output.

12.8 Change the temperature setting of the environmental chamber to 20 °C. Keep the environmental chamber at this temperature until thermal stabilization is achieved.

12.9 Record the zero force output.

12.10 For each of the three temperature changes, calculate the change in zero force output and divide this by the change in temperature. The temperature sensitivity at zero force shall be taken as the maximum of these three figures (when expressed as absolute values) and shall be expressed as a percentage of maximum deflection per degree Celsius.

13 Supplementary calibration G — Temperature sensitivity at maximum calibration force

13.1 Position the loading fittings to ensure axial force application.

13.2 Unless specified otherwise by the customer, arrange the load cell and its cable in an environmental chamber such that the minimum cable length is outside the chamber. Attach the temperature sensors at agreed positions around the body of the load cell. Apply the recommended excitation voltage and allow the system to stabilize.

13.3 Set the temperature of the chamber to 20 °C. Ensure that the load cell has obtained a stable temperature before commencing the tests.

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

13.5 Apply the maximum calibration force, maintain it for a period of 60 s, and record the output.

13.6 Remove the force and record the zero force output 60 s after removal of the force.

13.7 Repeat **13.5** and **13.6** twice to give three applications of the maximum calibration force.

13.8 Calculate the three individual deflections and the mean deflection.

13.9 Change the temperature setting of the environmental chamber to the lower limit of the compensated temperature range. Keep the environmental chamber at this temperature until thermal stabilization is achieved.

13.10 Repeat **13.4**, **13.5**, **13.6**, **13.7** and **13.8**.

13.11 Change the temperature setting of the environmental chamber to the upper limit of the compensated temperature range. Keep the environmental chamber at this temperature until thermal stabilization is achieved.

13.12 Repeat **13.4**, **13.5**, **13.6**, **13.7** and **13.8**.

13.13 Change the temperature setting of the environmental chamber to 20 °C. Keep the environmental chamber at this temperature until thermal stabilization is achieved.

13.14 Repeat **13.4**, **13.5**, **13.6**, **13.7** and **13.8**.

13.15 For each of the three temperature changes, calculate the change in mean deflection and divide this by the change in temperature. The temperature sensitivity at maximum calibration force shall be taken as the maximum of these three figures (when expressed as absolute values) and shall be expressed as a percentage of maximum deflection per degree Celsius.

14 Supplementary calibration H — Concentric inclined application of force

NOTE This test is for compression load cells only.

14.1 Install the device in the force machine with wedge-shaped pads (**5.2**) above and below the load cell as shown in Figure 2. Ensure that the load cell is positioned so that its principal axis is coincident with the loading axis of the machine at its upper loading point.

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

14.3 Check that the zero force output is stable and then record the reading.

14.4 Apply the maximum calibration force to the load cell, maintain this force for a period of 60 s, and record the output.

14.5 Remove the force, record the zero force output 60 s after removal of the force, and calculate the deflection.

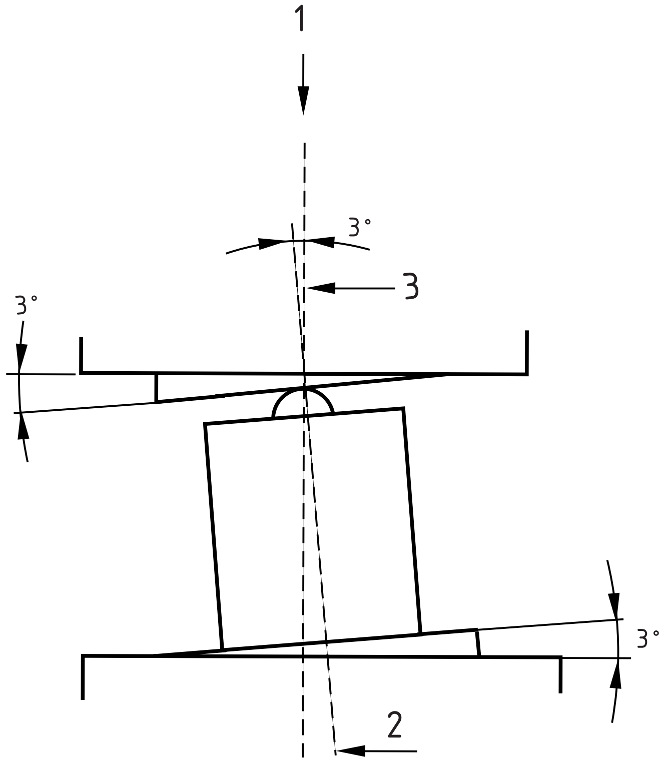
14.6 Repeat the tests to give three applications of the maximum calibration force and calculate the mean deflection d_1.

14.7 Calculate the effect of the concentric inclined application of force, e_1, expressed as a percentage of maximum deflection d_{max}, using equation 1.

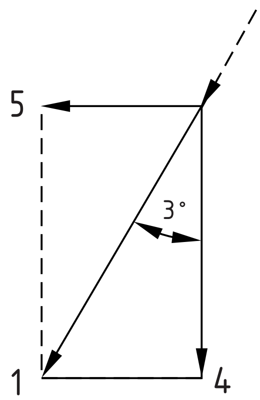
$$e_1 = \frac{(d_1/\cos 3°) - d_{max}}{d_{max}} \times 100 \qquad (1)$$

14.8 Repeat the operations specified in **14.2**, **14.3**, **14.4**, **14.5**, **14.6** and **14.7** to obtain further sets of readings at each of seven steps of rotation of the load cell through 45° about its principal axis, to give a total of eight e_1 values. At each angular position, ensure that the principal axis of the load cell is still aligned with the loading axis of the machine at its upper loading point.

14.9 Record the highest value of e_1 (when expressed as absolute values) on the calibration certificate (see Clause **23**).



a) Compression load cell with a loading dome

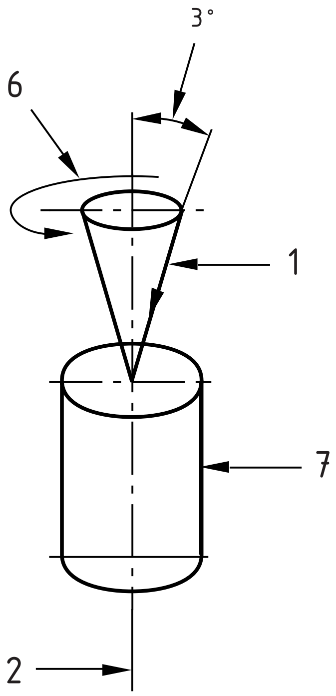


b) Force diagram

Key

1	Applied force	5	Side force
2	Principal axis	6	Rotational angle
3	Loading axis	7	Load cell
4	Force along principal axis		

Figure 2 — Concentric inclined application of force



c) Representation of concentric angular loading

Key

1 Applied force
2 Principal axis
3 Loading axis
4 Force along principal axis
5 Side force
6 Rotational angle
7 Load cell

Figure 2 — Concentric inclined application of force (*concluded*)

15 Supplementary calibration J — Eccentric inclined application of force

NOTE This test is for compression load cells only.

15.1 Use one wedge-shaped pad of the type described in **5.2**. Position the load cell on this pad in the force machine, as shown in Figure 3. Ensure that the load cell is positioned so that the upper loading point is on the loading axis of the machine.

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

15.3 Check that the zero force output is stable and then record the reading.

15.4 Apply the maximum calibration force to the load cell and maintain this force for a period of 60 s. Record the output.

15.5 Remove the force, record the zero force output 60 s after removal of the force, and calculate the deflection.

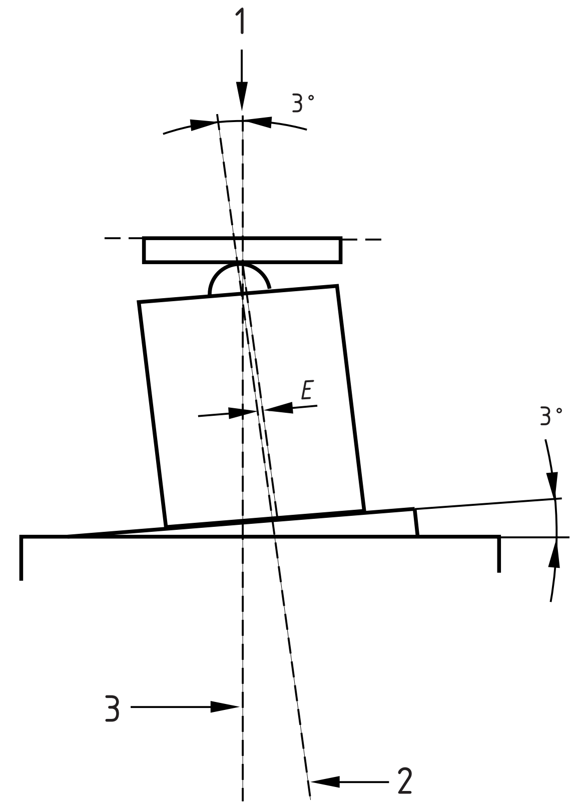
15.6 Repeat **15.3**, **15.4** and **15.5** to give three applications of the maximum calibration force and calculate the mean deflection d_2.

15.7 Calculate the effect of the eccentric inclined application of force, e_2, expressed as a percentage of maximum deflection d_{max}, using equation 2.

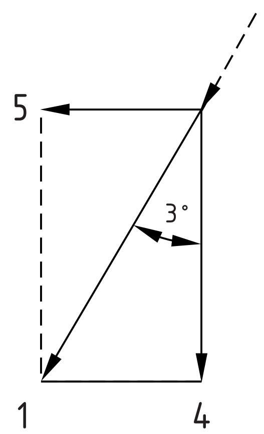
$$e_2 = \frac{\left(d_2/\cos 3°\right) - d_{max}}{d_{max}} \times 100 \qquad (2)$$

15.8 Repeat the operations specified in **15.2**, **15.3**, **15.4**, **15.5**, **15.6** and **15.7** to obtain further sets of readings at each of seven steps of rotation of the load cell through 45° about its principal axis, to give a total of eight e_2 values. At each position of rotation ensure that the upper loading point is still on the loading axis of the machine.

15.9 Record the highest value of e_2 (when expressed as absolute values) on the calibration certificate (see Clause **23**), together with the eccentricity value E, as shown in Figure 3.



a) Compression load cell with a loading dome

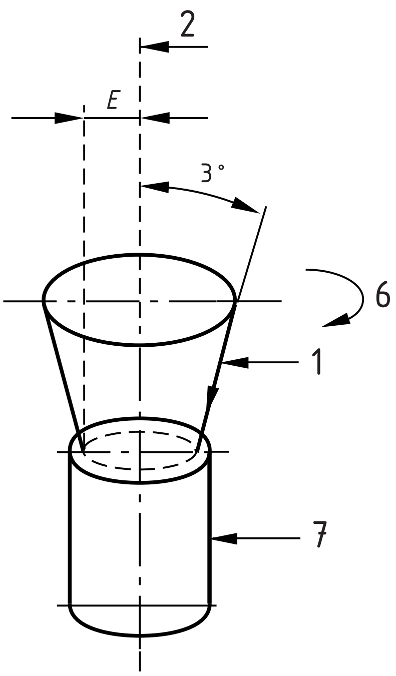


b) Force diagram

Key

1 Applied force
2 Principal axis
3 Loading axis
4 Force along principal axis
5 Side force
6 Rotational angle
7 Load cell

Figure 3 — Eccentric inclined application of force



c) Representation of eccentric angular loading

Key

1 Applied force
2 Principal axis
3 Loading axis
4 Force along principal axis
5 Side force
6 Rotational angle
7 Load cell

Figure 3 — Eccentric inclined application of force (*concluded*)

16 Supplementary calibration K — Eccentric force effects

NOTE This test is for compression load cells only.

16.1 Position the load cell on a plane pad (**5.1**), as shown in Figure 4.

NOTE This test cannot be carried out on a load cell with a domed loading button.

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

16.3 Arrange a load application point displaced by an amount E, as shown in Figure 4. Record the zero force output.

16.4 Apply the maximum calibration force to the device and maintain this force for a period of 60 s. Record the output.

16.5 Remove the force, record the zero force output 60 s after the removal of the force, and calculate the deflection.

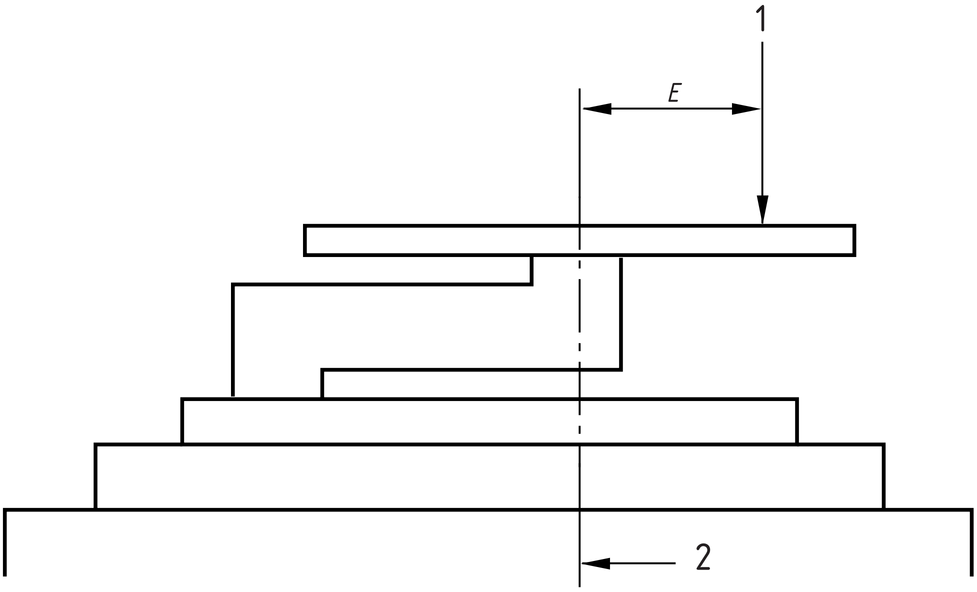
16.6 Repeat **16.4** and **16.5** twice to give three applications of the maximum calibration force and calculate the mean deflection d_3.

16.7 Calculate the effect of the eccentric application of force, e_3, expressed as a percentage of maximum deflection d_{max}, using equation 3.

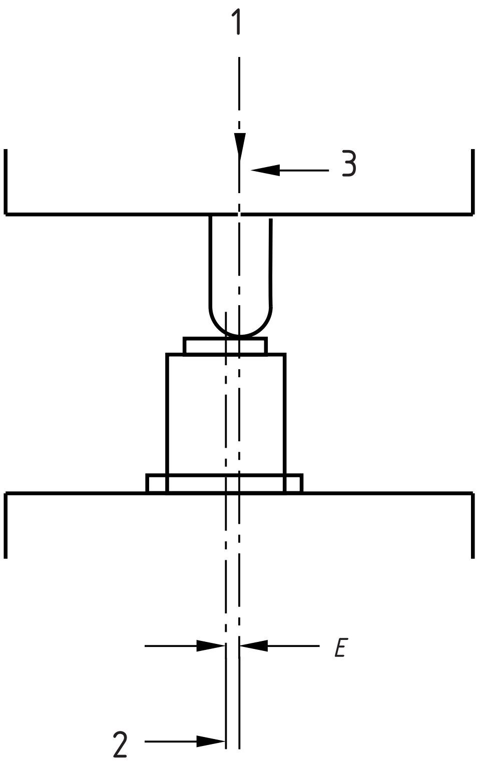
$$e_3 = \frac{d_3 - d_{max}}{d_{max}} \times 100 \tag{3}$$

16.8 Repeat **16.2**, **16.3**, **16.4**, **16.5**, **16.6** and **16.7** to obtain further sets of readings at each of seven steps of rotation of the load cell through 45° about its principal axis, to give a total of eight e_3 values. At each position of rotation ensure that the eccentricity of the principal axis of the load cell is maintained with respect to the loading axis of the machine.

16.9 Record the highest value of e_3 (when expressed as absolute values) on the calibration certificate (see Clause **23**), together with the eccentricity E.



a) Single point load cell with a platform fitting

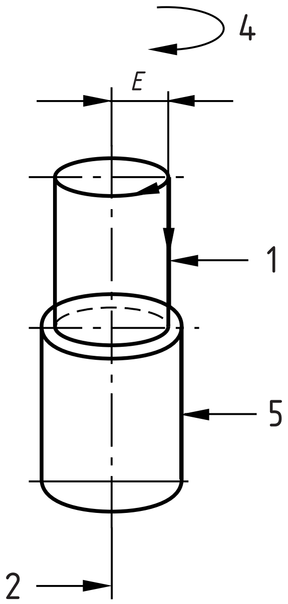


b) Compression load cell with flat loading surface

Key

1 Applied force
2 Principal axis
3 Loading axis
4 Rotational angle
5 Load cell

Figure 4 — Eccentric application of force



c) Representation of eccentric application of force

Key

1 Applied force
2 Principal axis
3 Loading axis
4 Rotational angle
5 Load cell

Figure 4 — Eccentric application of force (*concluded*)

17 Supplementary calibration L — Base-loading effects

NOTE This test is for compression load cells only.

17.1 If the load cell is submitted for calibration with compression fittings that will subsequently always be used with the load cell, perform this calibration on the combination of the load cell and its compression fittings.

17.2 Place the load cell on a plane pad (**5.1**).

17.3 Position the loading fittings to ensure axial force application.

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

17.5 Record the zero force output.

17.6 Apply the minimum calibration force, wait for a period of not less than 30 s, then record the output.

17.7 Apply the maximum calibration force, wait for a period of not less than 30 s, then record the output.

17.8 Remove the force and then, after a period of not less than 30 s, record the final zero force output.

17.9 Calculate the deflections at minimum and maximum calibration force.

17.10 Repeat **17.5**, **17.6**, **17.7**, **17.8** and **17.9** twice to give three sets of deflections, and calculate the mean deflection at each force.

17.11 Replace the plane pad with a convex pad (**5.3**) and repeat **17.3**, **17.4**, **17.5**, **17.6**, **17.7**, **17.8**, **17.9** and **17.10**.

17.12 Replace the convex pad with a concave pad (**5.4**) and repeat **17.3**, **17.4**, **17.5**, **17.6**, **17.7**, **17.8**, **17.9** and **17.10**.

17.13 Calculate the spread of the three mean deflections at the minimum calibration force and the spread of the three mean deflections at the maximum calibration force, and express them as percentages of the maximum deflection.

18 Supplementary calibration M — Zero force output stability

NOTE If the output stability at maximum calibration force is also to be determined, the results obtained at zero force during supplementary calibration N (see Clause **19**) may be used to determine the output stability at zero force.

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

18.2 Place the load cell in a location where the ambient disturbances are likely to be minimal. Apply the recommended excitation voltage and allow the system to achieve thermal stability.

18.3 Record the zero force output and the temperature of the load cell, at intervals not exceeding 3 days for a period of not less than 3 weeks. Take not less than 15 readings.

18.4 Calculate the spread of the zero force outputs and express this value as a percentage of maximum deflection. This figure shall be recorded on the calibration certificate (see Clause **23**), together with the temperature range.

NOTE If required, a correction to this figure may be applied to allow for the temperature sensitivity at zero force, as determined in Clause **12**.

19 Supplementary calibration N — Output stability at maximum calibration force

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

19.2 Record the zero force output, apply the maximum calibration force, record the output and temperature after not less than 30 s, calculate the deflection, and return to zero force.

19.3 Repeat **19.2** twice (to obtain three deflections in total) and calculate the mean deflection.

19.4 Repeat **19.1** to **19.3** (with the load cell at the same orientation in the machine) at intervals not exceeding 3 days for a period of not less than 3 weeks. Take not less than 15 sets of readings.

19.5 Calculate the spread of the mean deflections and express this value as a percentage of maximum deflection. This figure shall be recorded on the calibration certificate (see Clause **23**), together with the temperature range.

NOTE If required, a correction to this figure may be applied to allow for the temperature sensitivity at maximum calibration force, as determined in Clause **13**.

20 Supplementary calibration P — Damp heat

NOTE It is generally accepted that a good measure of a load cell's susceptibility to moisture ingress is drift of the zero force output.

20.1 Subject the load cell and its cable (excluding the instrumentation end, which shall be outside the chamber) to the cyclic damp heat test specified in BS EN 60068-2-30 and BS EN 60068-3-4. The upper temperature of the test shall be 55 °C. The temperature shall be lowered in accordance with variant 2 as given in BS EN 60068-2-30:1999. The load cell shall be energized throughout the test.

20.2 Subject the load cell to ten cycles, unless otherwise specified by the customer.

20.3 Calculate the difference between the zero force output of the load cell measured immediately before the start of the test and immediately after the completion of the test and express it as a percentage of maximum deflection. Record this figure on the calibration certificate (see Clause **23**), together with the number of test cycles performed.

20.4 Either make the zero force output measurements at similar temperatures or, if this is not possible, make a correction to the result to allow for the temperature sensitivity of zero force output, as determined in Clause **12**.

21 Supplementary calibration Q — Sealing

21.1 Subject the load cell and its cable (excluding the instrumentation end, which shall be outside the chamber) to the IP rating test specified by the customer, as defined in BS EN 60529. The load cell shall be energized throughout the test.

21.2 Calculate the difference between the zero force outputs of the load cell measured immediately before the start of the test and immediately after the completion of the test, and express this as a percentage of maximum deflection. Record this figure on the calibration certificate (see Clause **23**).

21.3 Either make the zero force output measurements at similar temperatures or, if this is not possible, make a correction to the result to allow for the temperature sensitivity of zero force output, as determined in Clause **12**.

22 Supplementary calibration R — Excitation voltage effects

22.1 Energize the load cell initially at the recommended excitation voltage.

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

22.3 Record the load cell zero output, and then apply the maximum calibration force. Record the output at maximum force, remove the force and calculate the deflection.

22.4 Repeat **22.3** twice to give three deflections, and calculate and record the mean deflection.

22.5 Energize the load cell at its maximum excitation voltage, allowing time for the temperature to stabilize after the voltage change.

22.6 Repeat **22.3** and **22.4** to give the mean deflection at the maximum excitation voltage.

22.7 Calculate the difference between the two mean deflections and express it as a percentage of the maximum deflection.

23 Calibration certificate

The calibration certificate shall include at least the following information:

a) description and identification of the load cell and its associated instrumentation;

b) customer's name and address;

c) laboratory name;

d) traceability and uncertainty of standards used;

e) date of the calibration;

f) details of calibration method[2];

g) details of any adjustments made prior to calibration;

h) results of all calibrations performed (with uncertainty statements).

NOTE 1 An example of a calibration certificate is given in Annex A.

NOTE 2 Guidance on the estimation of uncertainty is given in Annex B.

[2] Marking BS 8422:2003 on or in relation to a calibration represents a calibrator's declaration of conformity, i.e. a claim by or on behalf of the calibrator that the calibration has been carried out in accordance with the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

Annex A (informative)
Example of content of a calibration certificate

Figure A.1 shows an example of the content of a certificate for the calibration of a load cell system in accordance with this British Standard.

STRAIN GAUGE LOAD CELL
A123

FOR	BSI 389 Chiswick High Road LONDON W4 4AL
IDENTIFICATION	A compression strain gauge load cell, made by Cells“R”Us Ltd, with a serial number A123 and a nominal capacity of 3 000 kN. A digital indicator, made by Cheap Boxes Ltd, with a serial number 4567.
BASIS OF CALIBRATION	BS 8422:2003 Standard Calibration Supplementary Calibrations B, C, and L
DATES OF CALIBRATION	30 to 31 October 2003

SUMMARY OF RESULTS

Reproducibility = 0.028 % of maximum deflection

Non-linearity (second order, through zero) = 0.011 % of maximum deflection

Hysteresis = 0.047 % ± 0.020 % of maximum deflection

Creep = 0.085 % ± 0.050 % of maximum deflection

Base-loading effect (100 kN) = 0.028 % ± 0.005 % of maximum deflection

Base-loading effect (3 000 kN) = 0.094 % ± 0.054 % of maximum deflection

The reported uncertainties are based on a standard uncertainties multiplied by a coverage factor k, providing a level of confidence of approximately 95 %.

Figure A.1 — Example of content of a calibration certificate

STRAIN GAUGE LOAD CELL
A123

METHOD

The calibration was made in a 5 MN force standard machine, serial number 1234, in terms of the SI unit of force, the newton. The uncertainty of the forces applied by this machine is ±0.05 % of the applied force.

The force was applied through a flat soft steel pad, placed centrally on the load cell's domed loading button.

MEASUREMENTS

1. The temperature of the load cell during the calibrations varied between 19.8 °C and 20.3 °C. The temperature was measured using a thermometer, serial number 3807. The uncertainty of the temperature measurement was ±0.5 °C.
2. The indicator reading at zero applied force during the calibrations varied between 65 units and 67 units.
3. The forces applied during the standard calibration and the resulting deflections are given in Table 1; no correction for temperature has been applied to these results.
4. The results of the fits giving force in terms of deflection and deflection in terms of force are given in Tables 2 and 3 respectively.
5. The results of supplementary calibration B – Hysteresis – are given in Table 4.
6. The results of supplementary calibration C – Creep – are given in Table 5.
7. The results of supplementary calibration L – Base-loading effects – are given in Table 6.

Figure A.1 — Example of content of a calibration certificate (*continued*)

STRAIN GAUGE LOAD CELL
A123

STANDARD CALIBRATION RESULTS

DEFLECTIONS

Table 1: Standard calibration results

Force	Test no. 1, orientation 0°	Test no. 2, orientation 120°	Test no.3, orientation 240°	Spread	Mean deflection
kN	Deflection units			units	units
100	709	711	709	2	710
200	1 421	1 424	1 422	3	1 422
300	2 133	2 137	2 135	4	2 135
600	4 268	4 272	4 269	4	4 270
1 200	8 526	8 532	8 529	6	8 529
1 800	12 774	12 780	12 777	6	12 777
2 400	17 015	17 021	17 017	6	17 018
3 000	21 247	21 253	21 249	6	21 250
2 400	17 019	17 023	17 019	4	17 020
1 800	12 781	12 785	12 781	4	12 782
1 200	8 535	8 539	8 535	4	8 536
600	4 278	4 282	4 278	4	4 279
300	2 141	2 145	2 141	4	2 142
200	1 427	1 431	1 427	4	1 428
100	713	716	712	4	714

REPRODUCIBILITY

Reproducibility is defined as the maximum incremental spread, expressed as a percentage of maximum deflection.

Maximum incremental spread = 6 units

Maximum deflection = 21 250 units

Reproducibility = 100 × 6 / 21 250 = 0.028 % (equivalent to 0.84 kN)

Uncertainty associated with mean deflection values = ±0.34 % of deflection.

Figure A.1 — Example of content of a calibration certificate (*continued*)

STRAIN GAUGE LOAD CELL
A123

NON-LINEARITY

FORCE IN TERMS OF DEFLECTION

For a given measured deflection D (in units), the applied force F (in kN) is calculated from:

$$F = a_0 + a_1 D + a_2 D^2 + a_3 D^3$$

where a_0 to a_3 are coefficients as given in Table 2.

Table 2: Coefficients for fit of force in terms of deflection

Fit order	Forced through zero	a_0	a_1	a_2	a_3	Non-linearity[a]	
First	Yes	—	0.141 036	—	—	0.101 %	3.0 kN
First	No	–1.76	0.141 155	—	—	0.075 %	2.3 kN
Second	Yes	—	0.140 404	3.654 E-08	—	0.011 %	0.3 kN
Second	No	0.23	0.140 356	3.845 E-08	—	0.007 %	0.2 kN
Third	Yes	—	0.140 397	3.770 E-08	–3.9 E-14	0.012 %	0.3 kN
Third	No	0.47	0.140 184	5.891 E-08	–6.2 E-13	0.003 %	0.1 kN

[a] For the purposes of this table, the non-linearity is defined as the maximum difference between the increasing applied force and its calculated value, expressed as a percentage of maximum calibration force.

DEFLECTION IN TERMS OF FORCE

For a given applied force F (in kN), the expected deflection D (in units) is calculated from:

$$D = b_0 + b_1 F + b_2 F^2 + b_3 F^3$$

where b_0 to b_3 are coefficients as given in Table 3.

Table 3: Coefficients for fit of deflection in terms of force

Fit order	Forced through zero	b_0	b_1	b_2	b_3	Non-linearity[b]	
First	Yes	—	7.090 40	—	—	0.101 %	21.5 units
First	No	12.5	7.084 39	—	—	0.075 %	16.0 units
Second	Yes	—	7.122 11	–1.300 E-05	—	0.011 %	2.4 units
Second	No	–1.6	7.124 47	–1.366 E-05	—	0.007 %	1.4 units
Third	Yes	—	7.122 67	–1.361 E-05	1.5 E-10	0.012 %	2.5 units
Third	No	–3.3	7.133 37	–2.117 E-05	1.6 E-09	0.003 %	0.5 units

[b] For the purposes of this table, the non-linearity is defined as the maximum difference between the measured increasing deflection and its calculated value, expressed as a percentage of maximum deflection.

Uncertainty associated with use of second order fits, forced through zero = ±0.68 % of deflection/force.

Figure A.1 — Example of content of a calibration certificate (*continued*)

STRAIN GAUGE LOAD CELL
A123

SUPPLEMENTARY CALIBRATION RESULTS

SUPPLEMENTARY CALIBRATION B – HYSTERESIS

Table 4: Hysteresis

Force kN	Mean deflection units	Hysteresis units
100	710	—
200	1 422	—
300	2 135	—
600	4 270	—
1 200	8 529	—
1 800	12 777	—
2 400	17 018	—
3 000	21 250	—
2 400	17 020	3
1 800	12 782	5
1 200	8 536	7
600	4 279	10
300	2 142	7
200	1 428	6
100	714	4

Hysteresis is defined as the maximum difference between the incremental and decremental deflections, expressed as a percentage of maximum deflection.

Maximum difference = 10 units

Maximum deflection = 21 250 units

Hysteresis = 100 × 10 / 21 250 = 0.047 % (equivalent to 1.41 kN)

Uncertainty = ±0.10 % of deflection = ±4.2 units = ±0.020 % of maximum deflection.

Figure A.1 — Example of content of a calibration certificate (*continued*)

STRAIN GAUGE LOAD CELL
A123

SUPPLEMENTARY CALIBRATION C – CREEP

Table 5: Creep

Time minutes	Force kN	Output units	Time at force minutes	Difference units	Difference %
00:00	0	65			
30:00	0	66			
30:42	3 000	21 316	00:00	—	—
35:42	3 000	21 322	05:00	6	0.028
40:42	3 000	21 326	10:00	10	0.047
45:42	3 000	21 329	15:00	13	0.061
50:42	3 000	21 331	20:00	15	0.071
55:42	3 000	21 333	25:00	17	0.080
60:42	3 000	21 334	30:00	18	0.085
65:42	3 000	21 335	35:00	19	0.089
70:42	3 000	21 335	40:00	19	0.089
75:42	3 000	21 336	45:00	20	0.094

Creep is defined as the maximum change from the initial output at maximum force within the following 30 minutes, expressed as a percentage of maximum deflection.

Maximum difference in first 30 minutes = 18 units

Maximum deflection = 21 250 units

Creep = 100 × 18 / 21 250 = 0.085 % (equivalent to 2.55 kN)

Uncertainty = ±10.6 units = ±0.050 % of maximum deflection.

Figure A.1 — Example of content of a calibration certificate (*continued*)

STRAIN GAUGE LOAD CELL
A123

SUPPLEMENTARY CALIBRATION L – BASE-LOADING EFFECTS

Table 6: Base-loading effects

Pad	Force	Deflection			
	kN	Test 1 units	Test 2 units	Test 3 units	Mean units
Plane	100	709	711	709	710
	3 000	21 247	21 253	21 249	21 250
Convex	100	707	708	707	707
	3 000	21 236	21 238	21 239	21 238
Concave	100	712	713	713	713
	3 000	21 258	21 255	21 262	21 258

At the minimum calibration force, the spread of the three mean deflections is 6 units which, expressed as a percentage of maximum deflection, is equal to 0.028 % (equivalent to 0.84 kN).

Uncertainty = ±0.16 % of deflection = ±1.2 units = ±0.005 % of maximum deflection.

At the maximum calibration force, the spread of the three mean deflections is 20 units which, expressed as a percentage of maximum deflection, is equal to 0.094 % (equivalent to 2.82 kN).

Uncertainty = ±11.5 units = ±0.054 % of maximum deflection.

Figure A.1 — Example of content of a calibration certificate (*concluded*)

Annex B (informative) Uncertainty budget

B.1 General

The following contributions might need to be considered in the formulation of an uncertainty budget for the calibration results:

- — uncertainty of generated force;
- — reproducibility of deflections;
- — resolution of indicator;
- — temperature effects.

An example of an uncertainty budget for a standard calibration is given in B.2.

NOTE Further information is given in UKAS publication M3003 [3] and European Co-operation for Accreditation publication EA-10/04 [4].

B.2 Example of uncertainty budget for standard calibration

B.2.1 The calculations shown in **B.2.2**, **B.2.3**, **B.2.4**, **B.2.5** and **B.2.6** are carried out at each increasing force.

B.2.2 The standard uncertainty of mean deflection, u_{rep}, is calculated as a percentage (%) using equation B.1.

$$u_{rep} = 100 \times \frac{\sigma}{d\sqrt{n}} \quad \text{(B.1)}$$

where:

d is the mean deflection;

n is the number of runs;

σ is the standard deviation of deflections.

B.2.3 The standard uncertainty of calibration force, u_F, is calculated using equation B.2.

$$u_F = \frac{F}{2} \quad \text{(B.2)}$$

where F is the uncertainty of applied force, as a percentage (%), at 95 % confidence level.

B.2.4 The standard uncertainty due to resolution, u_{res}, is calculated as a percentage (%) using equation B.3.

$$u_{res} = 100 \times \frac{r}{2d\sqrt{3}} \quad \text{(B.3)}$$

where:

d is the mean deflection;

r is the resolution, in indicator units.

B.2.5 The combined uncertainty, u_c, is calculated as a percentage (%) using equation B.4.

$$u_c = \sqrt{u_{rep}^2 + u_F^2 + u_{res}^2} \quad \text{(B.4)}$$

B.2.6 The expanded uncertainty of mean deflection values, U, is calculated as a percentage (%) using equation B.5.

$$U = k \times u_c \quad \text{(B.5)}$$

where k is the coverage factor as determined from the Welch–Satterthwaite equation (see UKAS M3003 [3]).

B.2.7 The calibration uncertainty is the sum of maximum value of U and the maximum deviation from the fitted line, expressed as a percentage of deflection.

blank

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BS EN ISO 376:2002, *Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines.*

ASTM E74:2002, *Standard practice of calibration of force-measuring instruments for verifying the force indication of testing machines.*

Other publications

[1] INSTITUTE OF MEASUREMENT AND CONTROL. *A procedure for the specification calibration and testing of strain gauge load cells for industrial process weighing and force measurement*. WGL9301. London: Institute of Measurement and Control, 1993.[3)]

[2] ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE. *Metrological regulation for load cells*. R60. Paris: Organisation Internationale de Métrologie Légale, 2000.[4)]

[3] UNITED KINGDOM ACCREDITATION SERVICE. *The expression of uncertainty and confidence in measurement*. M3003. Feltham, Middlesex: United Kingdom Accreditation Service, 1997.[5)]

[4] EUROPEAN CO-OPERATION FOR ACCREDITATION. *Uncertainty of calibration results in force measurements*. EA-10/04. Paris: European Co-operation for Accreditation, 1996.[5)]

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3) Available from the Institute of Measurement and Control, 87 Gower Street, London WC1E 6AF, UK. Website: www.instmc.org.uk.

4) Available from the Organisation Internationale de Métrologie Légale, Bureau International de Métrologie Légale, 11 rue Turgot, F-75009 Paris, France. Website: www.oiml.org.

5) Available from the United Kingdom Accreditation Service, 21–47 High Street, Feltham, Middlesex TW13 4UN, UK. Website: www.ukas.com.

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