CARE AND USE OF LIQUID-IN-GLASS LABORATORY THERMOMETER

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Care and Use of Liquid-in-Glass Laboratory Thermometers*

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This paper is intended to deal with the practical application of liquid-in-glass thermometers in the laboratory and does not concern itself with the theoretical aspects of thermometry. If the reader comes away with some knowledge of how to select and use precision glass thermometers properly, it will have served its purpose.

INTRODUCTION

LIQUID-IN-GLASS thermometers are a relatively inexpensive means of accurately measuring temperature in the laboratory. These thermometers are widely used and are found in practically every lab. There is hardly an industry that is not concerned with temperature measurements. There are some that are literally dependent upon the reading of a thermometer. In many instances the value of the products is determined by the temperature of a freezing or melting point. The petroleum industry in particular is greatly concerned with accurately measuring temperature with glass thermometers.

Oddly enough, the chemists and technicians who continuously use these instruments in their daily work have little or no formal training in the proper use of a liquid-in-glass thermometer. If one were to try to remember one's first encounter with a laboratory thermometer, it probably would be a course in elementary chemistry where it was used as a stirring rod and only incidentally to measure temperature. After all, what is there to know about using a thermometer? One inserts it into a beaker and takes a reading. Nothing could be simpler. Unfortunately this is not all there is to it.

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TECHNIQUES AND FACTS

Any knowledge of thermometers we may have acquired is usually from experience rather than instruction. Too often the techniques we develop from these experiences are not the best. As a result we are confronted with a puzzling variance in our readings for which we can give no account. In all likelihood the difficulties encountered may be traced to the improper use of a thermometer.

To begin with, thermometers are made to be used in one of three ways to indicate true temperature: total immersion, partial immersion, and complete or full immersion. An understanding of these terms is essential if one is to get the best results from a particular instrument. The following are the definitions of the various immersions:

Total immersion:	The bulb and entire liquid column of the thermometer are exposed to the temperature to be measured.
Partial immersion:	The bulb and a specified portion of the stem are exposed to the temperature to be measured.

Complete (full) immersion: The entire thermometer is exposed to the temperature to be measured including the expansion chamber.

In the United States, thermometers that have been graduated for total immersion usually have no markings on the backs pertaining to immersion. Partial immersion thermometers are identified by either an immersion ring on the stem at the immersion point or an inscription on the back indicating the depth of the immersion, or both. Complete immersion thermometers bear the inscription "complete immersion" on the back.

For the most accurate temperature determinations, total immersion thermometers are recommended and should be used wherever possible. There are times when it is not possible to immerse a total immersion thermometer so that the bulb and entire liquid column come in contact with the temperature to be measured. In such instances it is still possible to use this instrument, providing one can accurately measure the temperature of the exposed liquid column and apply the necessary stem corrections.[1]

Where total immersion thermometers cannot be used for lack of space or inability to measure accurately the temperature of the exposed stem, partial immersion thermometers are recommended.

Where the temperature of an enclosed bath or chamber is to be measured and the entire instrument will come in contact with the temperature, a "complete" immersion thermometer is recommended. It usually is read through a window or port built into the apparatus.

The differences in the readings between a total, partial, or a complete immersion thermometer will be insignificant at temperatures between 20 and 30°C (68 or 86°F). The higher or lower we go from room temperature the greater the differences will be in the indications of the thermometers if improperly immersed. The following will serve to illustrate what one might expect under certain conditions. We will use two thermometers with similar ranges: one graduated for total immersion, the other for 76-mm immersion.

Type	*Range, °C*	*Division, °C*	*Immersion*
ASTM 8C	−2–400	1	Total
ASTM 3C	−5–400	1	76 mm

Immerse both thermometers for their respective immersions in a well-stirred water bath with a temperature of 30°C, and observe the readings of both thermometers. Then, inversely, immerse them so that the partial immersion thermometer (3C) is immersed totally and the total immersion thermometer (8C) is immersed only to the 0°C mark, and observe that both thermometers will read the same no matter how they are immersed at this temperature.

Using a high-temperature bath at 350°C, immerse both instruments for their respective immersions and observe the readings of both: They should indicate the same temperature to within 1 or 2°C. Now withdraw the total immersion thermometer up to the 50°C mark, which will approximate a 76-mm immersion, and allow the stem to cool until the exposed column stabilizes so that it is the same as the temperature of the stem of the partial immersion thermometer. Take another reading of both thermometers. Let us assume that at the first reading both thermometers read 350°C. The second reading will indicate that the partial immersion thermometer still reads 350°C, but the total immersion thermometer immersed up to the 50°C will read approximately 337°C, or 13°C lower.

Take the total immersion thermometer and again lower it into the bath so that it is at total immersion with the bath temperature constant. It should once again read 350°C and should agree with the reading of the 3C thermometer.

Now take the 3C thermometer and lower it into the bath so that it too is at total immersion, and after approximately 1 min take a third reading. You will now find that the 8C thermometer will continue to read 350°C but the 3C thermometer will read approximately 366°C, or 16°C higher.

The greater error here of 16°C, as against 13°C in the case of the 8C in the previous example, is caused by the fact that more of the stem of the 3C thermometer is being exposed to the higher temperature when it is used at total immersion.

To illustrate and observe the differences that can occur in the indications of a total immersion thermometer that is used at complete (full) immersion, take two ASTM 110F thermometers with a range of 272.5–277.5°F graduated in 0.1°F for total immersion. Immerse them both in a constant temperature visibility bath maintained at 275.00°F. Take readings on both instruments for total immersion. Let us assume that they both read 275°F to within 0.02°F with the bath temperature remaining constant. Lower one thermometer into the bath so that it is completely immersed (including the expansion chamber). Allow it to stabilize for about 1 min and take a second reading. The thermometer that is completely immersed will now read 2 to 6 scale divisions (0.2 to 0.6°F) *lower*, depending upon the size of the expansion chamber and the amount of gas pressure developed above the mercury column.

At this point it would be interesting to note what happens to the indication of a thermometer of this type when it is not properly immersed for total immersion and the contraction chamber is not immersed into the bath. Using the same two thermometers and the temperature of the bath maintained at 272.5°F, immerse one for total immersion so that it reads 272.5°F. Immerse the second thermometer so that the bulb and stem just below the contraction chamber come in contact with the liquid in the bath. Allow it to come to equilibrium and you will notice that the mercury column will not emerge from the top of the chamber into the capillary. Now slowly lower the second thermometer into the bath so that one half of the contraction chamber is in contact with the heated liquid. Observe that the mercury will start to emerge from the chamber into the capillary. As you continue to

immerse the instrument slowly into the bath, the mercury will rise higher in the capillary until you reach total immersion, when both thermometers again will indicate 272.5°F.

In illustrating the aforementioned possibilities it is not the intention of the writer to frighten the reader and thereby cause him to lose faith in glass thermometers. On the contrary, by familiarizing him with the structure and function of these instruments, he will be better able to use them with consistent and accurate results.

To choose the most suitable thermometer for a particular application where there is no specified method (ASTM, NGAA, etc.) the following factors should be taken into consideration:

1. The degree of accuracy required.
2. The apparatus available for the investigation.
3. The ability to use the thermometer for its proper immersion without any correction factors.

Let us use the following as an example. We are to determine the boiling point of a solution between 140 and 145°C to within 1°C. The flask we will use has a maximum depth of 6 in. We have two thermometers available:

	Type	Range, °C	Divisions, °C	Immersion	Length, in.
A	SAMA CT-50	−1–201	0.2	Total	24
B	ASTM-1C	−20–150	1.0	76 mm	13

Even though instrument A is the more sensitive one, instrument B will be the more practical and accurate one *in this application.* Thermometer A could only be immersed to approximately the 40°C mark, leaving almost 100°C emergent from the flask. An error of about 1.5°C would be encountered if the correction for the emergent stem was not calculated, whereas thermometer B, the ASTM 1C, could be used for 76-mm immersion and would be accurate to well within the 1°C required.

Many laboratories engaged in quality control or research are equipped with a wide variety of glass thermometers. Many go to the added expense of procuring a series of National Bureau of Standards certified thermometers, which they may use in critical temperature measurements or as standards to calibrate or check their routine instruments. Often, rather than reduce the chance of error by using these certified thermometers, the errors are compounded by improper usage.

In order to get the best results from a certified instrument, one should have a basic understanding of the capabilities of the particular thermometer. It would be well worthwhile for the reader to refer to the tables of probable accuracy in Monograph 90.[2]

The most common mistake made by most users of certified thermometers is the failure to read the applicable notes on the reverse side of the certificate (report of calibration) before applying the tabulated corrections. It is essential, where the value for an ice point is given, that the ice point be taken in the manner described in the applicable note of the certificate. Failure to do so can compound the errors in the following manner. The ice point of an ASTM 30F, a thermometer used to determine kinematic viscosity at 210°F, is to be checked. It has a range of 207.5 to 212.5°F graduated in 0.1°F with an auxiliary scale at 32°F and is calibrated for total immersion. Let us assume the instrument has been certified and the following are the tabulated corrections:

Thermometer reading, °F	*Correction, °F*
32.02	−0.02
208.00	+0.02
210.00	+0.04

The notes on the reverse side of the certificate that apply are as follows:

Note A: The tabulated corrections apply for the condition of total immersion of the bulb and liquid column. If the thermometer is used at partial immersion, an emergent stem correction must be applied.

Note J: The tabulated corrections apply for the condition of immersion indicated provided the ice point reading, taken after heating to 210°F for not less than 3 min, is 32.02°F. If the ice point reading, which should be taken within 5 min after removal of the thermometer from the heated bath, is found to be higher (or lower) than stated, all other readings will be higher (or lower) by the same amount.

Let us assume that the user took the instrument, which has been stored at room temperature for at least 3 days, and proceeded to take the ice point without following the procedure outlined in Note J, inserting the thermometer into the ice bath without heating it to 210°F. The odds are that the ice point reading will be anywhere from 0.08 to 0.13°F higher than if it were heated to 210°F for at least 3 min.

The user, unaware that the preconditioning is necessary, will assume that the ice point reading that he now finds to be 32.12°F represents a secular change in the indication of the thermometer. (This phenomenon is known as a temporary ice point depression and is not to be confused with a secular or permanent change in bulb volume.) Thinking that the scale has raised 0.10°F from the tabulated corrections, he proceeds to add this change to the other readings that now become −0.08°F at 208°F and −0.06°F at 210°F. Had he preconditioned the instrument by heating it to 210°F as outlined in the applicable note, he probably would have found the ice point to read 32.02°F as stated in the certificate. He would have been better off if the thermometer was not certified, and he assumed it was correct. He would have been out only 0.04°F at 210°F; but by taking the ice point incorrectly, he increased his error so that now he is incorrect by 0.10°F. (It is imperative, therefore, that the applicable notes be referred to before applying the tabulated corrections.)

When fractionally graduated thermometers are sent to

the National Bureau of Standards for reports of calibration (graduated in 0.1 or 0.2°C) between the range of 0 to 100°C, the bureau will give values for the ice point according to Note E on the reverse side of the document, which reads as follows:

> Note E: The tabulated corrections apply provided the ice point reading taken after exposure for not less than 3 days to a temperature of about 25°C (77°F) is -----. If the ice point reading is found to be higher (or lower) than stated, all other readings will be higher or lower by the same amount. If the thermometer is used at a given temperature shortly after being heated to a higher temperature, an error of 0.01° or less for each 10° difference between the two temperatures may be introduced. The tabulated corrections apply if the thermometer is used in its upright position; if used in a horizontal position, the indications may be a few hundredths of a degree higher.

After reading the note one might ask if it is absolutely necessary to rest the thermometer for at least 72 hr after use at the higher temperatures of the scale before checking the ice point. The answer is obviously in the affirmative if one is to determine any secular or permanent changes in bulb volume accurately.

After careful study of the note one can deduce that it is possible to eliminate the waiting period providing one preconditions the instrument. To illustrate, on pages 3 and 4 of Monograph 90,[1,2] there is a facsimile of a report of calibration for a thermometer range −2 to 102°C in 0.2°C calibrated for total immersion (see Figures 1 and 2).

The applicable notes that must be taken into account are A and E. In taking our initial ice point reading it is essential to follow the procedure exactly as outlined in the note. Let us assume the ice point reading was found to be exactly as noted on the certificate. Immediately thereafter heat the thermometer in a bath to a temperature of 100°C as outlined in Note J for a period of not less than 3 min. Then take the ice point as further described in Note J. Make a note of the ice point reading after heating to 100°C. Let us assume that the ice point reading is found to be −0.11°C. From this value we can deduce there is a 0.05°C depression in the ice point reading after heating to 100°C. We now can calculate that there is a 0.0067°C depression for each 10°C between 100 and 25°C. Having ascertained this information we can now accurately take an ice point reading at any time by preconditioning the thermometer (heating to 100°C) without waiting the 72 hr period.

It might be noted that if one has the need to have thermometers calibrated by the National Bureau of Standards it might be wise to inform the bureau how he intends to use the instruments so that the bureau may perform the calibration to his best advantage.

A further word of caution when checking ice points. Make sure the ice being used is pure. The ice should be shaved and mixed with distilled water to form a slush without floating the ice. Rinse the instrument in pure water before inserting it into the ice bath. Do not touch the bulb after rinsing it because you may contaminate the ice with salts due to perspiration of the hand.

Thermometers are not always used to indicate true temperatures, particularly where they are used in methods specified by technical societies such as ASTM. It is most important to use the specific instrument mentioned in the method and to position it exactly as outlined therein.

In many methods total immersion thermometers are specified but are used at partial immersion. The indication of the thermometer is a number rather than the true temperature. Any deviation may result in erroneous indications.

There has always been a great deal of confusion as to what constitutes a precision laboratory thermometer. Most users are under the mistaken notion that the prime difference as to the precision of one thermometer over another is the subdivisions, i.e., a thermometer with a range of 0 to 100°C graduated in 1°C is not considered a precision instrument, while one covering the same range but graduated in 0.1°C is considered a precision instrument. This is not necessarily true. The following factors go into the making of a precision thermometer:

1. The type of glass used.
2. The quality of annealing of the bulb to ensure stability.
3. Proper construction.
4. The accuracy of the instrument over its entire range.
5. The quality and legibility of the markings (proper spacing).

It is possible to have two similar thermometers covering an identical range with the same subdivisions, one a precision instrument, the other not. As a rule, thermometers that meet with bureau requirements for construction, stability, and accuracy are considered to be precision instruments. All thermometers specified by ASTM are precision thermometers although in some instances they do not meet with National Bureau of Standards requirements of construction because of limitations imposed by their particular applications. All SAMA thermometers must meet with NBS requirements for accuracy and should be used where no particular thermometer is specified.

All of the foregoing has dealt with mercury-filled thermometers that cover the approximate range −38 to 600°C. The range of mercury thermometers is extended below the freezing point of mercury (−38.9°C, −38.0°F) by adding thallium to the mercury. Mercury–thallium thermometers are used successfully at temperatures as low as −56°C (−68.8°F). For temperatures below −56°C it is necessary to resort to organic (spirit) liquids as the filling. While it is quite true that organic-filled (spirit) thermometers are not as reliable as mercury-filled instru-

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(7-1-63)

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

NATIONAL BUREAU OF STANDARDS

REPORT OF CALIBRATION

LIQUID-IN-GLASS THERMOMETER

Tested for: National Bureau of Standards
Division 221, Section 01

Marked: Surety 198692

Range: -2 to +102 °C in 0.2°

Thermometer Reading	Correction
- 0.06 °C	+0.06 °C
10.00	+ .08
20.00	+ .14
30.00	+ .10
40.00	+ .04
50.00	+ .04
60.00	+ .04
70.00	+ .06
80.00	+ .06
90.00	+ .06
100.00	+ .04

If the correction is + the true temperature is higher than the indicated temperature; if the correction is - the true temperature is lower than the indicated temperature. To use the corrections properly, reference should be made to the notes marked by asterisks on the reverse of this sheet.

Estimated uncertainties in the above corrections do not exceed 0.05° up to 102 °C , and between and . For a discussion of accuracies attainable with such thermometers see National Bureau of Standards Circular 600, Calibration of Liquid-in-Glass Thermometers.

For the Director
James F. Swindells

Test No. 311-30-64
Completed: December 3, 1964
KSL:dh

James F. Swindells, Chief
Thermometry Laboratory
Heat Division

USCOMM-DC 18807-P63

Figure 1. Facsimile of face of a report of calibration, Natl. Bur. Std. Monograph 90, p. 3.

NOTES

*NOTE A.-The tabulated corrections apply for the condition of total immersion of the bulb and liquid column. If the thermometer is used at partial immersion, apply an emergent stem correction as explained in the accompanying stem correction sheet.

NOTE B.-The tabulated corrections apply for the condition of total immersion of the bulb and liquid column. Although this thermometer is not ordinarily used in this way, no significant errors should be introduced by neglecting the corrections for emergent stem.

NOTE C.-The thermometer was tested in a large, closed-top, electrically heated, liquid bath at an immersion of The temperature of the room was about 25° C (77° F). If the thermometer is used under conditions which would cause the average temperature of the emergent liquid column to differ markedly from that prevailing in the test, appreciable differences in the indications of the thermometer would result.

NOTE D.-The tabulated corrections apply provided the ice-point reading is If the ice-point reading is found to be higher (or lower) than stated, all other readings will be higher (or lower) by the same amount.

*NOTE E.-The tabulated corrections apply provided the ice-point reading, taken after exposure for not less than 3 days to a temperature of about 25° C (77° F) is −0.06 °C . If the ice-point reading is found to be higher (or lower) than stated, all other readings will be higher (or lower) by the same amount. If the thermometer is used at a given temperature shortly after being heated to a higher temperature, an error of 0.01° or less, for each 10° difference between the two temperatures, may be introduced. The tabulated corrections apply if the thermometer is used in its upright position; if used in a horizontal position, the indications may be a few hundredths of a degree higher.

NOTE F.-The tabulated corrections apply provided the reading when the thermometer is immersed in steam at 100° C (212° F) is If the reading is found to be higher (or lower) than stated, all other readings will be higher (or lower) by the same amount. The temperature of steam is 100° C (212° F) only if the pressure is 760 mm (29.921 inches). If the pressure differs from 760 mm (29.921 inches) allowance must be made for this. If the pressure is higher (or lower) than 760 mm (29.921 inches) the temperature will be higher (or lower) than 100° C (212° F) by approximately 0.037° C per mm difference (1.68° F per inch difference).

NOTE G.-The thermometer, before testing, was heated to the temperature of the highest test point. The application of the tabular corrections to the readings of the thermometer will give true temperature differences provided the thermometer is used in its upright position and is heated previously (within an hour before using) to the highest temperature to be measured.

NOTE H.-The thermometer was tested for use in differential measurements, such as the measurement of temperature differences in a flow calorimeter. The two thermometers used in a flow calorimeter should be compared occasionally in stirred water at some convenient temperature and if their indications, after application of the tabular corrections, are found to differ, an additional correction equal to the difference should be applied to the indications of one of them.

NOTE I.- The tabulated corrections apply for a "setting" of 20° C. Setting factors for use with other settings are given on the accompanying sheet.

NOTE J.-The tabulated corrections apply for the condition of immersion indicated provided the ice-point reading, taken after heating to for not less than 3 minutes, is If the ice-point reading, which should be taken within 5 minutes after removal of the thermometer from the heated bath, is found to be higher (or lower) than stated all other readings will be higher (or lower) by the same amount.

NOTE K.-At temperatures below the ice-point this thermometer was tested under conditions of total immersion of the bulb and liquid column. The stated corrections were computed using a value of K= /° and an assumed temperature of ° for the emergent stem.

Special Note.-

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Figure 2. Facsimile of back of a report of calibration, Natl. Bur. Std. Monograph 90, p. 4.

ments, they serve a useful purpose in that they extend the range of glass thermometers to about −200°C (−328°F), depending on the liquid used (alcohol, toluene, pentane, or mixtures of these).

In using organic-filled (spirit) thermometers certain precautions should be taken to ensure the best results. Unlike mercury, the liquid is wet and has a tendency to wet and cling to the bore. Extreme caution should be exercised before putting these instruments into use. Some helpful suggestions follow.

It is possible for some of the liquid to work its way up into the expansion chamber, becoming colorless and not readily visible to the naked eye. It is good practice to assume that this is true before using this type of instrument and to proceed to drain any liquid that may be trapped in the expansion chamber by either gently heating the expansion chamber in a soft bunson burner flame or inverting the expansion chamber into a heated bath. Care should be taken that the liquid column does not come in contact with the heated portion of the stem. After heating the chamber and a portion of the stem above the liquid column, keep the thermometer in an upright position so that, if there is any liquid in the chamber, it will run down and join with the main liquid column. Allow the heated portion to cool. Because this type of thermometer wets the bore and requires some time to drain, it is good practice to precool it slowly directly before using it to a temperature *several degrees below the temperature to be measured.* This should be done by cooling the bulb and a portion of the stem well below the indications at which it will ultimately be used and keeping the instrument in an upright position at this lower temperature for a time sufficient to allow for complete drainage (15 min to 1 hr), depending on the drainage characteristics of the particular instrument. It then should be quickly transferred to the bath or medium, the temperature of which is to be measured. The column will be rising and will have a tendency to pick up any liquid that may not have drained completely. Allow several minutes for the bulb and liquid column to come to equilibrium before taking a reading.

The drainage of the expansion chamber need not be repeated once it has been done, provided the thermometer is stored in an upright position in a cool place away from the rays of the sun. If it is stored in a drawer lying on its side, the procedure should be repeated before each use.

Reuniting Separated Mercury Columns

The largest single cause for the failure of liquid-in-glass thermometers in the lab is separated mercury columns. This usually occurs in shipment or may be due to improper handling in the lab. This difficulty can be easily corrected and the life of the instrument extended, provided the proper procedures are carefully employed. The following methods are recommended. Other methods may cause irreparable damage to the instrument.

A. Cooling method: With the thermometer in an upright position, gradually immerse only the bulb into a solution of solid CO_2 (dry ice) and alcohol or acetone so that the mercury column retreats *slowly* into the bulb. Take care not to cool the stem or mercury column. Retract the bulb several times if need be to slow down the action. Continue until the main column, as well as the separated portion, retreats into the bulb. Remove and swing the thermometer in a short arc, forcing all the mercury into the bulb. Allow the bulb to come to room temperature, keeping the instrument in an upright position so that the gas remains on top of the mercury.

Caution: (1) Do not touch the bulb until it has warmed sufficiently for the mercury to emerge from the bulb into the capillary. (2) Never subject the stem or mercury column to the CO_2 solution as it can freeze the mercury in the capillary and cause the bulb to fracture.

Most mercury thermometers can be united by use of this method (with the exception of deep immersion thermometers).

B. Heating method: This method applies to thermometers with a maximum range of 260°C or 500°F equipped with expansion chambers sufficiently large to accommodate the separation plus a portion of the main column. Immerse as much of the bulb and stem as possible into a large beaker containing a liquid whose flash point is well above the highest indication of the thermometers being reunited. Heat the beaker, stirring the liquid with the thermometer (unless a well-stirred bath is used) until the separation and a portion of the main column enter the chamber. Tap the thermometer in the palm of a gloved-hand reuniting column. Allow it to cool slowly.

Caution: (1) Never use an open flame to heat the bulb. (2) Never fill the expansion chamber more than two-thirds full. (3) Make certain the flash point of the liquid is well above the highest indication of the thermometer. (4) Thermometers whose range exceed 260°C or 500°F cannot be reunited using heat without damaging the instrument.

Where thermometers cover a short range that starts well above room temperature, they are usually constructed with a contraction chamber (enlargement of capillary above the bulb) to prevent the mercury from retreating into the bulb when the thermometer is not in use. This type of construction is prone to separations if the instrument is jarred. Often, after rough handling in transit this type of thermometer may come into the laboratory with several separations in the contraction chamber, gas in the bulb, and broken threads of mercury in the capillary. Many users when faced with this problem send the instrument back to the supplier as defective rather than take the chance of breaking it trying to reunite the column. This condition can be rectified easily by exercising a little care coupled with some know-how.

The bulb of this type of thermometer should be examined closely for any small gas bubbles that may have worked their way into it. If this condition exists do not try

to collect the gas by tapping the bulb of the thermometer on a hard surface. By doing this you may cause the gas to splatter into many smaller bubbles and aggravate, rather than alleviate, the condition. Using the cooling method previously outlined, cool a portion of the bulb so that a large bubble of gas enters it. Invert the thermometer so that the bulb is facing up (the thermometer is upside down). Gently tap the thermometer against the palm of your hand so that the gas bubble runs up the length of the bulb. Do not touch the bulb until it has warmed sufficiently so that the mercury is not frozen or the bulb may shatter. The gas, being lighter than the mercury, will always rise to the surface. Roll the thermometer around with it tilted (stem up) so that the gas bubble will come in contact with the surface of the bulb. As the large gas bubble comes in contact with the smaller particles of gas it will pick them up. Continue to roll the thermometer until the large gas bubble has picked up all the smaller gas particles. If the large gas bubble is big enough, it will run readily as you revolve the bulb and tilt it back and forth. Once all the small particles of gas have been collected, you can get the gas above the mercury by following the procedure outlined in Method A.

Separated columns in organic-filled (spirit) thermometers require a somewhat different technique in order to be reunited. The simplest and safest method is to force the liquid down the capillary by using a centrifuge, if one is available, with a cup deep enough to ensure that the centrifugal force is below the liquid column. Carefully insert the thermometer, bulb down, in the centrifuge. Have some cotton wadding at the bottom of the cup to prevent any damage to the bulb. Turn on the centrifuge and in just a few seconds all the liquid will be forced past the separation. If the cup is not deep enough and all the centrifugal force is not below the column, the column will split, forcing part of the liquid down. The remainder will be forced up, filling the expansion chamber. If a centrifuge is not available, the column can be reunited by getting the liquid to run down. This can be accomplished by holding the thermometer in an upright position and gingerly tapping the stem above the separation against the palm of your hand. As you gently tap the thermometer, observe the liquid above the separation and you will see that it breaks away from the wall of the capillary and runs down to join the main column. This method can be employed successfully even if the separation has previously worked its way up and filled the expansion chamber. This procedure should be continued until all the liquid has joined the main column. Before putting the instrument into use, follow the suggestions previously outlined for organic-filled (spirit) thermometers.

CONCLUSION

In conclusion the following are some specific "Do's and Don'ts" for best results when using liquid-in-glass thermometers.

Do's

1. Be sure that the instrument is used for its proper immersion when you are trying to ascertain true temperatures.
2. In choosing an instrument for a particular application, be sure to consider all the governing factors.
3. When using a thermometer in conjunction with a specified method, always use the instrument expressly named and in the exact manner outlined in the method.
4. When using a certified thermometer, always read and follow the applicable notes.
5. When reuniting a separated mercury column, try the cooling method first. It is the safest.

Don'ts

1. Do not apply an open flame to the bulb of a thermometer when reuniting a separated column.
2. Never use the heating method to reunite a separated mercury column of a thermometer whose range exceeds 260°C or 500°F.
3. Do not tap the bulb on a hard surface (use a large rubber stopper).
4. Do not place a heated thermometer on a cold surface, as the instrument may crack.
5. Do not clean the bulb of thermometers with steel wool or other strong abrasives.

REFERENCES

1. Swindells, J. F., "Calibration of Liquid-in-Glass Thermometers," *Natl. Bur. Std. Monograph* **90**, 11–13, February 12, 1965.
2. Swindells, J. F., "Calibration of Liquid-in-Glass Thermometers," *Natl. Bur. Std. Monograph* **90**, 15–17, February 12, 1965.