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Some helpful information on ASTM and other glass laboratory thermometers

All ASTM and other glass laboratory thermometers can be classified into 2 general groups - those designed and fabricated for **total immersion** and those designed and fabricated for **partial immersion**. If you use glass thermometers, it is essential that you understand the difference, and how each type of thermometer is used.

Most laboratory errors in temperature measurement result from incorrect usage (immersion) of the thermometer!

Total immersion thermometers are designed with scales which indicate actual temperature when the **bulb and the entire liquid column** are exposed to the temperature being measured. In practice, a short length of liquid column (usually one-half inch) is permitted to extend above the surface of the liquid being measured to allow reading of the thermometer.

Most *total immersion* thermometers can also be used in a condition of complete immersion, wherein the entire thermometer is exposed to the temperature being measured, as with a thermometer inside a refrigerator, freezer, incubator or other chamber.

Partial immersion thermometers are designed to indicate the actual temperature when a **specified portion of its stem is exposed to the temperature being measured**.

How can I know the difference?

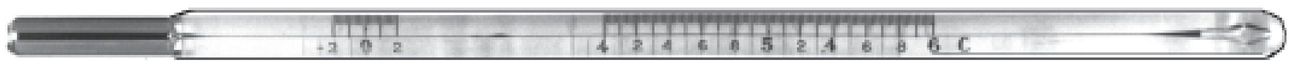
Partial immersion thermometers

The immersion line is a quick and easy visual indication to the user. The thermometer should be immersed to this line for correct temperature indication. The reverse of the thermometer should have the inscription “76MM IMM” (or as appropriate). Partial immersion thermometers are usually easy to identify.

Note: some partial immersion thermometers do not have an immersion line inscribed; ie, thermometers with standard taper joints, or thermometers with very short immersions, such as for melting point applications. Pay special heed to the inscription on these thermometers, and immerse them as specified for the most accurate readings.

Total immersion thermometers are sometimes a little trickier to identify. Some of the better manufacturers are inscribing TOTAL or TOTAL IMMERSION on the reverse of the thermometer, but regrettably this is not an industry-wide practice. The photo below is of an older ASTM 112C thermometer, designed for total immersion. There is no immersion line, and there is no “TOTAL IMMERSION” marking on the reverse.

If there is no inscription on the reverse indicating immersion, you should assume the thermometer is designed for total immersion.



What's the difference in use?

As explained above, the partial immersion thermometer is immersed in the liquid being measured up to the line, or ring.

The total immersion thermometer must be immersed into the medium being measured to within approximately one-half inch of where the top of the liquid column (the meniscus) resides (ASTM E-77).

So what happens if the total immersion thermometer is not immersed to the depth it should be?

You will have an erroneous temperature reading. The amount of the error depends upon what the temperature is that you are measuring, and **how much of the liquid column that should be immersed** is outside the medium you are measuring. An extreme example: you have a -1/201^{o}C thermometer, 24 inches in length, total immersion, and you are testing the liquid in a beaker on a hotplate. Only about 2 inches of the thermometer is in the liquid. The thermometer indicates 190^{o}C. How much error do we have? **Almost 5 degrees C.** The liquid in the beaker is 5 degrees **hotter** than the thermometer indicates.

I have this expensive, calibrated, total immersion thermometer I bought recently, similar to the one in the example above. I need it for applications similar to that described. Is this useless to me?

No, it may not be the best thermometer for your application, but you can use it. However, you'll need to calculate and apply a correction, which we will explain below.

Below you will find 2 different scenarios: using a total immersion thermometer in condition of partial immersion, and using a partial immersion thermometer in condition of total immersion.

Total immersion thermometers used only partially immersed - calculate the error and apply a correction

When total immersion thermometers are used in a condition wherein the entire liquid column is not exposed to the temperature being measured, a stem correction must be computed and applied to the observed reading to obtain the actual temperature of the liquid being measured.

Example: You have a total immersion mercury thermometer graduated from -1 to 101^{o}C in 0.1 divisions. You are measuring the temperature of liquid in a beaker on a hot plate; the thermometer is immersed to the 31 degree mark. The reading of the thermometer is 90.15^{o}C.

How much error do you have for incorrect immersion of the thermometer?

What is the actual temperature of the liquid being measured?

1. We need to determine 4 variables:

k=the coefficient of expansion of the thermometric liquid and the glass, combined. For Celsius mercury thermometers, k=0.00016; for Fahrenheit mercury thermometers, k=0.00009; for red liquid Celsius thermometers, k=0.001; for red liquid Fahrenheit thermometers, k=0.0006

n= the number of *scale degrees* of the thermometer column between the surface of the liquid being measured and the meniscus of the liquid column. In this example, the thermometer is immersed to to 31 degree mark, and the reading of the thermometer is 90.15, so the value of N is 90.15 minus 31, or 60.15 (the distance, expressed in *scale degrees* between the 31 graduation at the surface of the liquid in the beaker and the meniscus at 90.15).

T= the reading of the thermometer in situ (In this example, 90.15^{o}C)

t= average temperature of the emergent liquid column. To obtain this value, suspend alongside the main thermometer a secondary, total immersion thermometer. Position this thermometer so that its bulb is centered halfway between the surface of the liquid and the temperature indicated on the main thermometer. The temperature indicated on the second thermometer will be the average temperature of the emergent liquid column. For this example, we will assume a temperature of 25^{o}C was observed.

2. Now, find the magnitude of the correction from the following equation:

correction = **kn(T-t)**

(0.00016 x 60.15) x (90.15-25) = 0.627

Adding this value to the observed reading of the thermometer yields 90.15^{o} + .627 = 90.777^{o}C which is the actual temperature of the liquid being measured.

If this were a red liquid filled thermometer, you would need to use a different value for k (above). Notice how much greater the correction is:

(0.001 x 60.15) x (90.15-25) = 3.918

Adding this value to the observed reading of the thermometer yields 90.15^{o} + 3.918^{o} = 94.068^{o}C which is the actual temperature of the liquid being measured.

Caution: although this equation (from ASTM E-77and NBS Monograph 150) is reasonably accurate, the measurement of the temperature of the emergent stem is difficult and often imprecise, and will increase the measurement uncertainty.

Remember that the greater the departure of the test temperature from room temperature, the greater the correction - and the greater the uncertainty of the measurement.

The ideal situation is to use the correct thermometer for your application, and not try to 'make do' with what you have at hand.

Using a partial immersion thermometer totally immersed - calculate the error and apply a correction

Suppose you have an ASTM 91C thermometer, with a range of +20 to 50°C in 0.1 divisions, 76mm immersion, and you want to place the thermometer inside an incubator (in condition of total immersion) and read the temperature. Do you have to make a correction? **Yes.**

As above, we have to first determine 4 variables, but 2 of them are different than the explanation above. Note also that the equation changes.

k=the coefficient of expansion of the thermometric liquid and the glass, combined. For Celsius mercury thermometers, k=0.00016; for Fahrenheit mercury thermometers, k=0.00009; for red liquid Celsius thermometers, k=0.001; for red liquid Fahrenheit thermometers, k=0.0006

n= the number of *scale degrees* of the thermometer column between the immersion mark on the thermometer and the meniscus of the liquid column. The ungraduated portion of the thermometer between the immersion line and the start of the scale (if any) must be evaluated and included in the value of n. This concept is a little more difficult. Suppose on this thermometer the scale starts (the first graduation is at 20°C) 25mm above the immersion line. The thermometer in situ reads 37.12°C The value of n, therefore is the number of scale degrees between 20° and 37.12°C (17.12) plus the number of degrees represented by the 25mm of ungraduated capillary. Using a metric ruler, place the 0 on the ruler at 20°C on the thermometer. What temperature on the thermometer coincides with 25 on the ruler? Let's say 23.8°C. So, 25mm equals the span from 20 to 23.8, or 3.8 degrees. Add the 3.8 thus determined to the 17.12 we figured above, and we find that n=20.92

$\mathbf{t_o}$= the reading of the thermometer in situ (In this example, 37.12°C)

$\mathbf{t_s}$= The specified temperature of the emergent liquid column, from ASTM E-1 'Specifications for ASTM Thermometers'. This particular thermometer was manufactured anticipating an emergent stem temperature of 25°C at all temperatures, so use this value for t_s Thumbnail rule: if your thermometer is NOT to be an ASTM thermometer, use 23°C as the value of t_s.

2. Now, find the magnitude of the correction from the following equation:

Magnitude of the correction = $\mathbf{kn(t_s - t_o)}$

(0.00016 x 20.92) x (25-37.12) = -0.04°C

Add this value (algebraically) to the observed temperature to find the actual temperature in the incubator:

37.12° + (-0.04°) = 37.08°C

Remember that the greater the departure of the test temperature from the specified stem temperature, the greater the correction - and the greater the uncertainty of the measurement.

The ideal situation is to use the correct thermometer for your application, and not try to 'make do' with what you have at hand.

SOME HELPFUL THERMOMETER SUGGESTIONS:

GENERAL CONSIDERATIONS FOR MAKING AN ACCURATE READING

The error due to parallax may be eliminated by taking care that the reflection of the scale can be seen in the mercury thread, and by adjusting the line of sight so that the graduation of the scale nearest the meniscus exactly hides its own image: the line of sight will then be normal to the stem at that point. In reading thermometers, account must be taken of the fact that the lines are of appreciable width. The best practice is to consider the position of the lines as defined by their middle parts.

PERFORMING A CALIBRATION AT THE ICE POINT (0^oC or 32^oF) *

Select clear pieces of ice, preferably ice made from distilled water. Rinse the ice with distilled water and shave or crush into small pieces, avoiding direct contact with the hands or any chemically unclean objects. Fill a Dewar or other insulated vessel with the crushed ice and add sufficient distilled and preferably pre-cooled water to form a slush, but not enough to float the ice. Insert the thermometer, packing the ice gently about the stem, to a depth sufficient to cover the 0^oC (32^oF) graduation (total immersion), or to the immersion line (partial immersion). As the ice melts, drain off some of the water and add more crushed ice.

Raise the thermometer a few millimeters after at least 3 minutes have elapsed, tap the stem gently and observe the reading. Successive readings taken at least one minute apart should agree within one tenth of one graduation.

APPLYING THE CORRECTION AT ICE POINT*

Record readings and compare with previous readings. If the readings are found to be higher or lower than the reading corresponding to a previous calibration, readings at all other temperatures will be correspondingly increased or decreased.

*Reproduced in part from ASTM E77 and http://www.icllabs.com/thergenlinfo.html