INTERNATIONAL STANDARD ISO 386-1977 (E)/ERRATUM

Published 1978-08-01

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Liquid-in-glass laboratory thermometers – Principles of design, construction and use

ERRATUM

Page 2

In sub-clause 8.3, replace the first line by the following :

"For solid-stem thermometers, the stem may incorporate"

INTERNATIONAL STANDARD 386

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Liquid-in-glass laboratory thermometers — Principles of design, construction and use

Thermomètres de laboratoire à dilatation de liquide dans une gaine de verre — Principes de conception, de construction et d'utilisation

First edition — 1977-12-01

UDC 536.513

Ref. No. ISO 386-1977 (E)

Descriptors : laboratory equipment, laboratory glassware, temperature measuring instruments, thermometers, specifications, equipment specifications, utilization.

Price based on 12 pages

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 386 was developed by Technical Committee ISO/TC 48, *Laboratory glassware and related apparatus*, and was circulated to the member bodies in May 1976.

It has been approved by the member bodies of the following countries :

Australia	Ireland	Romania
Austria	Israel	South Africa, Rep. of
Belgium	Italy	Spain
Canada	Korea, Rep. of	Turkey
Chile	Mexico	United Kingdom
France	Netherlands	U.S.A.
Germany	Philippines	U.S.S.R.
Hungary	Poland	

The member body of the following country expressed disapproval of the document on technical grounds :

Czechoslovakia

This International Standard cancels and replaces ISO Recommendation R 386-1964, of which it constitutes a technical revision.

Printed in Switzerland

CONTENTS

Liquid-in-glass laboratory thermometers — Principles of design, construction and use

1 SCOPE AND FIELD OF APPLICATION

This International Standard sets out principles for the design, construction and use of liquid-in-glass laboratory thermometers.

Each thermometer consists of a glass bulb filled with liquid and connected with a glass capillary tube. A scale is associated with the tube in such a way that the temperature can be read from the position of the liquid surface in the tube.

2 TYPES OF THERMOMETER

Two types of liquid-in-glass thermometer are described :

2.1 Solid-stem thermometer

Thermometer having a thick-walled capillary stem, on which the scale is etched or marked.

2.2 Enclosed-scale thermometer

Thermometer having a capillary stem adjacent to a separate strip bearing the scale, both being enclosed in a protective sheath. There are other types of thermometer with separate but external scales; these however do not fall within the scope of this International Standard.

3 TEMPERATURE SCALE

The thermometers shall be graduated in accordance with the Celsius scale as defined in the current definition of the International Practical Temperature Scale (IPTS) adopted by the Conférence générale des poids et mesures, and in accordance with the International System of Units (SI).

4 CONDITIONS OF IMMERSION

In measuring the temperature of a medium by means of liquid-in-glass thermometers, the following methods are used.

4.1 Partial immersion

4.1.1 The thermometer is immersed to a prescribed depth in the medium so that not all the liquid column is immersed in the medium.

4.1.2 The emergent liquid column is that in the part of the capillary tube which is filled with liquid but not immersed in the medium.

4.1.3 The adopted value of the mean temperature of the emergent liquid column shall be specified to provide reference for graduation, calibration and use of the thermometer. Either this temperature may be the same for all scale readings, or different temperatures may be specified applicable to different points of the scale.

4.2 Total column immersion (total immersion)

The entire liquid column is immersed in the medium so that the top of the liquid column is in the same plane as the surface of the medium. (For practical considerations, see annex B, clause B.2.)

4.3 Complete immersion

The entire thermometer is immersed in the medium.

5 GLASS

The thermometer shall be made of suitable thermometric glass selected and processed so that the finished thermometer shows the following characteristics.

5.1 Stress in the glass of the bulb, capillary stem and, where appropriate, the protective sheath shall be reduced to a level sufficient to minimize the possibility of fracture due to thermal or mechanical shock.

5.2 The bulb glass shall be stabilized by suitable heat treatment to ensure that the accuracy requirements of 10.1 and 10.3 can be met.

5.3 The legibility of the reading shall not be impaired by devitrification or clouding.

5.4 The image of the meniscus shall be distorted as little as possible by defects or impurities in the glass.

6 LIQUID FILLING

The general requirements for the liquid filling shall include the following.

6.1 There shall be no freezing or partial freezing of the liquid filling throughout the temperature range under the pressures prevailing in the thermometer.

6.2 The liquid shall be free from any contamination likely to interfere with the proper functioning of the thermometer.

6.3 The boiling point of the liquid shall be high enough to minimize vaporization under the conditions prevailing in the thermometer.

6.4 For liquids which wet glass, additional requirements are as follows.

6.4.1 The physical properties of the liquid shall be such as to ensure that the drainage time when the thermometer is cooled, is within specified limits.

6.4.2 If the liquid is artificially coloured, a light-fast dye which does not stain the glass shall be used.

7 GAS FILLING

When gas filling is employed above the liquid filling, a dry gas shall be used at a pressure which raises the boiling point of the liquid sufficiently to ensure that the requirements of 6.3 are satisfied. In the case of mercury filling the gas shall be inert.

8 CONSTRUCTION

8.1 Shape

The thermometers shall be straight and their external cross-section approximately circular. For special thermometers, deviation from the straight shape and circular cross-section is permitted.

8.2 Top finish

The top of the thermometer may have a plain finish or a glass ring or button (see figure 1). The outer diameter of the ring or button shall not exceed that of the stem.

8.3 Enamel backing

For enclosed-scale thermometers, the strip bearing the scale an enamel backing so positioned that it lies behind the liquid column when the latter is viewed in alignment with the right-hand ends of the shortest scale lines and also when viewed in alignment with the left-hand ends of all of the scale lines.

8.4 Strip bearing the scale

For enclosed-scale thermometers, the strip bearing the scale shall be of a material suitable for the temperature to be measured and compatible with the method of fixing the strip. It shall be placed tightly against the capillary tube inside the sheath and shall be firmly and securely fastened at the top of the thermometer. A suitable method of fixing is by fusing a glass tube or rod to the sheath and to the upper end of the strip bearing the scale, while the lower end of the strip shall be freely held in a suitable saddle. Alternatively it shall be fixed inside the sheath in any other suitable manner that also allows for differential expansion (see figure 2 for recommended designs).

8.5 Capillary tube

The inside of the capillary tube shall be smooth. The cross-sectional area of the bore shall not show variations from the average greater than 10 %. The size of the bore shall be such that when the temperature is rising at a specified uniform rate, any jumping of the meniscus does not exceed a specified proportion of the graduation interval.

8.6 Enlargement of bore

No expansion or contraction chamber or other enlargement of the bore shall be so located as to produce any variation (greater than that permitted in 8.5) in the cross-section of the capillary tube in the scale ranges, and unless otherwise specified (see 8.7 and 8.8) there shall be at least 5 mm of unchanged capillary tube between any enlargement of the bore and any adjacent scale line. In the case of partial immersion thermometers no variation (greater than that permitted in 8.5) in the cross-section of the capillary tube is allowed between the immersion line (see 9.2) and the first scale line above it.

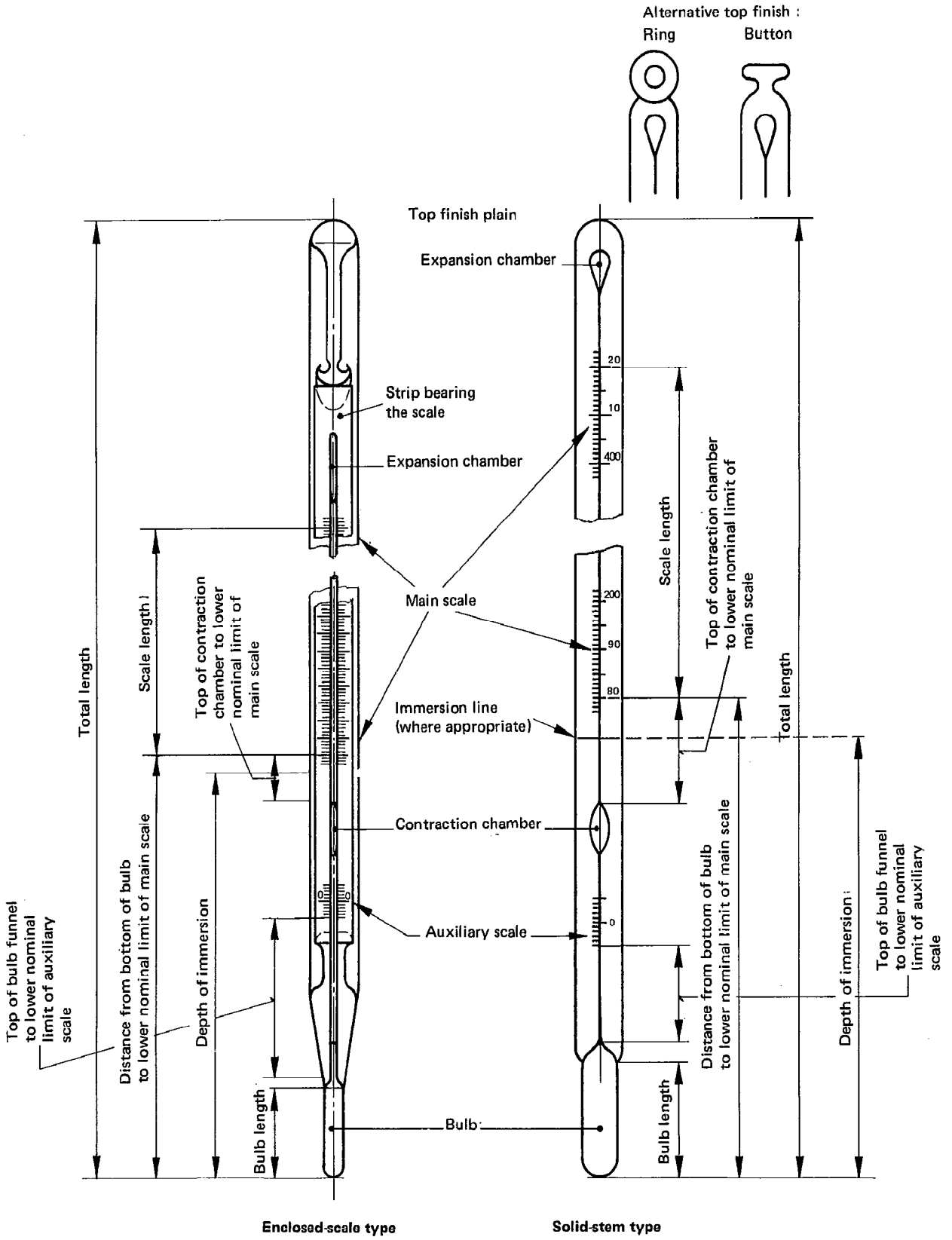
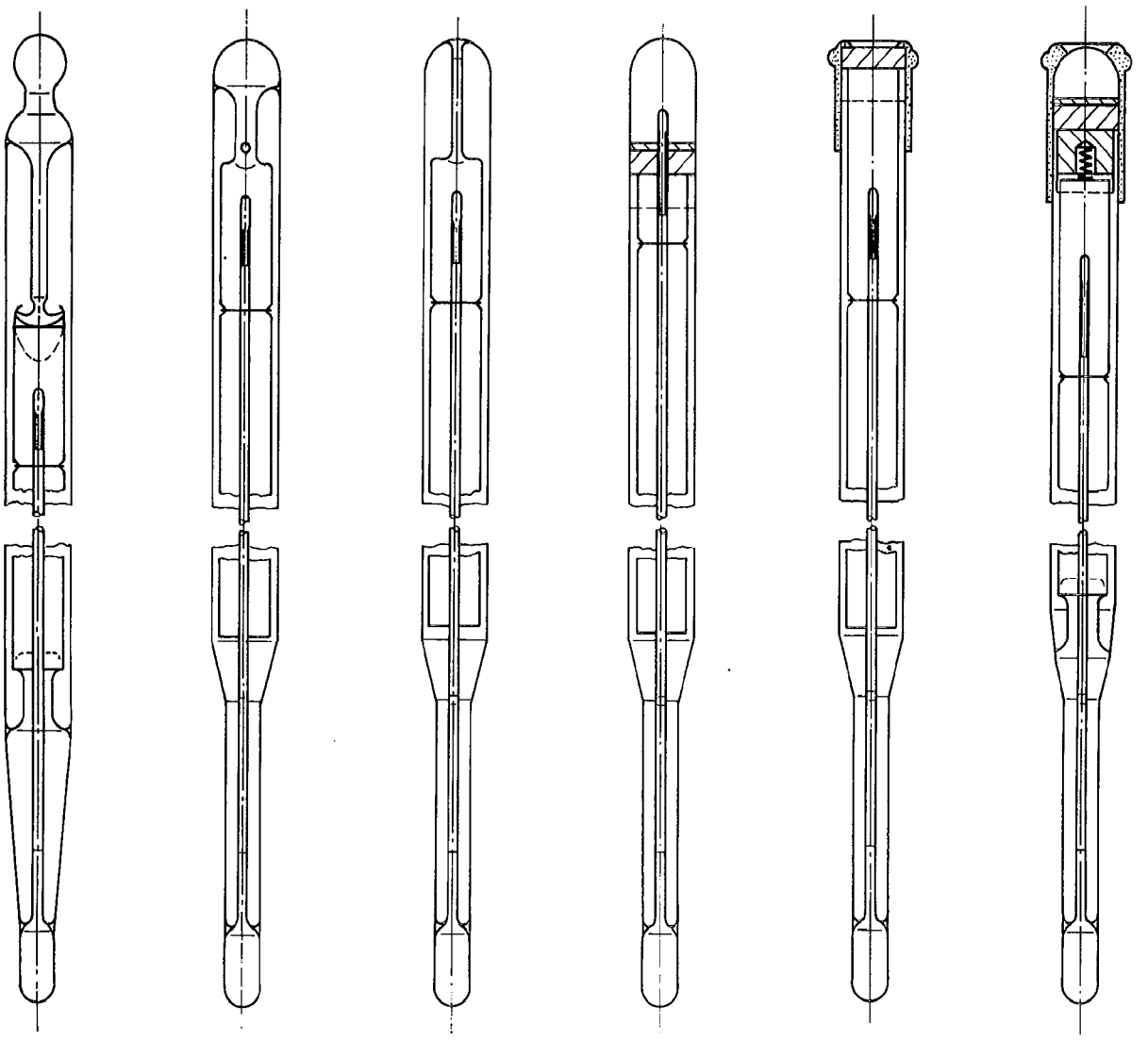


FIGURE 1 – **General design and terminology for liquid-in-glass thermometers**



2.1 with glass saddle and spring (Fuess top finish).

2.2 with fused-in glass tube (Richter top finish).

2.3 with fused-in glass pin.

2.4 cork-glass top finish.

2.5 cork and metal cap top finish.

2.6 with glass saddle and spring in metal support with cap.

FIGURE 2 — **Top finish and method of fixing the strip bearing the scale of enclosed-scale thermometers**

8.7 Expansion volume

A thermometer ought not to be heated above its upper nominal limit of scale because it may be damaged and may require recalibration even though it has not burst and any damage may not be visible. To minimize the effect of being accidentally overheated, and to provide for the exceptional case of a thermometer whose temperature range is below ambient being stored at ambient temperature, an expansion volume shall be provided at the top of the capillary tube.

This volume should preferably consist of an expansion chamber with at least 10 mm of unchanged capillary tube between the highest scale line and the commencement of the widening of the capillary tube. Such a chamber shall be pear-shaped with the hemisphere at the top. The approximate capacity of the expansion chamber shall be specified in terms of either the equivalent length of capillary tube or the corresponding temperature interval. In the case of gas filling, the expansion volume may consist of at least 30 mm of unchanged capillary tube above the highest scale line.

8.8 Contraction chamber

To prevent the liquid withdrawing into the bulb during storage or to allow the inclusion of an auxiliary scale, the bore may be enlarged above the bulb or above the auxiliary scale in an elongated manner to form a contraction chamber. This enlargement may be situated immediately above the bulb in the case of enclosed-scale thermometers but should preferably be separated from the bulb by a short length of capillary tube in the case of solid-stem thermometers. Where the enlargement is situated above an auxiliary scale, it shall be not less than 5 mm above that scale.

If the lower nominal limit of the scale is below 100 °C, the distance from the top of the contraction chamber to the first scale line of the main scale shall be not less than 10 mm.

In the case of partial immersion thermometers, this distance (10 mm) shall be measured either to the first scale line of the main scale or to the immersion line, whichever is the lesser distance. If the lower nominal limit of the scale is 100 °C or above, the corresponding distance shall be not less than 20 mm.

8.9 Specification of dimensions (see figure 1)

The following dimensions of a thermometer should be specified as required. These dimensions are consistent with producing a well designed thermometer but for specific purposes it may be necessary to state tolerances with these dimensions or to specify additional dimensions.

8.9.1 *Total length*

This is the overall length of the thermometer, including bulb and top finish. The maximum dimension only shall be specified.

8.9.2 *Bulb length*

The bulb length is defined (see figure 3) as the distance from the bottom of the bulb to the point at which the internal bulb diameter begins to decrease as the bulb merges into the stem. In general the minimum dimension only shall be specified.

8.9.3 *Distance from top of bulb funnel to lower nominal limit of scale* (see figure 3)

If the thermometer has more than one scale (for example main scale and auxiliary scale) this distance shall be to the lower nominal limit of the lowest scale. The minimum dimension only shall be specified. This distance shall be at least :

– 30 mm for thermometers having the lower nominal limit 100 °C or above;

– 13 mm for thermometers having the lower nominal limit less than 100 °C.

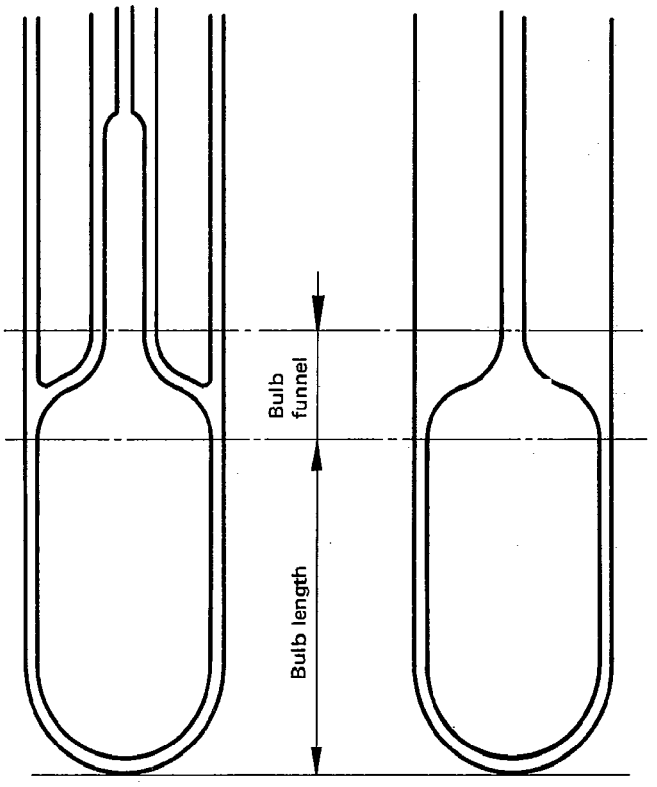


FIGURE 3 – **Definition of bulb length**

8.9.4 *Scale position*

The minimum dimension for the distance from the bottom of the bulb to the lower nominal limit of the main scale shall be specified.

8.9.5 *Scale length*

The scale length is the distance between the nominal limits of the main scale. (The nominal limits are marked with long lines and may or may not be figured.) The minimum dimension only shall be specified.

If the thermometer is intended to be read with normal or corrected eyesight but without (or with comparatively simple) optical equipment, this minimum scale length should be specified so as to obtain a distance between the centres of consecutive scale lines of preferably not less than 0,8 mm for solid-stem thermometers and 0,6 mm for enclosed-scale thermometers.

NOTE – This latter distance is smaller owing to the smaller parallax error which is likely with this type of thermometer.

8.9.6 *Depth of immersion* (if required)

To be measured from the bottom of the bulb.

8.9.7 *Diameter of stem or sheath*

The maximum and minimum dimensions shall be specified.

8.9.8 *External diameter of bulb*

The minimum dimension only shall be specified. It shall also be specified that the diameter of the bulb shall not exceed that of the rest of the thermometer, except in cases where this is necessary for special reasons.

9 MARKING

9.1 Scale lines and figuring (see figures 4 and 5)

The scheme of graduation and figuring shall be stated in the individual specifications for thermometers.

9.1.1 One of the following three patterns of graduation shall be selected.

9.1.1.1 On thermometers where the smallest scale division is 1 °C (or a decimal multiple or sub-multiple thereof) :

a) every tenth scale line is a long line;

b) there is a medium line midway between two consecutive long lines;

c) there are four short lines between consecutive medium and long lines.

9.1.1.2 On thermometers where the smallest scale division is 2 °C (or a decimal sub-multiple thereof) :

a) every fifth scale line is a long line;

b) there are four short lines equally spaced between two consecutive long lines.

9.1.1.3 On thermometers where the smallest scale division is 5 °C (or a decimal sub-multiple thereof) :

a) every tenth scale line is a long line;

b) there are four medium lines equally spaced between two consecutive long lines;

c) there is one short line between two consecutive medium lines or between consecutive medium and long lines.

9.1.2 Every tenth scale line shall be figured.

Thus, in the case of a smallest scale division of

0,01 °C, the series of figures shall be : 0,1 – 0,2 – 0,3 – etc.

0,1 °C, the series of figures shall be : 1 – 2 – 3 – etc.

1 °C, the series of figures shall be : 10 – 20 – 30 – etc.

0,02 °C, the series of figures shall be : 0,2 – 0,4 – 0,6 – etc.

0,2 °C, the series of figures shall be : 2 – 4 – 6 – etc.

2 °C, the series of figures shall be : 20 – 40 – 60 – etc.

0,05 °C, the series of figures shall be : 0,5 – 1,0 – 1,5 – etc.

0,5 °C, the series of figures shall be : 5 – 10 – 15 – etc.

5 °C, the series of figures shall be : 50 – 100 – 150 – etc.

Scale lines at 0 °C or 10 °C or 100 °C may be emphasized (for example, by full figuring if either the first or first and second digits are omitted at intermediate scale lines).

9.1.3 The scale lines shall be clearly and durably marked and of a uniform thickness, which shall not exceed one-fifth of the interval between the centres of consecutive lines. In practice this may be specified as a dimension calculated as one-fifth of the specified minimum graduation interval. The lines shall be at right angles to the axis of the thermometer.

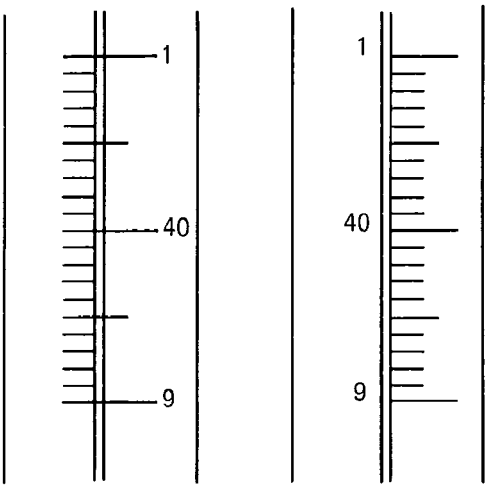
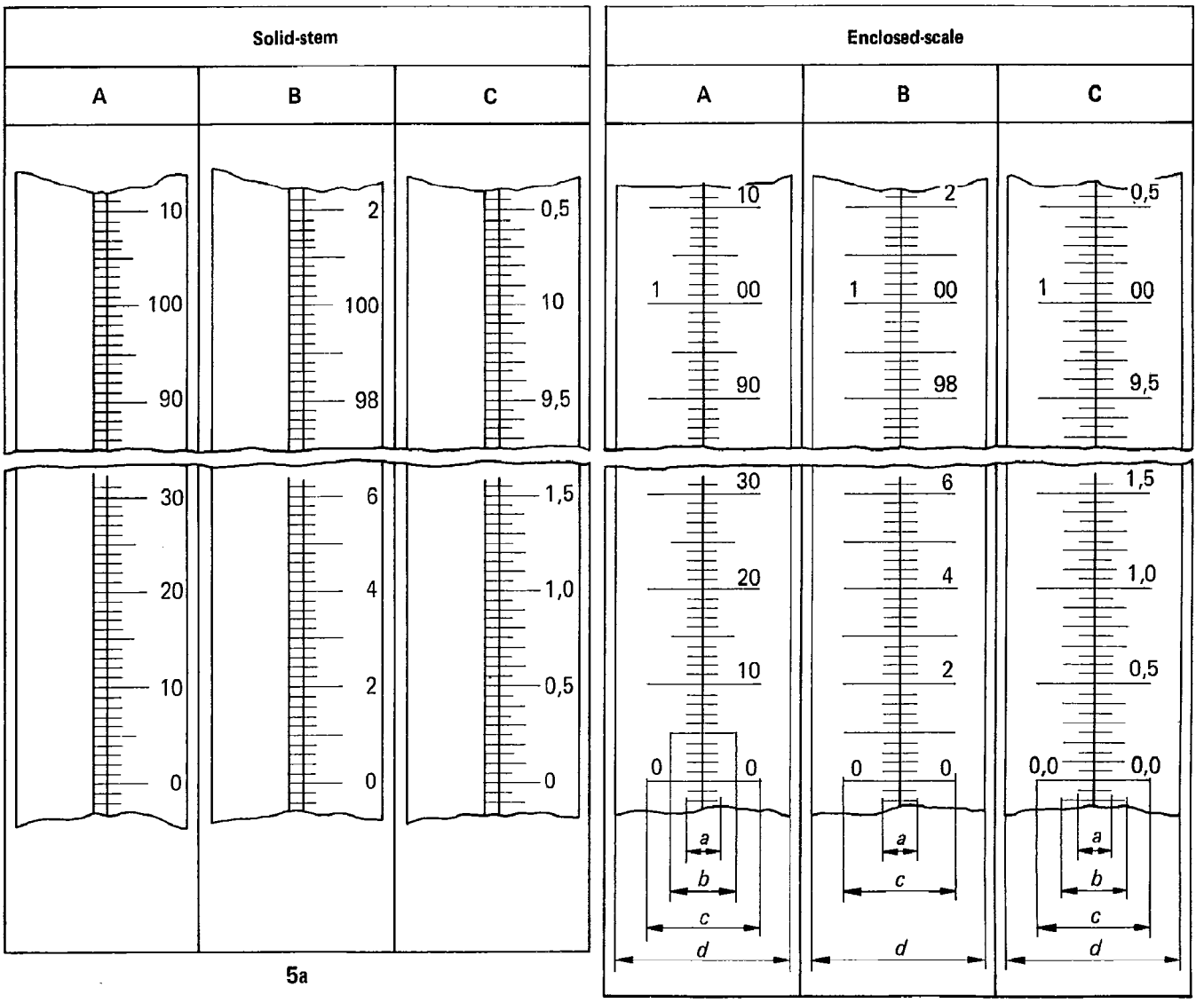


FIGURE 4 – **Examples of positioning of scale lines and figuring for solid-stem thermometers**

9.1.4 For solid-stem thermometers, when the thermometer is held in a vertical position and viewed from the front, the left-hand ends of all the scale lines shall lie on an imaginary vertical line. When the thermometer is viewed so that the right-hand ends of the shortest scale lines align with the left-hand side of the bore, the medium and longer lines referred to in 9.1.1 shall extend across the bore towards the right. (See figure 4.)

The figures should be placed either slightly to the left or to the right of the line to which they refer, as preferred, in such a way that an extension of the line would bisect them or pass immediately under them. The figures may be placed either parallel to, or at right angles to, the axis of the thermometer, as preferred. For solid-stem thermometers (see figure 5a) the length of the shortest scale lines shall be between one and three times the graduation interval, and the longer lines shall be suitably extended.



5a

5b

Graduation type A : smallest scale division 0,01 — 0,1 — 1 or 10 °C (1 °C shown)

Graduation type B : smallest scale division 0,02 — 0,2 or 2 °C (0,2 °C shown)

Graduation type C : smallest scale division 0,05 — 0,5 or 5 °C (0,05 °C shown)

$a = 0{,}3\ c$; $b = 0{,}6\ c$; $c \geqslant 0{,}8\ d$

FIGURE 5 — **Examples of scale lines and figuring**

9.1.5 For enclosed-scale thermometers (see figure 5b) the longest lines shall extend across not less than 0,8 of the width of the strip bearing the scale, and the lengths of the medium and short lines should preferably be approximately 0,6 and 0,3 (respectively) times the length of the longest lines. All lines shall extend equally on both sides of the bore when the thermometer is held in a vertical position and viewed from the front. The figures shall be placed immediately above the line to which they refer.

9.1.6 Each end of the scale shall be extended by a specified number of divisions beyond the nominal limits of the scale.

9.1.7 If appropriate, an auxiliary scale, centring around a reference point (for example 0 °C, 100 °C etc.) and consisting of a specified number of divisions above and below the reference point, shall be provided in order to allow changes in the volume of the bulb to be measured.

9.1.8 All negative numbers should be indicated by minus signs, for example – 5 or $\bar{5}$ as preferred, so placed that they are not liable to be confused with the scale lines, datum line or other marking.

9.2 Immersion line

9.2.1 *Solid-stem thermometers*

A line may be etched or otherwise permanently marked on the stem of partial immersion thermometers at the point to which the thermometer is intended to be immersed. (In general a tolerance of ± 1 mm is considered satisfactory.) If the immersion point is below the lowest scale line, the immersion line shall be a ring carried completely round the stem. If the immersion line is above the lowest scale line, the immersion line shall be confined to the back of the stem.

9.2.2 *Enclosed-scale thermometers*

An immersion line may be etched or otherwise permanently marked on the back of the strip bearing the scale (see also 11.2 b).

9.3 Datum line

On enclosed-scale thermometers, if the strip bearing the scale is not fused to the top of the thermometer, an indelible datum line of thickness comparable with that of the scale lines shall be placed on the right-hand side of the sheath on a level with the lowest (or lowest figured) scale line so that any displacement of the scale can easily be noticed.

9.4 Pigment filling

In the case of etched scales, the pigment filling shall remain in the scale lines, figures and inscriptions under normal conditions of use and under such other special conditions as may be specified between purchaser and vendor or manufacturer.

10 ACCURACY

10.1 Instrument error

The maximum permissible instrument error shall be specified and should not be more than one scale division when the thermometer is in a vertical position and at the prevailing atmospheric pressure under the conditions of immersion and average emergent liquid column temperature specified for use.

NOTE – For thermometers having scale divisions of 0,01, 0,02 or 0,05 °C or indicating temperatures above 300 °C or below −38 °C a larger error is permitted and should be specified.

10.2 Interval error

The maximum permissible difference between the instrument errors in a stated interval shall be specified as not more than x times one scale division under the conditions of immersion and average emergent liquid column temperature specified for use.

10.3 Change in zero indication

After being subjected, under precisely defined conditions of test (see annex A, clause A.2), to a temperature corresponding to the highest scale reading, the change in the indication corresponding to a temperature of 0 °C or other reference point, measured according to the conditions of test, shall not be greater than that specified in the relevant thermometer specification.

11 INSCRIPTIONS

The following inscriptions, as appropriate, shall be specified to be durably and legibly marked on the thermometer :

11.1 Temperature scale indication

The official symbol "°C"; an abbreviation of the name Celsius (for example "C") is also permitted.

11.2 Immersion

a) If required, for thermometers to be used at total immersion : "total" or suitable abbreviation.

b) For thermometers to be used at partial immersion the depth shall be indicated (for example "100 mm") and if the thermometer is adjusted for a single average temperature of emergent liquid column (see clause 4) this may be marked on the stem or for enclosed-scale thermometers on the back of the strip bearing the scale.

c) For thermometers to be used at complete immersion : "complete" or suitable abbreviation.

11.3 Gas filling, if required, for example "nitrogen filled", or suitable abbreviation.

11.4 Bulb glass

The glass from which the bulb is made should preferably be identified by means of a coloured stripe or stripes, or by an inscription on the thermometer.

11.5 Manufacturer's identification or serial number (where required)

11.6 Vendor's and/or maker's name or readily identifiable mark

11.7 Specification number

11.8 Schedule or designation number as in the relevant specification (see 11.7).

ANNEX A

GENERAL RECOMMENDATIONS FOR THE CALIBRATION AND VERIFICATION OF THERMOMETERS

A.1 STANDARDS

All thermometers should be calibrated or verified with reference to thermometers or other temperature-measuring devices which have themselves been calibrated in terms of the IPTS. (See clause 3.) For the most precise work, direct reference to a standard platinum resistance thermometer complying with and calibrated in accordance with the recommendations and requirements of the IPTS is desirable. For less accurate work liquid-in-glass thermometers or other secondary standards for temperature measurement may be used. Such secondary standards should be calibrated by a suitably equipped laboratory providing traceability to the IPTS.

A.2 METHOD OF DETERMINING CHANGE IN ZERO INDICATION

Heat the thermometer immersed in a test bath to the specified immersion level to a temperature equal to its highest reading and keep it at this temperature for 5 min. Allow the thermometer to cool either naturally in still air or slowly in the test bath (at a reproducible rate) to 20 °C above ambient temperature or to 50 °C, whichever is the lower, and then determine the zero. If natural cooling is used the zero should be determined within one hour. Heat the thermometer again to a temperature equal to its highest reading, keep it at this temperature for 24 h, allow the thermometer to cool to one of the two temperatures referred to above, at the same rate as at the start of the test, and redetermine the zero under the same conditions as before.

NOTE – This test is appropriate to thermometers having an upper nominal limit of scale above 100 °C.

A.3 CHOICE OF CALIBRATION POINTS

Experience with a particular type of thermometer provides the most reliable guide to the choice of points, but as a rough guide five calibration points or points at every 100 scale divisions covering at least 80 % of the range of the thermometer should give an assessment of the instrument.

When the highest accuracy or least uncertainty is required, points at each 50 scale divisions at and between the manufacturer's pointing marks should be included.

A.4 TOTAL IMMERSION THERMOMETERS

Thermometers should preferably be calibrated according to the conditions of immersion specified for the instrument (see clause 4). In practice, however, this may not be possible because of limitations imposed by the calibrating equipment and may also not be convenient (for example when calibrating a number of similar thermometers). In either of these circumstances the use of an alternative immersion condition, requiring the application of a correction to the indication of the thermometer, may be used. For practical considerations, see annex B.

A.5 PARTIAL IMMERSION THERMOMETERS

Partial immersion thermometers should be calibrated under conditions which reproduce as nearly as possible the specified conditions. A correction should be made for the difference between the actual and the prescribed temperature of the emergent liquid column (see annex B, clauses B.6 and B.7).[1)]

1) Information relating to methods for the calibration of thermometers can be found in the following publications :

Australia	*Techniques of calibration of liquid-in-glass thermometers.* (Published by National Measurement Laboratory, CSIRO, Chippendale, 2008, Australia.)
Germany	Physikalisch – Technische Bundesanstalt. *Prüfregeln, Flussigkeits – Glasthermometer.* (Published by Deutscher Eichverlag GmbH Braunschweig.)
India	Indian Standard IS 6274 : 1971 – *Methods of calibrating liquid-in-glass thermometers.* (Published by the Indian Standards Institution, New Delhi.)
United Kingdom	British Standard BS 1041 : *Code for temperature measurement.* Section 2.1 : 1969 – *Liquid-in-glass expansion thermometers.* (Published by the British Standards Institution.)
	National Physical Laboratory (N.P.L., Department of Industry) *The calibration of thermometers*, C.R. Barber. (Published by Her Majesty's Stationery Office.)
U.S.A.	American National Standard Z 104.1 (ASTM E-77), *Standard method for verification and calibration of liquid-in-glass thermometers.* (Published by the American Society for Testing and Materials.)
	National Bureau of Standards (NBS), *Calibration of liquid-in-glass thermometers.* (Published by the National Bureau of Standards, United States Department of Commerce.)
	National Research Council, *International critical tables* 1926, Vol. 1, p. 56. (Published by McGraw Hill, New York.)

ANNEX B

GENERAL RECOMMENDATIONS FOR THE USE OF THERMOMETERS

B.1 Before use, a thermometer should be examined for visible defects such as flaws in the bulb glass or stem, detached liquid in the expansion chamber, gas trapped in the bulb, or a divided liquid column. Where possible, faulty thermometers must be rectified before use, but usually a flawed thermometer should be discarded.

B.2 Total immersion thermometers should normally be used immersed up to the end of the liquid column (see 4.2) except for a minimum length of emergent liquid column (for example one or two scale divisions) to enable the reading to be taken.

B.3 When the use of a thermometer requires it to be kept at an elevated temperature (for example above 100 °C) for a long time, the liquid filling may tend to distil into the capillary tube and/or expansion chamber. Ideally, the thermometer should be used under the same conditions as those obtaining during calibration. If this is not possible, steps should be taken to reduce the distillation, otherwise the indication will be in error.

It may be convenient to withdraw the thermometer so that a small length of liquid column (at least 10 mm) emerges above the medium. A correction is then required and may be made in the same manner as for partial immersion conditions (see B.7 and B.8).

B.4 When it is necessary to use a total immersion thermometer partially immersed or a partial immersion thermometer totally immersed, a correction should be made for the temperature of the liquid column being different from that which is appropriate to the specified immersion condition. The correction to the indication, c_1, (which is estimated to be valid to ± 10 %) should be evaluated from the formula :

$$c_1 = k\,N\,(t_1 - t)$$

where

k is the apparent thermal expansion coefficient of the liquid in the particular type of glass from which the stem is made (see table); for the purposes of evaluation, the value of k may be considered as depending on the arithmetic mean of t_1 and t;

N is the number of degrees Celsius equivalent to the length of the emergent liquid column, and is the difference between the thermometer indication and the actual or extrapolated scale value corresponding to the specified immersion level;

t is the average temperature of the liquid column when in the emergent condition;

t_1 is the temperature of the thermometer bulb.

If this procedure results in large corrections, a second evaluation should be made using the indication corrected according to the first evaluation.

When total immersion thermometers are partially immersed, the correction c_1 is added to the indication of the thermometer when the mean emergent liquid column temperature is lower than the bulb temperature and subtracted when it is higher.

When partial immersion thermometers are totally immersed, the correction c_1 is subtracted from the indication of the thermometer when the mean emergent liquid column temperature is higher than ambient temperature of the emergent liquid column and added when it is lower.

B.5 When it is necessary to use a total immersion thermometer at complete immersion, allowance should be made for the effect on the indication due to a change of internal pressure caused by the temperature of the expansion chamber being different from ambient. Allowance should also be made for the effect of external pressure on the bulb being greater at the deeper immersion in the medium the temperature of which is to be measured. The magnitude of these effects is determined by calibration of the thermometer under both total and complete immersion conditions.

B.6 Partial immersion thermometers should be restricted to apparatus for which they are specifically designed, or where the average temperature of the emergent liquid column will not be significantly different from that specified. If such a difference exists, a correction to the indication should be made (see B.7).

TABLE – Values of k, the apparent thermal expansion coefficient of thermometric liquids in glass

Mean temperature $\frac{1}{2}(t_1 + t)$	Apparent thermal expansion coefficient, k, 10^{-4} (°C)$^{-1}$				
	Borosilicate glass	Other glasses			
	Mercury	Pentane	Toluene	Ethanol	Mercury
– 180		9,0			
– 120		10,0			
– 80		10,0	9,0	10,4	
– 40		12,0	10,0	10,4	
0	1,64	14,0	10,0	10,4	1,58
20		15,0	11,0	10,4	
100	1,64				1,58
200	1,67				1,59
300	1,74				1,64
400	1,82				
500	1,95				

B.7 When partial immersion thermometers are used at the prescribed depth in the medium, there may be a difference between the actual and the specified temperature of the emergent liquid column. In this case a correction to the indication, c_2, (which is estimated to be valid to ± 10 %) should be evaluated from the formula :

$$c_2 = k\,N\,(t_s - t_f)$$

where

k and N are as defined in B.4;

t_s is the average emergent liquid column temperature specified;

t_f is the average emergent liquid column temperature in use or during calibration.

Typical values of k [unit 10^{-4} (°C)$^{-1}$] which for most purposes will give sufficiently accurate corrections are as follows :

Mercury and mercury-thallium alloy : 1,6

Ethanol : 10,4

Toluene : 10,3

Pentane : 14,5

B.8 The temperature of the emergent liquid column is usually measured by one of the methods described in the following paragraphs :

B.8.1 Preferably by means of "faden" thermometers specially designed for this purpose. A faden thermometer is one with an extended bulb. They are produced in sets so that one may be selected having a bulb length at least 10 mm longer than the emergent liquid column so that it may also be immersed in the medium.

B.8.2 If the emergent liquid column is short (for example less than 100 mm) an auxiliary thermometer is placed adjacent to the thermometer to be corrected with the bottom of the bulb of the auxiliary thermometer at half the height of the emergent liquid column. In the case of a long emergent liquid column, several auxiliary thermometers should be used with the bottom of the bulb of the first of these thermometers at a distance of 10 mm from the point of emergence and the others evenly spaced along the length of the exposed column at intervals not exceeding 100 mm.

B.8.3 By means of thermocouples attached to the stem along the emergent liquid column in conjunction with a suitable potentiometer.