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CERT. 526.01 CALIBRATION

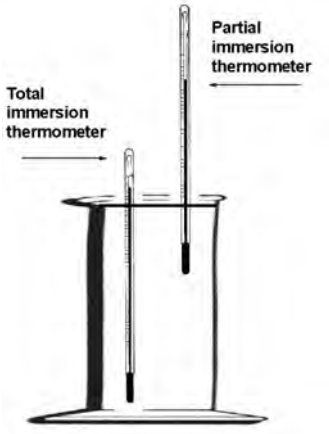
GENERAL INFORMATION ON THERMOMETERS

This information presented has been reproduced in part from ASTM E-1, ASTM E-77, and various NIST publications.

AN EXPLANATION OF TOTAL VS PARTIAL IMMERSION THERMOMETERS

TOTAL IMMERSION thermometers are designed with scales calibrated to 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 inch or less) is permitted to extend above the surface of the liquid being measured to permit 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 freezer.



PARTIAL IMMERSION thermometers are designed with scales calibrated to indicate the actual temperature when a specified portion of its stem is exposed to the temperature being measured. The portion that should be immersed is indicated on the back of each thermometer.

DETERMINATION OF EMERGENT STEM CORRECTIONS FOR TOTAL IMMERSION THERMOMETERS USED ONLY PARTIALLY IMMERSED

Many times a user has at hand a total immersion thermometer, and the medium he desires to measure does not have sufficient depth to permit proper immersion of the thermometer. Can he use the thermometer he has? Definitely – however ***an emergent stem correction*** must be calculated and applied to obtained readings in order to know the actual temperature of the medium.

Example: We have a total immersion thermometer graduated from -1 to 101C in 0.1 divisions. In the bath, it is immersed only to the 80 degree mark. The reading of the thermometer is 90C. What is the actual temperature of the liquid being measured?

1. Firstly, determine the following three variables:
N= the number of degrees of the column between the surface of the liquid being measured and the point of reading. In the example this value is 10 (distance between the 80 graduation at the surface of the liquid and the reading of 90).

T= thermometer reading in situ (In this example, 90C)
ST= 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 30C was ascertained.

2. Now, find the **stem correction** from the following formula:

Stem correction = (0.00016 x N) x (T-ST) for Celsius temperatures

Stem correction = (0.00009 x N) x (T-ST) for Fahrenheit temperatures

Our stem correction = (0.00016 x 10) x (90-30) = +0.096 Adding this correction to the observed reading of the thermometer yields 90.00 + .096 = 90.096C which is the actual temperature of the liquid being measured.

GENERAL CONSIDERATIONS FOR MAKING AN ACCURATE THERMOMETER 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 DEGREES C OR 32 DEGREES F*) from ASTM E-77*

Select clear pieces of ice, preferably made from distilled water. Discard any cloudy or unsound portions. 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 precooled water to form a slush, but not enough to float the ice. Allow 15 minutes for the ice, water and vessel to come to equilibrium. Insert the thermometer, packing the ice gently about the stem, to a depth sufficient to cover the 0C(32F) graduation. 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 *from ASTM E-77*

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.

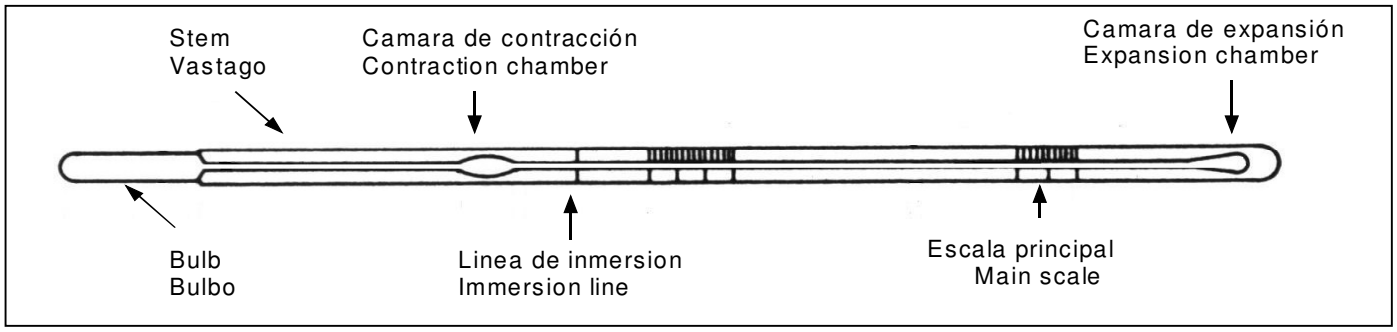
novatech INTERNATIONAL
sales@novatech-usa.com
www.novatech-usa.com
Tel: (866) 433-6682 Fax: (866) 433-6684
Tel: (281) 359-8538 Fax: (281) 359-0084

REJOINING MERCURY SEPARATIONS IN THERMOMETERS

PLEASE UNDERSTAND - A separation of the mercury in your thermometer is not a defect! It is a condition, normally caused by shock in transit, which of course must be rectified before using the thermometer, or you will experience significant errors in your readings.

PLEASE RESIST THE IMPULSE TO PUT THE THERMOMETER INTO DRY ICE OR TO HEAT IT! (YET) More often then not you will make the separation more difficult to rejoin, and you may damage the thermometer. PLEASE READ THESE INSTRUCTIONS BEFORE ATTEMPTING TO REJOIN THE SEPARATIONS!

First, let us review the basic components of the typical liquid-in-glass thermometer:



Most well constructed thermometers are filled above the mercury column with pressurized nitrogen gas (there are a few exceptions, which will not be considered here). The nitrogen serves many purposes: it is an inert gas, which minimizes the possibility of oxidation occurring inside the thermometer; the pressure is what makes the column retreat when the thermometer is removed from heat; and the pressurization is what permits the construction of thermometers for use above the boiling point of mercury (approximately 250C) The nitrogen gas is of course invisible. When you have a mercury separation in the capillary of the thermometer, the 'spaces' between the pieces of mercury are actually quantities of gas. In most cases it is virtually impossible to 'tap' the column back together - you cannot force the mercury through the gas in such a confined space, so don't bother trying - you may well break the thermometer. To be able to 'tap' the mercury back together, we must move the 'separations' into a larger chamber.

THE TRICK TO REMEMBER IS THAT WHILE THE MERCURY SEPARATIONS ARE IN THE CAPILLARY, THEY CANNOT BE EASILY REJOINED. WHEN WE MOVE THEM INTO A LARGER SPACE, THEY CAN BE EASILY MANIPULATED.

THIS IS EASY!

Firstly, determine the type of separation you have:

1. Separation(s) in a thermometer with a contraction chamber.

If your thermometer has a range that starts significantly above room temperature (for example, a range of 98 to 152C), the thermometer is constructed with an enlargement in the capillary between the bulb and the main scale. (See figure 1 below). This enlargement, or **contraction chamber**, is where the mercury normally resides at room temperature. This type of thermometer is extremely prone to mercury separations, especially during shipment. Fortunately, the separations are usually very easy to rejoin.

Firstly, determine how the separation(s) appear. If all the mercury appears to be within the chamber (figure 1), the thermometer may be tapped gently (vertically) onto a padded surface until the separated portion falls and rejoins with the mercury in the lower portion of the chamber.

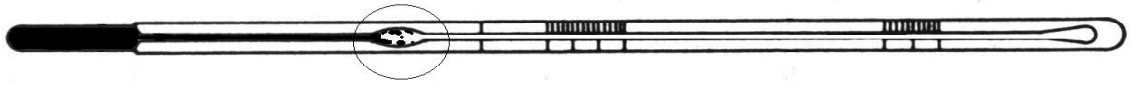


Fig. 1 Separation of mercury in contraction chamber. Separacion del mercurio en la camara de contraccion.

ONCE AGAIN - THE TRICK TO REMEMBER IS THAT WHILE THE MERCURY SEPARATIONS ARE IN THE CAPILLARY, THEY CANNOT BE EASILY REJOINED. WHEN WE MOVE THEM INTO A LARGER SPACE, THEY CAN BE EASILY MANIPULATED.

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If the separated mercury is lodged in the upper portion of the chamber, and/or is located in the column above the chamber (figure 1a), it will be necessary to bring the separation down into the chamber so that it may be tapped as described. Cool the thermometer bulb a little at a time (dip it into a mixture of ice and water) until the mercury retreats into the chamber. While it is lying in the chamber, tap as described above to rejoin the separation.

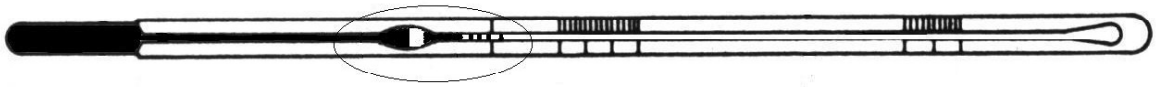

Fig. 1a Mercury is separated in chamber but is also lodged in upper part of chamber and in capillary. El mercurio esta separado en la camara, en la parte arriba de la camara y tambien in el capilar mas hacia arriba.

If the separation is located in the lower portion of the chamber, or in the capillary below the chamber (figure 1b), we must do the REVERSE of the above. Warm the bulb (try hot tap water first) a bit at a time until the separation is located in the chamber. When the separation is in the chamber, tap as described above to drive the separated mercury down (actually, we are forcing the gas up).

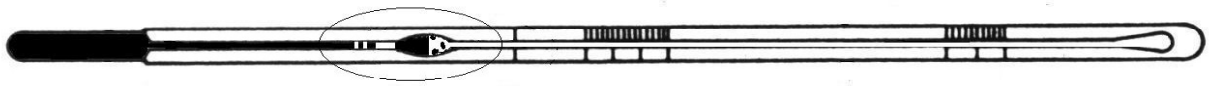

Fig. 1b The mercury is separated in the chamber and also in the capillary below the chamber. El mercurio esta separado en la camara de contraccion, y ademas en el capilar mas abajo.

Sometimes with severely separated thermometers it is necessary to rejoin the separation(s) in stages. Just remember that it is necessary to move the separation into the chamber to be able to rejoin it.

2. Separations in the column (thermometers without contraction chambers). See figure 2

Fig. 2 Separations in the upper part of the mercury column. Separaciones en la parte arriba de la columna.

This type of separation is less common, and a little trickier to rejoin. There are basically two methods:

COOLING METHOD (preferred)
Obtain a small quantity of dry ice or other source of extreme cold. Immerse the thermometer BULB ONLY (TAKE CARE NOT TO IMMERSE THE ENTIRE BULB OR ANY PORTION OF THE STEM) halfway into the dry ice and observe the descending mercury column carefully. The main column will disappear into the bulb, followed by the separated pieces of mercury. Wait a few seconds more, and then withdraw the thermometer from the dry ice and gently and carefully tap it onto a padded surface. The tapping will permit the separated pieces of mercury to fall and rejoin the main mass of mercury now within the bulb. Allow the thermometer to warm naturally (do not heat it) in a vertical position, and observe the mercury column as it ascends into the capillary to be certain it is intact.

HEATING METHOD CAUTION: DO NOT ATTEMPT THIS METHOD WITH THERMOMETERS WHOSE RANGE EXTENDS ABOVE 150C OR DAMAGE MAY RESULT!

Most well constructed thermometers have a small chamber at the extreme top of the capillary, called an **expansion chamber**. The purpose of this chamber is to provide overrange protection in case the thermometer is heated beyond its scale range. This chamber may be used to rejoin separations provided 1) the amount of separated mercury is very small (not more than a few scale divisions in length) and 2) the thermometer's range does not exceed 150C. The thermometer may be heated (in hot water, hot oil or other suitable medium compatible with the temperatures to be attained) so that the separation(s) enter the expansion chamber followed by a small portion of the main (intact) column. GREAT CARE MUST BE EXERCISED TO NOT FILL THE EXPANSION CHAMBER MORE THAN HALFWAY, OR BREAKAGE OF THE BULB (AND SPILLAGE OF THE MERCURY) MAY OCCUR). The separations will normally fall to the side of the expansion chamber, and the main column will come into contact with them. Remove the thermometer from the heat, maintain it in a vertical position, and observe the mercury column as it retreats to be sure it is intact.

3. Separations in the expansion chamber.

Some thermometers are designed with very low ranges (for example, ASTM 62C, a common certified reference thermometer, has a range of -38 to +2C) such that the mercury at room temperature resides in an oversized **expansion chamber** at the extreme top of the instrument. (figure 3) Again, often in shipment, this mercury can become separated.

Fig. 3 Separations in the expansion chamber. Separaciones en la camara de expansion.

Normally the separation is visually apparent, and can be rejoined quickly and easily by simply tapping, however, if you see a separation in the column, the thermometer must be heated (warm water) until the separation (gas) enters the expansion chamber, where it can be rejoined by tapping. Again - THE TRICK TO REMEMBER IS THAT WHILE THE MERCURY SEPARATIONS ARE IN THE CAPILLARY, THEY CANNOT BE EASILY REJOINED. WHEN WE MOVE THEM INTO A LARGER SPACE, THEY CAN BE EASILY MANIPULATED.

AFTER REJOINING MERCURY SEPARATIONS, IT IS HIGHLY RECOMMENDED THAT THE THERMOMETER BE VERIFIED IN A KNOWN TEMPERATURE PRIOR TO BEING PLACED INTO USE. IF THE THERMOMETER READS CORRECTLY AT THIS KNOWN TEMPERATURE, IT MAY BE SAFELY ASSUMED THAT THE SEPARATION HAS BEEN CORRECTLY REJOINED

IF THE THERMOMETER'S INDICATION AT A KNOWN TEMPERATURE IS HIGH, THERE IS GAS (A SEPARATION) EITHER IN THE BULB OR THE COLUMN WHICH IS DISPLACING MERCURY AND CAUSING A FALSELY HIGH READING. GO BACK AND FIND THE SEPARATION AND REMOVE IT.

IF THE THERMOMETER'S INDICATION AT A KNOWN TEMPERATURE IS LOW, IT MAY BE ASSUMED THAT THERE IS A MERCURY SEPARATION SOMEWHERE ABOVE THE COLUMN (LOOK FOR IT IN THE UPPER REACHES OF THE COLUMN OR IN THE EXPANSION CHAMBER).

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