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Liquid-in-glass thermometers — selection, use and calibration



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Liquid-in-glass thermometers — selection, use and calibration

1. Introduction

This Technical Note describes procedures for selecting liquid-in-glass thermometers, their use, the rectification of faults, and the comparison of working thermometers against calibrated reference thermometers via ice-point checks and single point checks at the temperature of use.

2. Construction and behaviour of thermometers

A liquid-in-glass thermometer consists of a bulb, a fine uniform bore capillary and one or more expansion chambers at the top of the column. There may also be an expansion 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 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 one point in working 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 must be applied to the thermometer readings to determine the true temperatures.

This correction will apply equally to readings at all points of the scale and for reference thermometers it is only necessary to repeat the entire scale calibration at ten-yearly intervals. For working thermometers it is necessary to repeat an entire scale calibration at five-yearly intervals.

If a wide range mercury-in-glass thermometer is heated to its maximum temperature and then reduced to ambient temperature, a temporary depression of the ice-point will be caused through bulb expansion which may take several days to 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. Since the liquids wet glass, such thermometers should not be warmed too quickly as this may cause the formation of gas bubbles. Cooling too quickly can lead to drainage problems.

3. Thermometer calibration schedule

NATA criteria for the calibration and checking of liquid-in-glass thermometers are specified in the NATA Accreditation Criteria.

4. Inspection and repair

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

Gas inclusions may be removed and broken liquid columns rejoined by carefully cooling the bulb of the thermometer in a mixture of ice and methanol, dry ice and methanol, 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 rejoined. Cooling too rapidly may freeze the liquid and break the bulb, and should be avoided. Gently tap the thermometer 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.

5. Types of thermometer

Types of thermometers	Temperature range (°C)	Smallest division (°C)	Expected accuracy (°C)
Laboratory Precision*	–40 to 100	0.1	0.05
	–25 to 100	0.2	0.1
	–5 to 50	0.1	0.02
	–5 to 105	0.2	0.1
	–35 to 30	0.2	0.1
General Purpose	–80 to 30	1.0	1.0
	–20 to 60	1.0	0.5
	–10 to 50	0.5	0.3
	–10 to 110	1.0	0.5
	–10 to 250	1.0	1.0
	–10 to 360	2.0	2.0
Industrial	–38 to 27	1.0	0.5
	–10 to 250	1.0	
	–90 to 260	2.0	
Special Types:			
Maximum reading	0 to 200	2.0	
Max/Min reading	–30 to 50	1.0	
Soil	0 to 115	1.0	
Gas Main	0 to 60	1.0	
Dairy	–10 to 110	1.0	

*Those listed as laboratory precision thermometers are suitable for use as reference thermometers for calibrating working thermometers.

6. Selection of thermometers for precision and general use

The choice of a reference 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 of measurement required of the working thermometer. For most purposes, a thermometer with a scale marked in divisions of 0.1° or 0.2° is suitable as a reference thermometer.

When selecting any thermometer for use, it should be checked for compliance with the relevant Australian Standard or other standard, for example:

AS 1006—1995: *Solid-stem general purpose thermometers*

It should also be examined to ensure that the glass is free of flaws which could distort the reading and that the bore and expansion chambers are free from oxidised deposits.

6.1 Selection of a total or partial immersion thermometer

The choice of a total or partial immersion thermometer is dependent upon the working environment in which the temperature is to be measured.

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 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.

7. 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 one point in working range against a reference temperature measuring device).

The reference thermometer should be properly conditioned and checked at ice 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 complete calibration of a 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 0.001°C and, by following the method given below, it is possible under optimum conditions to determine the thermometer reading at the ice point to within 0.003°C.

7.1 Ice-point check to an uncertainty of less than 0.02°C

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

- 7.1.1. Wash the thermometer with distilled water and store at 0°C for several hours before taking readings at the ice point.
- 7.1.2. Prepare a mixture of distilled water and finely crushed ice made from distilled water. Mix it until it no longer appears opaque. Place it in the insulated container, stirring thoroughly and draining if necessary until there is no free water.
- 7.1.3. Fully immerse the thermometer in the ice mixture to above the mercury column. Before taking a reading, lift the thermometer until the mercury is just visible through the viewer. It should then be raised a few centimetres and quickly lowered to the reading position.
- 7.1.4. Repeat this operation two or three times, or until there is no change in the reading. Wipe the thermometer stem with absorbent paper and take a reading.

Note: The purpose of this procedure is to avoid the tendency for the mercury to stick in the capillary bore. The magnitude of this effect is unpredictable and may amount to as much as a whole scale division.
- 7.1.5. Keep a record of all ice-point readings obtained during the life of the thermometer so that any anomalies may be detected.

8. Comparison of working thermometers with a reference thermometer

8.1 General procedures

The reference and working total immersion thermometers should be supported side-by-side in a temperature-controlled bath in such a manner that they may be easily raised and lowered. The bath must be allowed to stabilise at the temperature at which the readings of the thermometers are to be compared.

If the thermometers are to be compared at a particular temperature, then two sets of readings should be taken, on either side of the required 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.

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

8.2 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 must 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*, by Corinna Horrigan and Robin E. Bentley.

Example

To check a thermometer at the 40.0°C mark.

Firstly, 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
Note: If the working thermometer is only being checked at one point then only one set of readings is required. If the thermometer is being subjected to an initial check before being put into service then readings should be taken at approximately ten degree intervals along its scale.		

Secondly, 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		+0.005
Round to 0.1°C, the readability of the thermometer		0.0
Note: Working thermometers may alternatively be checked against a calibrated platinum resistance thermometer.		

9. References

AS 1006—1995: *Solid-stem general purpose thermometers*.

NMI Monograph 9 *Liquid-in-Glass Thermometry*, by Corinna Horrigan and Robin E. Bentley

AMENDMENT TABLE

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

Section	Amendment
Cover page	Removal of “Be Absolutely Assured” tagline.