General Accreditation Guidance

Liquid-in-glass thermometers - selection and use

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Liquid-in-glass thermometers - selection and use

Purpose

This document provides guidance for selecting liquid-in-glass thermometers, their use, the rectification of faults, and the comparison of working thermometers against calibrated reference thermometers using ice-point checks and single point checks at the temperature of use.

Construction and behaviour of thermometers

A liquid-in-glass thermometer consists of a thin glass bulb at the bottom of a thick glass stem, containing a column of liquid within, a fine uniform bore capillary, with one or more expansion chambers at the top of the stem. There may also be a contraction chamber between the bulb and the zero mark or at the beginning of the graduated scale. The liquid filling may be mercury or a suitable thermometric liquid such as ethanol or toluene coloured with a non-staining light-fast dye.

The glass in a thermometer, when first made, may be in a highly stressed state. This stress slowly relaxes with time, causing the bulb to contract, rapidly at first but decreasing with time.

This continuous, irreversible change is called the ‘secular change’ and should be monitored by checking the reading of a working thermometer at the ice-point or at a designated (reference) point in the working temperature range, every six months. Since the secular change is due to contraction of the bulb, its effect is to raise the reading of the thermometer, and a correction is applied to the thermometer readings to determine the true temperatures.

Thus, in addition to the correction from the calibration report, a further correction due to the secular change is to be equally applied to readings at all points of the scale.

If a wide range liquid-in-glass thermometer is heated to near its maximum temperature and then reduced to ambient temperature, a temporary depression of the reading of the ice-point/reference point will be caused through bulb expansion, which may take several days to weeks to fully recover.

Mercury-in-glass thermometers can be used over the range –38°C to 450°C. Mercury has a large coefficient of thermal expansion which is uniform over this range and it forms a well-shaped meniscus in a fine bore glass tube. Special thermometers containing a thallium/mercury alloy permit measurements to be made down to –50°C.

Temperatures below –38°C can be measured using alcohol or toluene thermometers, which cover the ranges –80°C to 75°C and –80°C to 110°C respectively, partial immersion thermometers are not recommended in this range due to the likely high variation of temperature in the emergent portion of the stem. Since the liquid wets glass, such thermometers should not be cooled too quickly as this may cause drainage problems. Warming too quickly can lead to the formation of gas bubbles.

Thermometer calibration and checking schedule

It is recommended reference thermometers be checked at the ice point at six-monthly intervals after their initial calibration. Working thermometers used only at a single temperature or over a narrow range (5 °C) should be checked at a single point at six-monthly intervals. The single point may be the ice point or the temperature of use. Working thermometers used over a wide range (>5 °C) should be checked at two points or more within the range of use at six-monthly intervals. The number of points will depend on the range of use.

For reference thermometers, it is recommended to repeat the entire scale calibration at ten-yearly intervals. For working thermometers it is recommended to repeat an entire scale calibration at five-yearly intervals.

Inspection and repair

Before carrying out checks on the calibration status, each thermometer should be carefully examined for defects such as bubbles of gas trapped in the bulb, breaks in the liquid column, oxidised mercury, uneven graduations and faded markings.

Gas inclusions may be removed and broken liquid columns re-joined by carefully cooling the bulb of the thermometer in a mixture of ice and ethanol, dry ice and ethanol, or liquid nitrogen, depending upon the temperature range of the thermometer. This will draw all the liquid into the bulb and allow the gas inclusion to be expelled, or the broken thread to be re-joined. Cooling too rapidly may freeze the liquid and break the bulb and should be avoided. Gently tap the thermometer may help if the broken thread sticks in the bore. Spirit left in the expansion chamber or near the top of the thermometer can be distilled off by gently heating the stem.

Selection for precision and general use

The choice of a thermometer is determined by the range of temperature measurements to be made and by the required uncertainty of measurement.

In general, the uncertainty of calibration of a reference thermometer should be 1/5th of the uncertainty of calibration required of the working thermometer. The reference thermometer should have scale divisions equal to, or less than, the uncertainty required of the working thermometer. For most purposes, a thermometer with a scale marked in divisions of 0.1°C or 0.2°C is suitable as a reference thermometer.

When selecting any thermometer for use, it should comply with a relevant standard, for example, *ISO 1770:1981*: *Solid-stem general purpose thermometers*

New thermometers should also be examined to ensure that the glass is free of strain/flaws which could break the thermometer or distort the reading, uneven divisions and faults in markings and that the bore and expansion chambers are free from oxidised mercury and impurities/deposits.

It is recommended mercury thermometers not be used. *ASTM D8055: ASTM Standard Guide for Selecting an Appropriate Electronic Thermometer for Replacing Mercury Thermometers in D04 Road Paving Standards* may be useful for facilities looking to replace their mercury thermometers.

Selection of a total or partial immersion thermometer

The choice of liquid-in-glass thermometer is dependent upon the working environment in which the temperature is to be measured and the accuracy required.

Total and partial immersion thermometers are differentiated by the length of stem that is immersed in the fluid of interest. Total immersion thermometers are to be immersed to the top of the liquid column. Partial immersion thermometers are to be immersed in the fluid to the specified immersion depth. This depth is indicated by a line or distance (measured from the base of the bulb) marked on the stem; typically 76 mm (3 inches). The remainder of the stem (the emergent stem) is exposed to ambient air. Partial immersion thermometers are best for general use due to the systematic error related to the length of column exposed to different air temperatures For precision use, it is better to use a total immersion thermometer..

For example, if it is required to measure the temperature of ambient air in a room or a heated enclosure with a glass window, or of a deep liquid in a glass container, a total immersion thermometer should be used. It should be fully immersed or placed so that only 1 or 2 divisions of the scale are outside the medium to be measured.

A partial immersion thermometer, immersed to the depth marked on the stem, should be used where the temperature is to be measured within a heated enclosure such as an oven, chamber or metal tank, or in a thermometer pocket, or in any situation where the depth of immersion is limited or where a thermometer cannot be moved.

An error of several degrees can result if a total immersion thermometer is used at partial immersion or if a partial immersion thermometer is used at full immersion.

Ice-point checks

Working thermometers should be checked every six months at the ice-point (0°C) for changes in calibration due to relaxation of the glass. Alternatively, working thermometers can be checked at a designated reference point in the working range against a reference thermometer.

The reference thermometer should be properly conditioned and checked at the ice point/reference point to ascertain any secular change, before being used.

When a thermometer is heated and then cooled to its initial temperature, the bulb does not contract immediately to its original volume. It is therefore important that the thermometer be conditioned by the same method before any determination of the secular change.

When the thermometer is to be relied upon to within an uncertainty of 0.02°C, the reference temperature should be read as precisely as possible. The temperature of a carefully prepared ice-point is reproducible to better than 0.01°C and, by following the procedure given below, it is possible under optimum conditions to determine the thermometer reading at the ice point to within 0.003°C.

Procedure

The ice-point apparatus consists of a thermally-insulated container such as a Dewar flask or other container up to about 25 cm deep and provided with a means of supporting the thermometer vertically. The thermometer scales should be observed through a 5X magnification viewer which can be adjusted to avoid parallax error.

1) Wash the thermometer with de-ionised or distilled water and store at 0°C for several hours before taking readings at the ice point.

2) Prepare a mixture of distilled water and finely crushed ice made from distilled water. Mix the ice with a small amount of distilled water until it no longer appears opaque. Place it in the insulated container, stirring thoroughly and draining if necessary until there is no free water.

3) Immerse the thermometer to the appropriate depth for 5 minutes to precool it. Remove and relocate the thermometer to another part of the ice bath and allow stabilisation for a further 5 minutes. Fully immerse the thermometer in the ice mixture to above the liquid-column for a total immersion thermometer and to the immersion line or marked depth for a partial immersion thermometer. Before taking a reading, lift the thermometer until the column is just visible through the viewer.

4) All thermometers should then be raised a few centimetres and quickly lowered to the reading position (gently dumped). Repeat this operation two or three times, or until there is no change in the reading. Wipe the thermometer stem with absorbent paper to remove condensation, if necessary, and take a reading.

   Note: The purpose of this procedure is to avoid the tendency for the liquid-to stick in the capillary bore. The magnitude of this effect is unpredictable and may amount to as much as a whole scale division.

5) Keep a record of all ice-point readings obtained during the life of the thermometer so that any anomalies may be detected.

Comparison of working thermometers with a reference thermometer

General procedures

The reference and working total thermometers should be supported side-by-side in a temperature-controlled bath in such a manner that they may be easily and safely raised and lowered to the correct immersion depth.

When the thermometers are to be compared at a particular temperature, then two sets of readings should be taken, each within a few minor divisions below and above the required check temperature and the two sets of readings averaged to find the correction to be applied to the readings of the working thermometer at the specified temperature. Note that this is usually done in a bath with slowly rising temperature. If this facility is not available, the bath to use is to be allowed to stabilise at the test point, then the thermometer gently dumped to avoid sticking of the liquid to the capillary before the reading of the thermometer is taken.

An example of the checking procedure is given below, including sample readings and the steps involved in calculating the corrections and readability.

Correction of partial immersion thermometers

When a thermometer is used at partial immersion, the temperature of the emergent liquid–in–glass column may be different from that at the time of calibration. For this reason, the mean temperature of the emergent column should be measured and a correction applied to adjust the reading of the thermometer to the conditions at the time of calibration.

The procedure for calculating the emergent stem correction is detailed in *NMI Monograph 9: Liquid-in-Glass Thermometry.*

Example

To check a thermometer at the 40.0°C mark:

First check the calibration at 39.9°C.

Thermometer	Reference (°C)	Working (°C)
Reading 1	39.88	39.8
Reading 2	39.92	40.0
Averages	39.90	39.9
Reference correction from calibration certificate	+0.02	
Corrected reference temperature (1)	39.92	
Subtract average bath temperature from average working thermometer reading to obtain error in working thermometer		(-39.92) -0.02
Correction (1) to working thermometer (change sign)		+0.02

Then check the calibration at 40.1°C.

Thermometer	Reference (°C)	Working (°C)
Reading 1	40.08	40.1
Reading 2	40.16	40.2
Averages	40.12	40.15
Reference correction from calibration certificate	+0.02	
Corrected reference temperature (2)	40.14	
Subtract average temperature from average working thermometer reading to obtain error in working thermometer		(-40.14) +0.01
Correction (2) to working thermometer (change sign)		-0.01
Average of correction (1) and (2) to working thermometer at 40°C		+0.02
Round to 0.02°C, the readability of the thermometer		0.00

Note: Working thermometers may alternatively be checked against a calibrated platinum resistance thermometer.

References

This section lists publications referenced in this document. The year of publication is not included as it is expected that only current versions of the references shall be used.

ASTM D8055	ASTM Standard Guide for Selecting an Appropriate Electronic Thermometer for Replacing Mercury Thermometers in D04 Road Paving Standards
ISO 1770	Solid-stem general purpose thermometers.
NMI Monograph 9:	Liquid-in-Glass Thermometry, Corinna Horrigan and Robin E. Bentley

Amendment table

The table below provides a summary of changes made to the document with this issue.

Section or Clause	Amendment
Whole document	Editorial revised.