

# ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE



INTERNATIONAL RECOMMENDATION

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High-precision line measures of length

Mesures matérialisées de longueur à traits de haute précision

OIML R 98

Edition 1991 (E)

## FOREWORD

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Bureau International de Métrologie Légale  
11, rue Turgot - 75009 Paris - France  
Telephone: 33 (0)1 48 78 12 82 and 42 85 27 11  
Fax: 33 (0)1 42 82 17 27  
E-mail: biml@oiml.org  
Internet: www.oiml.org

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# HIGH-PRECISION LINE MEASURES of LENGTH

## 1 General

This Recommendation applies to rigid line measures of length of high precision, either single-valued or multiple-valued, on bars of metal or glass. These measures are hereinafter referred to as "line measures" or "measures".

The Recommendation specifies the main technical requirements for the fabrication of line measures, and the metrological requirements applicable to them.

According to the International System of Units, SI, the base unit of length is the metre (symbol: m).

High-precision line measures are intended to be used as:

- reference standards, to transfer the unit of length to line measures of lower accuracy, and to calibrate length-measuring instruments and linear transducers,
- ordinary measures for the adjustment of length-measuring instruments and machine tools, for direct measurements of length, and for linear displacements in machine tools and instruments.

## 2 Terminology

### 2.1 Line measure of length

A measure representing one or several values of length determined by the shortest distance between the centers of two scale marks.

### 2.2 Nominal length of a line measure

The length the measure is expected to represent in the absence of any manufacturing error.

### 2.3 Error of a line measure

The algebraic difference between the nominal value of the length of the line measure and its conventional true value.

### 2.4 Main scale marks

The scale marks whose distance apart represents the total length or the most important length of the line measure.

### 2.5 Single-valued line measure

A line measure with two scale marks representing one value of length only.

## 2.6 Multiple-valued line measure

A line measure with a set of scale marks at intervals along its length.

## 2.7 Scale

The whole set of scale marks with their corresponding numbering.

# 3 General technical requirements

## 3.1 Nominal lengths

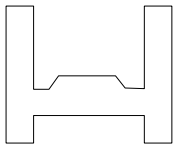
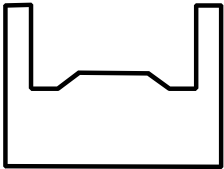
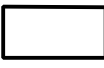

The recommended values for the nominal lengths in mm of line measures are:

60, 100, 150, 160, 200, 250, 300, 320, 400, 500, 630, 700, 800, 840, 910, 1 000, 1 200, 1 400, 1 500, 1 600 and 2 000.

## 3.2 Cross sections

The preferred cross sections and dimensions of line measures are given in Table 1.

Table 1

Type	Cross sections	Dimensions, mm		Nominal length mm
		height	width	
A		25	30	up to 1 000
		30	40	above 1 000
B		10	20	up to 250
		20	30	up to 500

Shapes and dimensions may be other than those indicated in the Table.

### 3.3 Materials

3.3.1 Line measures shall be made of materials suitable for the measures' intended use.

3.3.2 Materials recommended for the manufacture of line measures are indicated in Table 2.

Table 2

Material	Thermal coefficient of linear expansion $\times 10^{-6}\text{K}^{-1}$ (*)
Steel containing 36 % nickel	$1.0 \pm 0.5$
Steel containing 58 % nickel	$11.5 \pm 0.5$
Steel	$11.0 \pm 1.0$
Optical glass	8.0 à 11.0
Quartz glass	$1.0 \pm 0.5$

(\*) determined in the temperature range + 15 °C to + 30 °C.

3.3.3 The manufacturer shall indicate the value of thermal coefficient of linear expansion and its uncertainty in the relevant documents or on the line measure.

### 3.4 Scale

3.4.1 The scale surface of a line measure of type A shall coincide with the neutral plane; the scale surface of a line measure of type B shall coincide with the upper surface.

3.4.2 The scales of line measures shall be distinct, uniform and indelible. The surface occupied by the scale shall not be pitted or scratched. The scale marks shall be straight lines drawn perpendicular to the longitudinal axis of the measure and all shall be of the same width, uniform throughout their length. The measurement axis shall be represented.

3.4.3 The lengths of the scale marks denoting intervals of 1 mm, 5 mm and 10 mm should be chosen to have the relative proportions 1, 1.5 and 2. Scale marks may all have the same length if it is less than 1 mm.

3.4.4 The scale marks at intervals of 1 cm or 1 mm may be numbered. If the scale marks of line measures of type I are not numbered, an approximate scale divided in cm or mm may be applied to one of the upper edges.

### 3.5 Inscriptions

3.5.1 Line measures shall bear the following inscriptions:

- manufacturer's trade-mark,
- serial number,

- nominal length,
- material of manufacture,
- year of manufacture,
- location of the Bessel points or Airy points.

3.5.2 Advertising inscriptions shall not affect the use of the line measure, nor introduce stresses.

3.5.3 The inscriptions shall be applied in a way that does not deform the measure.

## 4 Metrological requirements

### 4.1 Accuracy classes

4.1.1 Line measures may belong to one of the following accuracy classes:

M, 0, 1, 2 or 3.

4.1.2 It is recommended that line measures of type A be of accuracy class 0 or 1, and those of type B of accuracy class 0, 1, 2 or 3.

4.1.3 The accuracy class of a line measure shall be indicated in the accompanying documents.

### 4.2 Maximum permissible errors and stability

4.2.1 The maximum permissible errors at the time of manufacture of the distance between any two marks of a line measure, at the reference conditions specified in 5.2.1, are given in the Table 3 where L is the numerical value of the nominal length of the interval between those two marks, in metres.

Table 3

Accuracy class of measures	Maximum permissible manufacturing errors ( $\mu\text{m}$ )
M	-
0	$\pm (0.5 + 0.5 L)$
1	$\pm (1 + 1 L)$
2	$\pm (2 + 2 L)$
3	$\pm (5 + 5 L)$

Note: Line measures of class M (metrological class) are measures of high stability for which the manufacturing errors are not specified but are measured and indicated in a certificate.

4.2.2 The annual variation in length due to the instability of the material of a line measure shall not exceed:

0.15  $\mu\text{m}/\text{m}$  for a line measure of accuracy class M or 0,

0.3  $\mu\text{m}/\text{m}$  for a line measure of accuracy class 1,

1.0  $\mu\text{m}/\text{m}$  for a line measure of accuracy class 2 or 3.

#### 4.3 Measurement axis and scale

4.3.1 For line measures belonging to accuracy classes M, 0 and 1, the measurement axis shall be represented as two parallel lines 0.2 mm to 0.3 mm apart, inscribed on the whole length of the scale surface.

For line measures with scale marks shorter than 1 mm or for single-valued line measures the measurement axis may be represented by a single line drawn at each end of the scale.

4.3.2 The width of scale marks shall be:

- between 3  $\mu\text{m}$  and 10  $\mu\text{m}$  for measures in accuracy class M, 0 or 1,

- between 10  $\mu\text{m}$  and 20  $\mu\text{m}$  for measures in accuracy class 2 or 3.

The maximum permissible difference between the widths of scale marks shall be 10 % of the mean value of width.

4.3.3 Deviations from the perpendicularity of scale marks to the measurement axis shall not exceed 5'.

#### 4.4 Surfaces

4.4.1 The surface roughness parameter  $R_z$  of metallic line measures shall not exceed the values given in Table 4.

Table 4

Accuracy class of measures	Maximum roughness values $R_z$	
	Scale surface $\mu\text{m}$	Lateral surfaces and base surface, $\mu\text{m}$
M, 0, 1	0.05	1.60
2, 3	0.2	6.3

4.4.2 The roughness of the scale surfaces and of the base surfaces of line measures made from glass shall not exceed 0.05  $\mu\text{m}$ ; the roughness of the lateral surfaces shall not exceed 10.0  $\mu\text{m}$ .

4.4.3 The permissible variations in the shape and in the position of the scale surface are given in Table 5.

Table 5

Accuracy class	Flatness tolerance	Tolerance of the parallelism of the scale surface to the base surface (*)	Deviation from perpendicularity to the lateral surface over the length of 1 m
M,0	10 $\mu\text{m}$	20 $\mu\text{m}/\text{m}$	$\pm 10 \mu\text{m}$
1	16 $\mu\text{m}$	32 $\mu\text{m}/\text{m}$	$\pm 16 \mu\text{m}$
2, 3	20 $\mu\text{m}$	40 $\mu\text{m}/\text{m}$	$\pm 20 \mu\text{m}$

(\*) when supported at the Bessel points or Airy points.

4.4.4 The Bessel points or Airy points shall be marked on both lateral surfaces of line measures of accuracy classes M, 0 and 1.

## 5 Verification

Line measures are verified by measuring their actual lengths and the lengths of given intervals, and checking that they meet the requirements stated in sections 3 and 4 of this Recommendation.

### 5.1 Measurement of lengths

5.1.1 Line measures may be calibrated according to their intended use and their accuracy classes, whether as secondary standards or as reference standards of the 1st, 2nd and 3rd orders. The uncertainty at a confidence level of 0.99 shall not exceed the values given in Table 6, where L is the numerical value of the nominal length of the interval, in metres.

Table 6

Intended use	Accuracy class	Acceptable uncertainty in length measurement, $\mu\text{m}$
Secondary standards	M, 0	$\pm (0.05 + 0.1 L)$
Reference standards of 1st order	M, 0, 1	$\pm (0.1 + 0.2 L)$
Reference standards of 2nd order	M, 0, 1, 2	$\pm (0.2 + 0.5 L)$
Reference standards of 3rd order	2, 3	$\pm (1 + 5 L)$



5.1.2 The length of a line measure shall be determined by an absolute interference method or by comparing it with a material measure via a comparator.

## 5.2 Verification conditions

5.2.1 The reference conditions to which the results of measurement shall be referred are:

- temperature: 20 °C,
- atmospheric pressure: 101 325 Pa,
- partial pressure of water vapour in air: 1 333 Pa,
- CO<sub>2</sub> content: ≤ 0.05 %,
- attitude of the line measure: horizontal.

5.2.2 If the actual conditions of measurement differ from the reference conditions, corrections shall be applied to the result obtained.

## 6 Metrological controls

When, in any country, high-precision line measures of length are subject to state metrological controls, those controls shall include, in accordance with national regulations, all or a part of the following controls.

### 6.1 Pattern approval

Each pattern of a line measure of each manufacturer shall be subject to pattern approval.

No changes may be introduced to the approved pattern without special permission.

### 6.2 Initial verification

New line measures and line measures that have been repaired shall be subject to initial verification.

### 6.3 Periodical verification

Line measures in use shall be periodically verified to check that they maintain their metrological properties. The verification interval is specified by national metrological regulations.

#### 6.4 Verification certificate

A verification certificate shall be issued after each verification, including in particular:

- serial number,
- manufacturer's trade-mark,
- customer's name,
- nominal and actual lengths of the line measure and of specified intervals, at 20 °C (and at 25 °C for line measures used in tropical countries),
- accuracy class,
- thermal coefficient of linear expansion for secondary standards and reference standards of the first order,
- estimate of the measurement uncertainty,
- date of verification,
- validity period of the verification.

### 7 Packing

All line measures except those incorporated in other instruments or machine tools shall be provided with protective cases for their storage and transportation in order to protect them against mechanical damage and corrosion. The case shall bear the following inscriptions:

- manufacturer's trade-mark,
- serial number,
- year of manufacture,
- number of the OIML Recommendation (or of the national regulation or specification standard).

Other inscriptions on cases are also permitted.