ITTC Quality System Manual

Sample Work Instructions

Work Instructions

Calibration of a Liquid-in-Glass Thermometer

7.6 Control of Inspection, Measuring and Test Equipment

7.6-02 Sample Work Instructions

7.6-02-11 Calibration of a Liquid-in-Glass Thermometer

Updated / Edited by	Approved
Quality Systems Group of the 28th ITTC	23rd ITTC 2002
Date: 01/2017	Date

Table of Contents

Source:

Verification regulation of liquid-in-glass thermometers for working

[Issued on Dec.13, 1984 and put into effect since Oct. 1, 1985 by National Technical Bureau - **JJG 130—1984, National Measuring Verification Regulation of People's Republic of China**]

Calibration of a Liquid-in-Glass Thermometer

1. PURPOSE

This work instruction can be applied to the verification of new and for the calibration of liquid-in-glass thermometers, with the measuring range of –100~+600°Cfor industrial and laboratory use in service. It cannot be applied to the calibration of the special thermometers such as meteorological thermometers. etc.

2. INTRODUCTION

Liquid–in-glass thermometers (hereinafter referred to as thermometers) measure the temperature by use of the thermal expansion of a temperature-sensitive liquid in a transparent glass bulb and a capillary tube. Its construction is shown in the Figure 1.

1. temperature-sensitive bulb;
2. temperature-sensing liquid;
3. middle bulb;
4. sub-scale mark;
5. main scale mark;
6. capillary tube;
7. safety bulb

Thermometers may be divided into the precision thermometers and ordinary, ones on the basis of the scale division value and the measuring range, shown in Table 1.

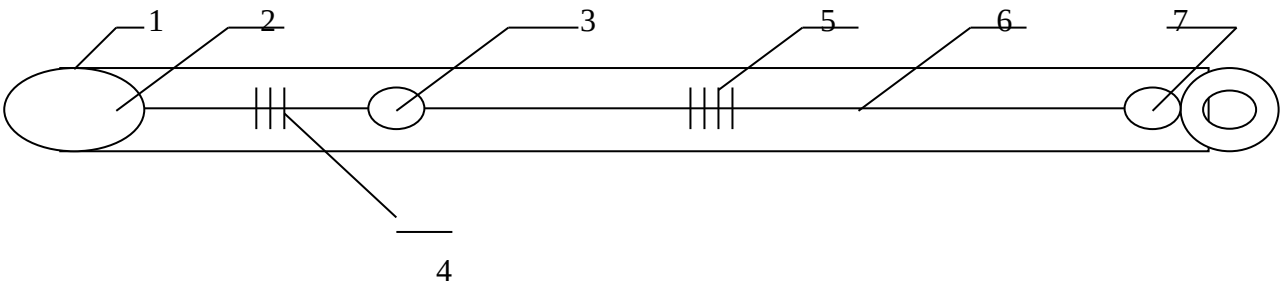

Fig 1. Liquid-in-Glass Thermometer

Table 1 (°C)

Name	Precision thermometer		Ordinary thermometer	
Scale division value	0.1, 0.2	0.5, 1.0	0.5, 1.0	2.0, 5.0
Measuring range	-60～+300	+300～+500	-100～+300	-30～+600

3. TECHNICAL REQUIREMENTS

3.1 Glass

The glass must be bright, clean and transparent without any crack or fault, such as internal stress, which affects its strength and without any fault, which affects the reading in the area of the scales.

The thermometer must be straight with well-distributed thickness and without any obvious curvature.

The capillary tube should be straight with constant diameter. The liquid column should have the maximum breadth when the observation side of the thermometer is observed. The connection between the capillary tube and the temperature-sensitive bulb, middle bulb, safety bulb should be circular arc shape without any necking phenomenon. Inside the tube should be clean, without any impurity.

An opal glaze or other colour must be behind the scale mark of the bar-type thermometer. The colour glaze must always be located at the back of the liquid column aligned at the left or the right edge of the scale mark. Thermometers with the upper limit temperature over 300°C are allowed without colour glaze.

The enclosed scale thermometer should be clean inside the capillary tube, without any impurity or other obscure phenomena which affect the reading.

3.2 Temperature-sensitive liquid and liquid column

The mercury or mercury-based alloy must be pure, without any gas bubbles. The liquid column of an organic liquid must appear clear without any sediment.

The liquid column must **not** be discontinuous, flow back (except vacuum), have an obvious halting motion during its rising or have any liquid drops or colour remaining on its tube wall following its descent.

3.3 Scale Marks and Signature

The lines of the scale mark should be vertical to the centre line of the capillary tube. The scale marks, numbers and other signs should be clear and accurate. The colouring should be solid and durable.

The distance between adjacent scale lines must not be less than:

0.6 mm for the enclosed scale thermometer with the mercury inside;
0.7 mm for the bar-type thermometer;
0.8 mm for the organic liquid thermometer.

The breadth of the lines must not exceed one-fifth of the distance of the adjacent lines.

The expanding lines which are not less than the allowable error of the indication of the thermometer should be marked beyond the upper and lower limit lines of the scale marks. The expanding lines above and under the zero line must

not be less than five for thermometers with zero point lower limit.

The longitudinal displacement of the scale mark panel for the enclosed scale thermometer must not exceed one-third of the minimum scale division value. The capillary tube should be located in the centre of the vertical axis of the scale mark panel without any obvious obliquity. The distance between the capillary tube and the scale mark panel must not exceed 1mm.

Relevant lines should be figured every 10~20 scale lines. The zero point、 the upper and lower limit temperature should be marked with the relevant figures.

The thermometer must be marked with the following signs: "°C" showing the international temperature scale "centigrade", name of the manufacturer or the emblem mark, date and the number of the production, type and the mark of the immersion.

3.4 Temperature-Sensitive, Middle and Safety Bulbs

Temperature-sensitive bulb: The diameter of the temperature-sensitive bulb for the bar-type thermometer mustn't exceed the diameter of the glass bar; That of the enclosed scale thermometer must not exceed the diameter of the lower body capillary tube.

Middle bulb: The distance between the upper edge of the middle bulb and the first scale line of the main scale mark lower edge must not be less than 30mm.

Safety bulb: The top edge of the safety bulb should be half the ball shape. It can hold the liquid volume when the temperature of the sensitive bulb exceeds the upper limit more than 60°C. A thermometer with an upper limit temperature beyond 300°C is allowed without the safety bulb. The length of the capillary tube above the scale line of the upper limit temperature must not be less than 20 mm.

3.5 Stability of Indication

The rising value of the zero point position of the thermometer must not exceed half of the scale division value. (The indication of the upper limit temperature can be measured for the thermometer without zero sub-mark.) The rising value of the zero point position of the thermometers with upper limit temperature beyond 200°C and with scale division values 0.1°C must not exceed one scale division value.

3.6 Permissible Error of Indication

The allowable indication error of the total immersion thermometer should meet the values given in Table 2; that of the part-immersion thermometer should meet the values of Table 3. The maximum allowable indication error should be taken when the measuring range of the thermometer leaps over several temperature ranges as shown in Tables 2 and 3.

Table 2 （°C）

Temperature-sensing liquid	Temperature range of upper and lower limit	Scale division value					
		0.1	0.2	0.5	1.0	2.0	5.0
		Indication allowable error of total immersion thermometer					
Organic liquid	-100～<-60	±1.0	±1.0	±1.5	±2.0	—	—
	-60～<-30	±0.6	±0.8	±1.0	±2.0	—	—
	-30～>＋100	±0.4	±0.5	±0.5	±1.0	—	—
Mercury-base	-60～<-30	±0.3	±0.4	±1.0	±1.0	—	—
Mercury	-30～<＋100	±0.2	±0.3	±0.5	±1.0	±2.0	—
	>100～200	±0.4	±0.4	±1.0	±1.5	±2.0	—
	>200～300	±0.6	±0.6	±1.0	±1.5	±2.0	±5.0
	>300～400	—	±1.0	±1.5	±2.0	±4.0	±10.0
	>400～500	—	±1.2	±2.0	±3.0	±4.0	±10.0
	>500～600	—	—	—	—	±6.0	±10.0

Table 3 （°C）

Temperature-sensing liquid	Temperature range of upper and lower limit	Scale division value			
		0.5	1.0	2.0	5.0
		Indication allowable error of part-immersion thermometer			
Organic liquid	-100～＜-60	±2.0	±2.5	-	-
	-60～＜-30	±1.5	±2.5	-	-
	-30～＋100	±1.0	±1.5	-	-
Mercury	-30～＋100	±1.0	±1.5	±3.0	-
	＞100～200	±1.5	±2.0	±3.0	-
	＞200～300	-	±2.0	±3.0	±7.5
	＞300～400	-	-	±6.0	±12.5
	＞400～500	-	-	±6.0	±12.5
	＞500～600	-	-	±8.0	±15.0

4. CALIBRATION DEVICES

4.1 Calibration Equipment

The following methods and calibration equipment can be selected on the basis of the actual need.

Second grade standard mercury thermometer (-30 ~ +500°C);

Second grade standard mercury-base thermometer (-60 ~ 0°C);

Second grade standard platinum resistance thermometer (-200 ~ +630°C) and the relevant supporting electrical measuring devices;

Standard copper-constantan thermocouple (-200 ~ 0°C) and the relevant supporting electrical measuring devices;

Thermostat (technical requirement is shown in Table 4) and ice trough;

Reading telescope, glass polarized stress gauge, steel sheet ruler and reading glass (5 ~10 times) etc.

Table 4 （°C）

Name of thermostat	Measuring range	For precision thermometer		For ordinary thermometer	
		Working area			
		Maximum temperature difference	Horizontal temperature difference	Maximum temperature difference	Horizontal temperature difference
Alcohol low-temperature trough	-100～-30	0.10	0.05	0.20	0.10
	-30～-0	0.04	0.02	0.10	0.05
Water thermostat	0～95	0.04	0.02	0.10	0.05
Oil thermostat	75～300	0.08	0.04	0.20	0.10
Salt or tin trough	300～600	0.20	0.10	0.40	0.20

Note:

(1) The depth of all the thermostat with cover must make sure that the standard thermometer can be fully immersed for the usage;

(2) The working area of the thermostat means the maximum range that the temperature-sensitive bulb of the standard thermometer and the calibrated ones can reach; the maximum temperature difference points the value between two random positions at the different depths.

5. CALIBRATION METHOD

5.1 Exterior Examination

Newly-produced thermometer: The exterior examination of the thermometer by use of the glass polarized stress gauge and the steel sheet ruler through eyesight should meet items1~ 4 of this work instruction.

Thermometer in use: The thermometer should be checked before calibration to see if there is any crack in the temperature-sensitive bulb and the glass bar or any liquid column stagnation or gas bubbles present. If there are any, they should be corrected before calibration.

5.2 Calibration of Indication Stability

A new thermometer with the upper limit temperature over 100°C should be random-tested. The detailed calibration steps are as follows:

The thermometer should be kept at the upper limit temperature for 15 minutes, then taken out and waited for the natural cooling down to the room temperature. The zero point position should be measured for the first time.

The thermometer should be kept again at the upper limit temperature for 24 hours (precision thermometer) or 48 hours (ordinary thermometer), then taken out and exposed to natural cooling to the room temperature. The zero point position should be measured for the second time. The difference of the second one minus the first one is the rising value of the zero point position that should meet the regulation of the item 5.

The upper limit temperature can be directly measured for the thermometer without the zero point, on the basis of the above-mentioned method. The difference of the front and back measured values, that is the rising value should meet the regulation in item 5.

It must be examined to see whether the mercury has evaporated or any gas bubbles have formed during the measurement of the zero point position and the indication.

5.3 Indication Calibration

The values of the calibrated points: The values for the interval of the calibrated points are shown in Table 5.

The beginning, the end and any middle point of the scale mark should be calibrated when the calibrated points of the thermometer are less than three on the basis of the values in Table 5. The thermometer in service can also be calibrated according to the requirement of the user.

The arbitrary point between two regulated calibration points of a newly-produced thermometer should be randomly calibrated. The allowable error of the indication should meet the values in Tables 2 and 3.

Table 5 （°C）

Scale division value	Interval of calibrated points
0.1	10
0.2	20
0.5	50
1, 2, 5	100

Calibration order: The calibration should be carried out one by one in the direction of the upper or lower limit, from the boundary or zero point respectively.

5.4 Immersion

The exposed liquid column length of the total immersion thermometer must not exceed 15mm. In the special case of part-immersion calibration of the total immersion thermometer, its indication should be modified on the basis of the following formula:

$$\Delta T = KN(T - T_1) \quad (1)$$

Where:

- ΔT the temperature deviation value of the exposed liquid column;
- K the apparent expansion coefficient of the temperature-sensitive liquid (mercury: 0.00016; kerosene: 0.00093)
- N integral number of degrees of the exposed liquid column;
- T_1 average temperature of the exposed liquid column measured by use of the auxiliary thermometer, which should be put at the one quarter position of the lower part of the exposed liquid column and in good contact with the calibrated thermometer;
- T temperature indicated by the calibrated thermometer.

Actual indication = indication of the calibrated thermometer + temperature deviation of the exposed liquid column.

The calibration of the part-immersion thermometer should be carried out at the regulated immersion depth (not less than 75mm). The standard nominal temperature is required to be 25°C.

During calibration for the part-immersion thermometer, if the nominal temperature T_2 of the exposed liquid column does not meet the requirement the correction should be made upon the following formula:

$$\Delta T = KN(25 - T_2) \quad (2)$$

Where: K, N, ΔT are the same as (1).

Actual indication = indication of the calibrated thermometer + temperature deviation of the exposed liquid column.

5.5 Calibration of Zero Point

Acquisition of zero point: Ice made of distilled water or drinking water (note that super cooled ice should be avoided.) should be broken into small pieces and put into the ice trough. After proper distilled or drinking water has been poured into the trough the combination of the ice and the water should be stirred by use of a clean glass rod and tightly pressed until the ice surface looks dark. It should be checked by use of the second grade standard mercury thermometer and used after becoming stable.

For the zero point calibration the thermometer should be inserted vertically inserted into the ice trough. Its distance from the container wall must not be less than 20 mm. The reading cannot be taken until the indication is stable.

5.6 Other Temperature Points

All other temperature points can be calibrated by use of the comparison method.

The thermometer should be preheated (above-zero thermometer) or pre-cooled (sub-zero thermometer), then put vertically into the trough according to item 4.4. The reading can be made when the temperature of the controlling thermostat stays within ±0.20°C around the calibrating point (based on a standard thermometer)

Generally, it takes 10 minutes for a mercury thermometer or 15 minutes for an organic liquid thermometer to be read after having been inserted into the thermostat. The temperature of the trough should be static or steadily rising during the reading. The trough temperature change must not exceed 0.10 °C during the process of the reading. The temperature control precision must not exceed ±0.05°C/10 min by use of an auto-control thermostat.

The reading should be take quickly. The time interval should be well distributed. The sight line should be vertical to the scale mark surface. The reading should be taken from the highest (mercury thermometer) or the lowest point (organic liquid thermometer) of the liquid column meniscus respectively. The figure should be estimate-read one-tenth of the scale division value.

The reading should be done four times for precision thermometer and twice for ordinary thermometers. Its order is standard → calibrating$_1$ → calibrating$_2$ …… calibrating$_n$, then back to the standard thermometer and then once more in the reverse order. At the end the arithmetic means can be taken as the indications of the standard and the calibrated thermometer respectively.

The zero point position of the second grade standard mercury thermometer should be measured every time after usage. It can be measured twice a month if it is continuously used. If the measured zero point position has changed, the deviation of the new indication for the points should be calculated by use of the following formula:

New deviation value = deviation in original certificate + (zero point position written in original certificate after upper limit temperature being calibrated – new measured zero point position after upper limit temperature being calibrated).

5.7 Calculation of Actual Temperature and Calibration Value

The actual temperature can be calculated by use of the following formula when the second grade standard mercury thermometer used:

Actual temperature = indication of the standard mercury thermometer + deviation of this point.

Deviation of the calibrated thermometer = actual temperature – indication of the calibrated thermometer.

6. TREATMENT OF CALIBRATION RESULTS

6.1 Calibration Protocol

For precision thermometers which meet the requirement of this work instruction, a calibration certificate should be supplied. For the ordinary thermometers which meet the requirement of this work instruction, a quality certificate will be supplied. For the ones which do not meet the requirement an advisory note of the calibration result will be supplied.

6.2 Calibration Period

The calibration period should be determined on the service condition, but no longer than one year.

Appendix A **CALIBRATION RECORDING CARD OF LIQUID-IN-GLASS THERMOMETER**

	Standard thermometer	Number of calibrated thermometer				
Serial number of standard thermometer						
Zero point position（Z_2）						
Scale division value						
Reading of indication						
Average of readings						
Indication deviation of standard thermometer						
Actual temperature						
Indication deviation of calibrated thermometer						

Calibrated by_____ Recorded by_____ Date_____

Calculated by_____ Date_____

Repeated by _____ Date_____ Checked by_____ Date_____

Appendix B **FORMAT OF THE CALIBRATION PROTOCOL FOR LIQUID-IN-GLASS THERMOMETER**

(back side)

Liquid-in-Glass thermometer

Measuring range_____°C Scale division value_____°C

Immersion _____ mm

Calibration result

Indication of thermometer °C					
Deviation °C					

Indication of thermometer °C					
Deviation °C					

Zero point position _____°C

Note: The formulae of the actual temperature calculated from the indication

Actual temperature = indication + deviation

This certificate should be available at the next calibration