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# Metallic materials — Calibration of extensometer systems used in uniaxial testing

*Matériaux métalliques — Étalonnage des chaînes extensométriques utilisées lors d'essais uniaxiaux*



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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9513 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This third edition cancels and replaces the second edition (ISO 9513:1999), which has been technically revised. It also incorporates the Technical Corrigendum ISO 9513:1999/Cor.1:2000.

## Introduction

This International Standard sets out criteria for the calibration of extensometer systems, covering general principles, the calibration equipment to be used, pre-calibration inspection and the measurement of gaugelength for various types of extensometer systems. Aspects of the calibration process are addressed, as are the assessment of the results, uncertainties, calibration intervals and reporting. Criteria for calibration apparatus, their calibration and grading are addressed, complemented by a Bibliography covering a number of important papers related to extensometer systems and their application [1] to [10]. Work is in progress to develop processes for dynamic extensometer calibration, however these have not reached, at the time of writing of this International Standard, the level of development appropriate for inclusion within this International Standard. For further information, refer to Reference [6].

Informative annexes address calculation of uncertainties of measurement for an extensometer system calibration (Annex A), calibration of calibration apparatus (Annex B) and an example of a calibration report (Annex C). Subsequent annexes address examples of extensometer system configurations (Annex D), laser extensometry (Annex E), video extensometry (Annex F), full field extensometry (Annex G) and calibration of a crosshead measurement system (Annex H).

# Metallic materials — Calibration of extensometer systems used in uniaxial testing

## 1 Scope

This International Standard specifies a method for the static calibration of extensometer systems used in uniaxial testing, including axial and diametral extensometer systems, both contacting and non-contacting.

## 2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**2.1**
**extensometer system**
equipment used to measure displacement or strain on the surface of a test piece

NOTE For the purpose of this International Standard, the term “extensometer system” includes the indicator. Some extensometers indicate strain directly (e.g. laser extensometers or digital image correlation techniques). Other extensometers indicate the change in gauge length of a test piece; this is converted into strain by dividing by the relevant gauge length.



**2.2**
**gauge length**
portion of a test piece where extension is measured



## 3 Symbols and designations

Symbols used throughout this International Standard are given in Table 1 together with their designation.

**Table 1 — Symbols and designations**

| Symbol | Designation | Unit |
|---|---|---|
| $L_e$ | Nominal gauge length of extensometer | mm |
| $L'_e$ | Measured gauge length of extensometer | mm |
| $l_{max}$ | Maximum limit of calibration range | mm |
| $l_{min}$ | Minimum limit of calibration range | mm |
| $l_i$ | Displacement indicated by extensometer | µm |
| $l_t$ | Displacement given by calibration apparatus | µm |
| $q_{L_e}$ | Relative gauge length error of the extensometer system | % |
| $q_{rb}$ | Relative bias error of the extensometer system | % |
| $q_b$ | Absolute bias error of the extensometer system | µm |
| $r$ | Resolution of the extensometer system | µm |

## 4 Principle

The calibration of extensometer systems involves a comparison of the readings given by the extensometer with known variations in length provided by a calibration apparatus.

NOTE 1 The user can define the displacement range(s) over which the calibration is to be performed. In this way, the performance of the extensometer system can be optimized. For example, for strain-controlled low cycle fatigue, only a small portion of the operating range of the extensometer is typically used. Hence, it would be appropriate, in this case, to concentrate the calibration on the centre portion of the operating range.

The calibration process compares the known displacement from the calibration device with the output of the extensometer system. This output can range from manual readings of high precision dial gauges to the displacement indication of a transducer/electronics/data-logging system. In the latter case, the extensometer system output would include any data curve fitting applied by the electronics/data-logging system.

NOTE 2 For certain types of extensometer systems, the calibration and classification will also be dependent upon the ability of the extensometer system to define the gauge length.

## 5 Calibration equipment

### 5.1 Calibration apparatus

The calibration apparatus, which allows a known displacement $l_t$ to be applied to the extensometer, may consist of a rigid frame with suitable coaxial spindles or other fixtures to which the extensometer can be attached. The calibration apparatus shall comprise a mechanism for moving at least one of the axial spindles together with a device for accurately measuring the change in length produced. These variations in length can be measured by, for example, an interferometer, a linear incremental encoder or gauge blocks and a comparator, or a micrometer.



NOTE Special attachments to the calibration apparatus spindles are utilized for the calibration of diametral extensometers.



The calibration apparatus should be calibrated in accordance with Annex B and should meet the performance requirements given in Table B.1.

Annex B gives a recommended calibration procedure for the calibration apparatus and details performance criteria that indicate that the apparatus is suitable for calibrating extensometer systems in accordance with this International Standard.

### 5.2 Calibration traceability

The calibration apparatus and the supporting equipment (such as micrometers, callipers, optical projection microscopes) shall be calibrated using standards that are traceable to the International System of Units (SI). The uncertainty associated with any measurements made by the supporting equipment shall not exceed one third of the permissible error of the extensometer system being calibrated (see Table 2). The temperature measurement instrument shall have a resolution of 0,1 °C.

## 6 Pre-calibration inspection

### 6.1 Objective

Prior to the calibration of the extensometer system it shall be inspected. This shall comprise, but not be limited to, inspection of the mechanical components for, for example, free movement, damaged parts, worn knife edges, and worn gauge length setting pins/fixtures. For extensometer systems incorporating electronic transducers, the cabling and connectors shall be examined for damage, wear, etc.

The extensometer system shall be calibrated in the as-found condition if at all possible. The results shall be assessed and, if necessary, the system shall be adjusted and re-calibrated. In this case, both data sets shall be reported.

### 6.2 Records of the inspection

Records of the pre-calibration inspection shall be kept, identifying the "as-found" condition of the extensometer system, when the inspection was performed and who performed it. These pre-calibration inspection records can take the form of either a written report or a completed "pro-forma" checklist.

### 6.3 Identification of extensometer system elements

The extensometer shall be uniquely identified. Parts that may be changed by the user during normal use of the extensometer that affect the calibration of the extensometer shall also be uniquely identified where possible. However, this requirement does not extend to clamping devices used to attach the extensometer to the test piece. These unique identifications form part of the records for the extensometer system.

## 7 Measurement of extensometer gauge length

### 7.1 Fixed gauge length extensometry

**7.1.1** The measured gauge length, $L'_e$, of a fixed gauge length extensometer shall be determined by either direct or indirect means. In both cases, the extensometer setting pin or gauge fixture is used to set the extensometer contact points to their pre-set displacement.

NOTE Variability of the measured gauge length might be experienced due to excessive play/wear in the gauge length setting mechanism.



**7.1.1.1** Direct measurement of the gauge length, $L'_e$, is performed between the extensometer contact points, using a calibrated measuring instrument such as a caliper or a shadowgraph/projection microscope.



**7.1.1.2** Indirect measurement of the gauge length, $L'_e$, is performed by placing the extensometer on a soft metal test piece in such a way that the blades or points of the extensometer leave their marks. Once the extensometer is removed, the distance between the marks on the test piece shall be measured, using equipment with an accuracy consistent with the required class of extensometer.

**7.1.2** The relative error on the gauge length, $q_{L_e}$, calculated from Formula (1) shall meet the requirements given in Table 2.

$$q_{L_e} = \frac{L'_e - L_e}{L_e} \times 100 \qquad (1)$$

### 7.2 Variable gauge length extensometry

**7.2.1** The gauge length of a variable gauge length extensometer shall be measured either directly, or indirectly.

**7.2.1.1** Direct measurement of the gauge length is performed by setting the extensometer to the required gauge length using jigs, fixtures or other tools, followed by measurement between the extensometer contact points, using a calibrated measuring instrument such as a calliper or a shadowgraph/projection microscope.

**7.2.1.2** Indirect measurement of the gauge length, $L'_e$ is performed by attaching the extensometer to a soft metal test piece in such a way that the blades or points of the extensometer leave their marks. Once the extensometer is removed, the distance between the marks on the test piece is measured, using equipment with an accuracy consistent with the required class of extensometer.

**7.2.2** Extensometers commonly used in creep, elevated temperature tensile or stress relaxation testing have their gauge length defined by small ridges machined on the parallel length of the test piece, to which the extensometer is clamped. The gauge length for such extensometers shall be determined directly from the test piece and shall be to an accuracy consistent with the required class of extensometer.

**7.2.3** The relative error on the gauge length, $q_{L_e}$, calculated from Formula (1), shall meet the requirements given in Table 2.

**7.2.4** Where an extensometer sets or measures the gauge length, the relative error on the gauge length shall be determined. If features on the test piece define the gauge length, the relative error on the gauge length does not need to be determined.

**7.2.5** Where an extensometer automatically sets the gauge length, the maximum and minimum gauge lengths used, plus three more gauge lengths between the minimum and maximum, shall be measured. Where fewer than five gauge lengths are used, all gauge lengths shall be measured.

### 7.3 Non-contacting extensometry

The gauge length for non-contacting extensometry is established in accordance with the manufacturer's instructions.

### 7.4 Extensometer gauge lengths established using setting gauges

Where an extensometer gauge length is set using a removable gauge, the relative error on the gauge length, $q_{L_e}$, calculated from Formula (1) shall not exceed the values given in Table 2.



The uncertainty of measuring the gauge length shall be three times better than the allowable error in gauge length.



## 8 Calibration process



### 8.1 Environmental considerations

**8.1.1** The ambient temperature during the calibration of the extensometer system shall be recorded.

In general, the calibration of the extensometer system should be carried out at a temperature stable to within ± 2 °C, the target temperature being within the range 18 °C to 28 °C. Temperature changes during the calibration process may add to the uncertainty of the calibration and in some cases may affect the ability to properly calibrate the extensometer.

**8.1.2** For extensometers used for uniaxial testing at temperatures outside the range 10 °C to 35 °C, the calibration should be carried out at or near the test temperature, if facilities exist.

**8.1.3** The extensometer shall be placed near the calibration apparatus, or be mounted on it, for a sufficient length of time prior to its calibration so that the parts of the extensometer system and of the calibration apparatus which are in contact stabilize at the calibration temperature.

### 8.2 Position of the extensometer

The extensometer shall be placed, wherever feasible, in the calibration apparatus in a similar orientation to that in which it will be used during uniaxial testing to avoid errors due to loss of equilibrium or to deformation of any part of the extensometer.

The extensometer shall be attached in a similar way as during uniaxial testing.

### 8.3 Calibration increments

**8.3.1** The user shall establish the range of displacements over which the extensometer system shall be calibrated.

**8.3.2** The number of calibration points, and the number of ranges over which calibration is performed, shall be based upon the relationship between the minimum displacement at which a property is determined, $l_{min}$, and the maximum displacement at which a property is determined, $l_{max}$.

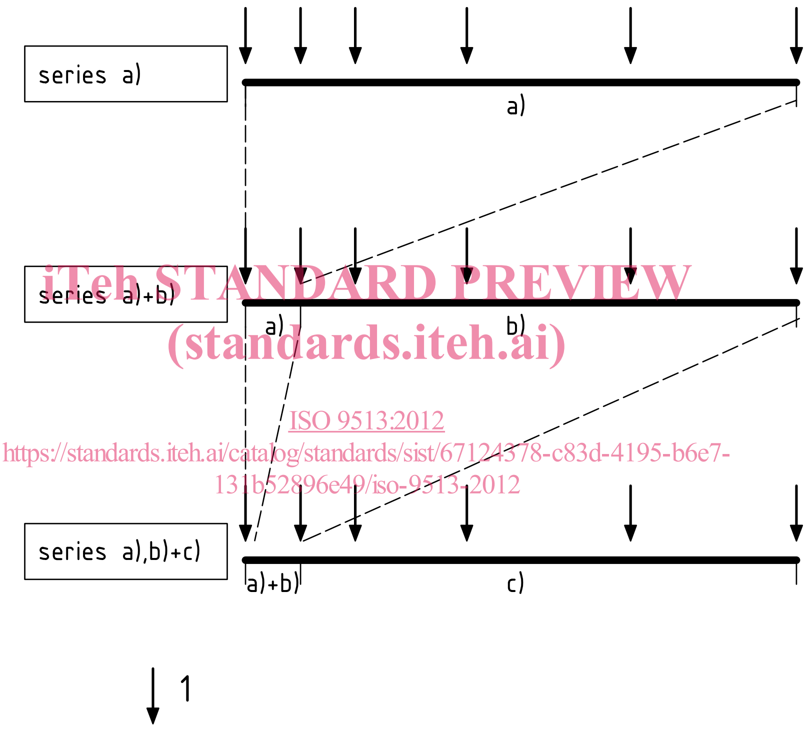
**8.3.3** For monotonic tests, the following series of readings shall be made.

a) If ($l_{max}/l_{min}$) is less than or equal to 10, one range of at least five increments shall be recorded.

b) If ($l_{max}/l_{min}$) is greater than 10 but less than or equal to 100, two ranges ($l_{min}$ to 10$l_{min}$ and 10$l_{min}$ to $l_{max}$), or ($l_{min}$ to 0,1$l_{max}$ and 0,1$l_{max}$ to $l_{max}$), each of at least five increments, shall be recorded.

c) If ($l_{max}/l_{min}$) is greater than 100, three ranges ($l_{min}$ to 10$l_{min}$, 10$l_{min}$ to 100$l_{min}$, 100$l_{min}$ to $l_{max}$), or ($l_{min}$ to 0,01$l_{max}$, 0,01$l_{max}$ to 0,1$l_{max}$, 0,1 $l_{max}$ to $l_{max}$), each of at least five increments, shall be recorded.

For each of the three categories [a), b), c) above], the increment between any two adjacent points shall not exceed one third of the range. Examples of these increments are shown in Figure 1.






**Key**

1 calibration points

**Figure 1 — Schematic diagram showing calibration point distribution**

NOTE 1 A tensile test measuring, from the extensometer, the modulus and proof stresses only, would fall into category a). A tensile test, establishing proof stresses and elongation at failure from the extensometer, or a creep to rupture test, would fall into category b) or category c).

NOTE 2 For fatigue tests, a range of at least five increments (with the increment between any two adjacent points not exceeding one third of the range between $l_{min}$ and $l_{max}$) is used.

NOTE 3 The values derived from the above calculations can be adjusted to the nearest convenient increments to match those of the calibration apparatus.

**8.3.4** When establishing $l_{max}$ and $l_{min}$, operational factors such as thermal expansion of elevated temperature tests and additional displacement contingencies to cover matters such as test to test set-up variability shall be taken into account.

## 8.4 Calibration process

**8.4.1** The calibration shall be undertaken in the as-found condition without special cleaning.

**8.4.2** When the temperature has stabilized, it is recommended that, before calibration and by means of the calibration apparatus, the extensometer be exercised twice over the calibration range of the extensometer system. If possible, the displacement is taken to a slightly negative value and returned to zero. Where appropriate, reset the extensometer system to zero.

**8.4.3** The calibration consists of two series of measurements with the increments as defined in 8.3.

— The first series of measurements is performed and recorded; the extensometer is removed and then placed back on the calibration apparatus.

— A second series of measurements is then made in the same manner as the first.

Depending on the expected use of the extensometer, the two series of measurements are made for increases in length or for decreases in length, or for both.

## 8.5 Determination of the characteristics of the extensometer system

### 8.5.1 Resolution

**8.5.1.1** The resolution, $r$, is the smallest quantity which can be read on the instrument.



**8.5.1.2** For extensometers with analogue scales, the resolution of the indicator shall be obtained from the ratio between the width of the pointer and the centre-to-centre distance between two adjacent scale graduation marks (scale interval), multiplied by the physical dimension which one scale increment represents. The resolution shall not be smaller than one fifth of the physical dimension represented by one scale interval unless the distance between two adjacent marks is greater than or equal to 2,5 mm, in which case the resolution may be as small as one tenth of a scale interval.

**8.5.1.3** For extensometer systems with an electronic display, the output shall be observed for 10 s and the maximum and minimum values recorded. One half the difference between the maximum and minimum observed values shall be established and recorded as the resolution, $r$. Where the minimum and maximum values are equal, the resolution shall be one digit on the display.

### 8.5.2 Bias error

#### 8.5.2.1 Relative bias error

The relative bias error, $q_{rb}$, for a given displacement, $l_t$, is calculated from Formula (2):

$$q_{rb} = \frac{l_i - l_t}{l_t} \times 100 \qquad (2)$$

#### 8.5.2.2 Absolute bias error

The absolute bias error, $q_b$, for a given displacement, $l_t$, is calculated from Formula (3):

$$q_b = (l_i - l_t) \qquad (3)$$

## 9 Classification of the extensometer system

### 9.1 Input data

The required input data for the classification of the extensometer system are:

a) the relative error of the gauge length (see 7.2.5);

b) the resolution (absolute and/or relative) of the extensometer system (see 8.5.1);

c) for each calibration data point, the bias error (absolute and/or relative) (see 8.5.2);

d) the confirmation that the calibration apparatus fulfilled the requirements of this International Standard for each calibration data point.

### 9.2 Analysis of the data

The collated data are assessed as follows:

a) the relative error of the gauge length is compared to the limits in Table 2 and a grading is obtained;

b) the resolution of the extensometer system for each calibration data point is compared to the limits in Table 2 and a grading obtained;

c) for each calibration data point, the bias error is compared to the limits in Table 2 and a grading is obtained.



### 9.3 Classification criteria

Table 2 gives the maximum permissible values for the relative gauge length error, the resolution and the bias error.



**Table 2 — Classification of the extensometer system**

| Class of extensometer system | Relative error of the gauge length | Resolution [a] | | Bias error [a] | |
|---|---|---|---|---|---|
| | | Percentage of reading | Absolute value | Relative value | Absolute value |
| | $q_{L_e}$ | $(r/l_i)\cdot 100$ | $r$ | $q_{rb}$ | $l_i - l_t$ |
| | % | % | µm | % | µm |
| 0,2 | ±0,2 | 0,1 | 0,2 | ±0,2 | ±0,6 |
| 0,5 | ±0,5 | 0,25 | 0,5 | ±0,5 | ±1,5 |
| 1 | ±1,0 | 0,5 | 1,0 | ±1,0 | ±3,0 |
| 2 | ±2,0 | 1,0 | 2,0 | ±2,0 | ±6,0 |

[a] Whichever is greater.

### 9.4 Assessment of the results

**9.4.1** The data specified in 9.2 are collated and the maximum classification value for each of the following is determined:

a) the relative error of the gauge length;

b) for each calibration data point the resolution of the extensometer system;

c) for each calibration data point the bias error;

d) for each calibration data point the classification of the calibration apparatus.

This maximum value of these four parameters is defined as the ISO 9513 classification for the extensometer system.

**9.4.2** Whenever adjustments are needed for the extensometer to comply with class requirements for its intended use, the calibration provider can, with laboratory approval, make such adjustments to enhance the extensometer system performance. The records from the initial calibration shall be retained and supplied as part of the calibration documentation. The post-adjustment results shall be reported on the calibration certificate.

## 10 Uncertainty determination

### 10.1 Uncertainty of the calibration

Many elements contribute to the uncertainty of the calibration process. The following shall be assessed and incorporated into the uncertainty budget calculation:

a) calibration uncertainty of the calibration device;

b) ambient temperature fluctuations during calibration;

c) inter-operator variability where more than one person performs calibrations within a laboratory;

d) gauge length setting;

e) gauge length measurement equipment.

For further information, refer to Annex A.

### 10.2 Uncertainty budget determination



The uncertainty shall be determined. An example calculation, showing how to perform an uncertainty evaluation for an extensometer system, is presented as Annex A.



NOTE The requirements of this International Standard limit the major components of uncertainty when calibrating extensometers. By complying with this metrological standard, uncertainty is explicitly taken into account as required by some accreditation standards. Reducing the allowable bias by the amount of the uncertainty would result in double counting of the uncertainty. The classification of an extensometer calibrated and certified to meet a specific class does not ensure that the accuracy including uncertainty will be less than a specific value. For example, an extensometer meeting Class 0,5 does not necessarily have a bias including uncertainty of less than 0,5 %.

## 11 Extensometer system calibration intervals

**11.1** The time between two calibrations depends on the type of extensometer system, the maintenance standard and the number of times the extensometer system has been used. Under normal conditions, it is recommended that calibration be carried out at intervals of approximately 12 months. This interval shall not exceed 18 months unless the test is expected to last more than 18 months; in such a case the extensometer system shall be calibrated before and after the test. Where long-term creep tests are performed according to ISO 204, the calibration interval for their extensometer systems, based upon extensive practical experience, is three years; a similar situation exists for long-term stress relaxation testing. In these cases, the testing standard requirement shall take precedence over the calibration intervals defined in this clause.

**11.2** The extensometer system shall be calibrated after each repair or adjustment which affects the accuracy of measurements.

## 12 Calibration certificate

### 12.1 Mandatory information

The calibration certificate shall contain at least the following information:

a) reference to this International Standard, i.e. ISO 9513;

b) name and address of the owner of the extensometer system;

c) identification of the extensometer (type, gauge length, mark, serial number and mounting position);

d) type and reference number of the calibration apparatus;

e) temperature during the calibration process;

f) nature of the variations of length for which the calibration was carried out, i.e. either for increases and/or for decreases in length;

g) date of calibration;

h) name of the person who performed the calibration, plus the name or mark of the calibrating organization;

i) all results from the calibration (as-found condition and, if adjusted, after adjustment measurements);

j) a statement of uncertainty;

k) classification for each range of the extensometer.

Items on the certificate may be presented in a referenced report.

### 12.2 Data presentation

The results of the calibration shall be tabulated in the certificate and shall include individual values of the bias error associated with each calibration point.



A graphical presentation of the results from the calibration may be presented as part of the certificate.

