



Designation: ~~E77-98(Reapproved 2003)~~ Designation: E 77 - 07

Standard Test Method for Inspection and Verification of Thermometers¹

This standard is issued under the fixed designation E 77; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers visual and dimensional inspection, test for permanency of pigment, test for bulb stability, and test for scale accuracy to be used in the verification of liquid-in-glass thermometers as specified in Specification E 1. However, these procedures may be applied to other liquid-in-glass thermometers.²

NOTE 1—The use of NIST SP250-23² is recommended.

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1.2 **Warning-** Mercury has been designated by EPA and many state agencies as a hazardous material that can cause central nervous system, kidney and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Material Safety Data Sheet (MSDS) for details and EPA's website- <http://www.epa.gov/mercury/faq.htm> - for additional information. Users should be aware that selling mercury and/or mercury containing products into your state may be prohibited by state law.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:³

E 1 Specification for ASTM Liquid-in-Glass Thermometers

E 344 Terminology Relating to Thermometry and Hydrometry

3. Terminology

3.1 Definitions:

3.1.1 The definitions given in Terminology E 344 apply. Some that are considered essential to this standard are given below.

3.1.2 *complete-immersion thermometer, n*— a liquid-in-glass thermometer, not specified in ASTM documents, designed to indicate temperature correctly when the entire thermometer is exposed to the temperature being measured.

3.1.3 *partial-immersion thermometer, n*— a liquid-in-glass thermometer designed to indicate temperature correctly when the bulb and a specified part of the stem are exposed to the temperature being measured.

3.1.4 *total-immersion thermometer, n*— a liquid-in-glass thermometer designed to indicate temperature correctly when just that portion of the thermometer containing the liquid is exposed to the temperature being measured.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *calibration, n*—the determination of the indications of a thermometer with respect to temperatures established by a standard resulting in scale corrections to be applied when maximum accuracy is required.

3.2.2 *reference point, n*—a temperature at which a thermometer is checked for changes in the bulb volume.

3.2.3 *verification, n*—the process of testing a thermometer for compliance with specifications.

3.2.4 *verification temperatures, n*—the specified temperatures at which thermometers are tested for compliance with scale error limits.

¹ This test method is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.05 on Liquid-in-Glass Thermometers and Hydrometers.

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² "Liquid-in-Glass Thermometer Calibration Service," NIST Special Publication 250-23, 1988, Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.5 Other descriptions of terms relating to thermometers are included in Sections 3 and 17 of Specification E 1.

4. Significance and Use

4.1 The test method described in this standard will ensure that the thermometers listed in Specification E 1 will indicate temperatures within the maximum scale errors listed, be compatible with the apparatus, and serve the purpose for which they were designed. Fig. 1

4.2 Thermometers that do not pass the visual and dimensional inspection tests may give erroneously high or low temperature readings, or may not fit into existing equipment used in ASTM methods. If the pigment in the scale etchings washes out or fades, the thermometer will be difficult to read. Improper annealing of the bulb, as determined by the bulb stability test, will result in thermometer readings rapidly changing with time and use. For accurate temperature measurements the scale readings of the thermometer should be verified as described in this test method.

5. Apparatus

5.1 *Graduated Metal Scales or Templates*—Maximum and minimum specified linear dimensions are measured with graduated metal sales and templates on which lines are ruled at suitable distances from reference points corresponding to the maximum and minimum values of the several specified dimensions.

5.2 *Micrometers and Ring Gages*—Specified diameters of ASTM thermometers are checked using micrometers, or more conveniently with ring gages consisting of metal plates in which holes have been formed corresponding to the maximum and minimum values of the several specified dimensions. The thickness of such gages should approximate the diameters of the holes to minimize errors resulting from the axis of the thermometer stem being other than normal to the plane of the gage. When specified, diameters may also be checked with conventional snap gages having plane parallel working faces.

5.3 *Comparators*—Comparators are required for verification of scale accuracy of liquid-in-glass thermometers. Suitable types are described in Appendix X1.

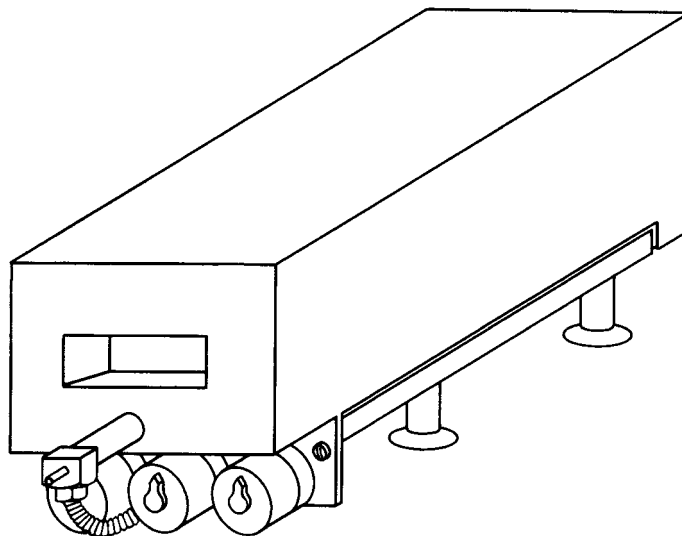
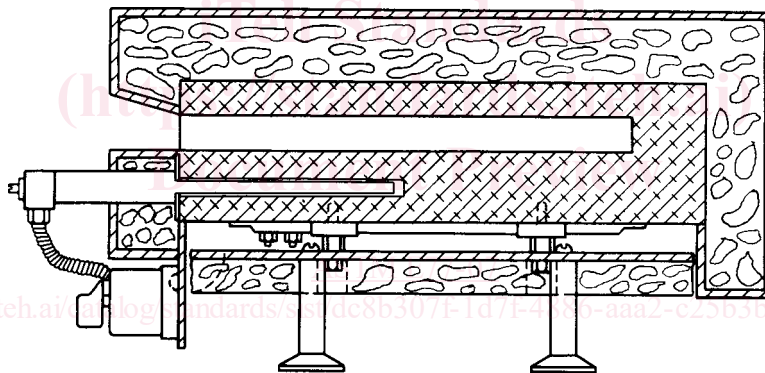


FIG. 1 Oven for Permanency of Pigment Test

5.4 *Oven*—The test for permanency of pigment may be conducted with any suitable oven, such as the type shown in Fig. 1.

5.5 *Metal Block Baths*—The bulb stability test may be conducted with a variety of devices. Metal block baths and the salt and tin comparator baths, described in Appendix X1, are examples of the type of equipment that has been found to be suitable for this purpose.

5.6 *Primary Standard Thermometer*—The primary standard thermometer in the range from -183 to 630 °C (-297 to 1166 °F) is the platinum-resistance thermometer. Temperatures are not measured directly with this instrument. Its electrical resistance is determined by comparison with a standard resistor, using a potentiometer, a Kelvin-type double bridge, or a Wheatstone bridge, (preferably of the Mueller type) or an AC resistance bridge. Temperatures may then be calculated using suitable resistance-temperature equations. In order that it shall be satisfactory for such use, the thermometer should meet the requirement that the ratio of resistances at the steam and ice points shall be greater than 1.3925. More complete information on the construction and use of primary standard thermometers may be obtained from NIST SP250-22.⁴

5.7 *Secondary Standard Thermometers*—Secondary standard thermometers are more suitable for routine work, and may be of various types as described below. They are simpler to use than a primary standard thermometer with its accessory equipment, the latter being capable of an order of precision and accuracy far in excess of that attainable with liquid-in-glass thermometers. The choice of a secondary standard will be governed by various factors. The following criteria should, in so far as possible, be satisfied: The standard should be a calibrated thermometer of equal or preferably higher sensitivity than the thermometer to be verified, and it should be capable of giving results of an equal or preferably higher order of accuracy and also of an equal or preferably higher order of reproducibility or precision. Scale corrections should always be applied in the use of these standards. Secondary standards may be of the following types.

5.7.1 *Direct-Reading Resistance Thermometers*—Direct-reading resistance thermometers are available commercially, are very convenient to use, and have the advantage over the primary type that temperature indications are given directly in the instrument reading. They should be completely recalibrated every 6 to 12 months, depending upon the temperatures of usage. Ice points should be taken every 3 months.

5.7.2 *Liquid-in-Glass Thermometers*—Liquid-in-glass thermometers, when used as secondary standards, may be classified into two groups, those intended for testing general purpose total or partial-immersion thermometers, and those for testing special use partial-immersion thermometers.

5.7.2.1 *Total-Immersion Thermometers*—In the case of general purpose total-immersion thermometers, the sensitivity of the thermometers to be tested will govern the choice of standard. For thermometers graduated in 1, 2, or 5° divisions, a set of well-made thermometers will be adequate when calibrated and used with applicable corrections. For fractionally graduated thermometers a calibrated set of the following thermometers is recommended. Specifications for these ASTM Precision Thermometers appear in Specification E 1.

ASTM Ther- mometer Number	Range	Celsius	Divisions	Length, mm
62C	-38 to	+2°C	0.1°C	380
63C	-8 to	+32°C	0.1°C	380
64C	25 to	55°C	0.1°C	380
65C	50 to	80°C	0.1°C	380
66C	75 to	105°C	0.1°C	380
67C	95 to	155°C	0.2°C	380
68C	145 to	205°C	0.2°C	380
69C	195 to	305°C	0.5°C	380
70C	295 to	405°C	0.5°C	380
ASTM Ther- mometer Number	Range	Fahrenheit	Divisions	Length, mm
62F	-36 to	+35°F	0.2°F	380
63F	18 to	89°F	0.2°F	380
64F	77 to	131°F	0.2°F	380
65F	122 to	176°F	0.2°F	380
66F	167 to	221°F	0.2°F	380
67F	203 to	311°F	0.5°F	380
68F	293 to	401°F	0.5°F	380
69F	383 to	581°F	1.0°F	380
70F	563 to	761°F	1.0°F	380

The foregoing set is calibrated for total immersion. With the exception of the first two, each thermometer is provided with an auxiliary scale including 0 °C (32 °F), thus providing means for checking at a fixed point, which should be done each time the thermometer is used. The change in ice-point reading should then be applied to all readings. It is only necessary to have a

⁴ "Platinum Resistance Thermometer Calibrations," NIST Special Publication 250-22, Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325.

liquid-in-glass thermometer completely calibrated one time. Recalibration is performed as described in 6.5.8.

5.7.2.2 *Partial-Immersion Thermometers*—General purpose partial-immersion thermometers, as commonly listed in manufacturers' catalogs according to their own specifications, are normally bought and sold without specification of the temperatures of the emergent column for the various temperature indications of the thermometers. In such cases, verification is usually carried out for the emergent column temperatures prevailing with the verification equipment being employed.

5.7.2.3 *Special Use Partial-Immersion Thermometers*—Special use partial-immersion thermometers, such as those covered in Specification E 1, have specified emergent mercury columns or stem temperatures. These thermometers can be used as standards to calibrate other thermometers similar in all details of construction above the immersion point, but may differ below the immersion point to the extent of including an auxiliary ice point scale.

5.8 *Engraving Date on ASTM Thermometers*—If a thermometer's specification was changed, the year that it was changed is engraved on the back of the thermometer after the ASTM designation. For example, "12C-98."

6. Procedure

6.1 *Visual Inspection:*

6.1.1 *Gas Bubbles and Separations*—Gas bubbles are readily detected and are more likely to occur in shipment than during service. No method has been discovered that will entirely prevent such displacement of the gas. If bubbles are observed in the bulb, they can generally be removed by cooling the bulb with dry ice or other convenient coolant until all the liquid is drawn into the bulb. Gentle tapping of the thermometer while held upright will cause the bubbles to rise to the surface. It is very important that, if the bulb is cooled in this process below the freezing point of the liquid, care should be exercised to warm the stem sufficiently during the melting process so that no solidification occurs in the stem; otherwise the bulb may burst or the capillary may split internally because of the expansion forces generated in the bulb.

6.1.1.1 If a mercury separation is observed in the stem, several different ways are suggested for joining the columns, depending on the construction of the thermometer and the type of separation. If a small portion of the liquid has separated at the top of the column and the thermometer is provided with an expansion chamber, the liquid usually can be joined by carefully and slowly heating the bulb until the separated portion is driven into the expansion chamber. Never heat the bulb in an open flame. When the column itself follows into the chamber, the separated portion usually will join onto the main column. A slight tapping of the thermometer against the palm of the hand will facilitate this joining. This method should not be employed for high-temperature thermometers (above 260 °C or 500 °F), because the heating of the bulb, which is necessary to drive the liquid into the expansion chamber, may overheat the glass and either break the bulb, because of the pressure of the gas, or destroy the accuracy of the thermometer by expanding the bulb. Thermometers that have a contraction chamber below the lowest graduation are likely to develop separations either in the chamber or above it. It is frequently possible to join such separations by cooling the thermometer so that the separated portion as well as the main column both stand in the chamber. Tapping the tube against the hand or the bulb on a soft spongy material, such as a rubber stopper, usually will bring the liquid together. For more stubborn separations it may be necessary to cool the bulb in dry ice to a point low enough to bring all of the liquid into the bulb itself. By softly tapping on a soft spongy material or against the hand it usually is possible to bring the liquid together in the bulb. The bulb should be allowed to warm up slowly. The liquid should emerge into the bore with no separation.

6.1.1.2 In organic-liquid-filled thermometers distillation may occur, with subsequent condensation of the colorless parent liquid in the upper part of the thermometer. Such thermometers should always be inspected for these separations, which can be repaired by the procedures described above. If the thermometer has an expansion chamber that is observed to be filled with liquid, the column can be reunited by very careful heating of the chamber to drive the liquid into the bore where it can be rejoined to the main body as described above.

6.1.1.3 Organic liquids as used in thermometers, in contrast to mercury, wet the glass. Sufficient time should always be allowed for drainage to occur, particularly when using or verifying such thermometers below 0 °C (32 °F). It is frequently a good practice to immerse only the bulb of the thermometer. This keeps the viscosity of the liquid in the capillary low and aids in hastening drainage.

6.1.2 *Globules of Liquid*—Globules of liquid in the stem, which result from mechanical separation, can normally be rejoined by heating the bulb until the liquid column merges with the globules. If such globules appear to unite and then reappear on cooling the bulb, they are indicative of oxidation of the mercury or the presence of obstructions in the bore, and should result in rejection of the thermometer.

6.1.3 *Foreign Matter*—Foreign matter in the bore can sometimes be detected with the unaided eye, but it is generally convenient to use a magnifying glass of low power for this examination. A magnifier of 10× is recommended for visual examination. The most common types of foreign matter which should be cause for rejection are glass chips, particles of dirt or lint, oxide of mercury (either red, yellow, or black), products of glass weathering commonly called white deposit, and stones or iron spots traceable to faulty glass fabrication.

6.1.3.1 Where a specific gas is specified to be used as filling above the liquid, any other gas present may be treated as foreign matter. The most common example is the use of air instead of nitrogen in mercury-in-glass thermometers, which may have been introduced by accident or in violation of the specifications. The presence of air can readily be detected by exposing the gas-filled portion of the thermometer and a short section of the liquid column to a temperature of 340 to 370 °C (644 to 698 °F), using an oven of the type illustrated in Fig. 1. Under these conditions oxidation of the mercury will occur and will normally be evidenced

by the production of crystals of red oxide of mercury after 10 to 12 h of exposure.

6.1.4 *Glass Faults*—Glass faults may be of various types. Any stones or striae that distort the bore or its appearance should be cause for rejection. Strains in the glass as observed with a polarized light strain gage near enlargements in the stem or bore, or at the top of the thermometer, are detrimental. If so, severe fire cracks may later occur. Strains near the bulb are indicative of incomplete glass stabilization and are particularly objectionable in thermometers for use above 150 °C (302 °F). The test for bulb stability will normally serve to reject high range thermometers in which this defect is most significant.

6.2 *Dimensional Inspection:*

6.2.1 Determine compliance with lineal dimensional specifications by comparison of the thermometer with the appropriate scale or template described in 5.1. In the case of diameter measurements, the bulb or other portions of the thermometer being tested should not enter the smaller of the holes in the ring gage (see 5.2), or fail to enter the larger of the holes. In the case of ASTM thermometers, the diameter limits apply over the entire length of the section of the thermometer being tested.

6.2.2 Inspect the thermometers for uniformity of graduation spacing. Normally, the effect of taper in the capillary or nonlinearity in the expansion characteristics of organic liquids is manifested by a gradual change in the spacing of the graduations. Discontinuities in the spacing are evidence of faulty graduating. Inspection for uniformity of spacing can generally be accomplished by eye, but for greater accuracy a pair of dividers may be used to advantage. Adjust the dividers to extend over 10 or 20 graduations, and successive intervals can be intercompared rapidly. Where marked changes in spacing are noted, it is well to include in the verification several temperatures in that region.

6.3 *Permanency of Pigment:*

6.3.1 The test for permanency of pigment is designed to determine the ability of the pigment material to withstand the exposure conditions encountered in use without being obliterated.

6.3.2 Place any convenient portion of the scale section of the thermometer to be tested in an oven of the type shown in Fig. 1. Heat for 3 h at approximately 260 °C (500 °F). Allow to cool slowly. Inspect the thermometer for differences in appearance of the tested and untested sections of the scale portion. Burning out, loosening, chalking, or fading of the pigment shall be cause for rejection.

6.4 *Bulb Stability:*

6.4.1 The test for bulb stability is designed to determine the adequacy of the stabilizing heat treatment accorded the thermometer bulb during manufacture. An inadequately stabilized bulb will undergo shrinkage with time which may be significant particularly in higher temperatures.

6.4.1.1 Heat the thermometer for 5 min at the temperature specified in 12.1 of Specification E 1 in a preheated bath which may be of the type shown in Fig. 2. Immersion must be sufficient that all of the thermometer bulb is at the specified temperature. Allow the thermometer to cool, either naturally in still air, or slowly in the test bath at a specified rate, to a span of 20° on the Celsius scale (36° on the Fahrenheit scale) above ambient temperature or to 50 °C (122 °F), whichever is the lower, and then determine the reading at some reference point, such as the ice point. If natural cooling in still air is used, determine the reference reading within 1 h. Return the thermometer to the bath, preheated to the temperature of test, and heat for 24 h. Allow the thermometer to cool, at the same rate as at the start of the test, to the temperature referred to above, and redetermine the reference reading under the same conditions as before. The magnitude of any change in this reference reading as a result of the 24-h heating period is a measure of the quality of the bulb glass and the adequacy of the previous heat treatment accorded the thermometer in manufacture.

6.4.2 For kinematic viscosity thermometers used for measuring temperatures at and above 50 °C (122 °F), the following bulb stability test is used.

6.4.2.1 Heat the thermometer to the selected reference point on the main scale, maintain the temperature for at least 15 min, and determine the scale correction at this point.

6.4.2.2 Allow the thermometer to cool slowly in the test bath (or naturally in still air) to at least a span of 20° on the Celsius scale (36° on the Fahrenheit scale) above ambient or to 50 °C (122 °F), whichever is the lower, and then determine the correction after at least 15 min at the ice point. If natural cooling is used, the correction should be determined within 1 h.

6.4.2.3 Heat the thermometer again to the selected reference point on the main scale, keep it at this temperature for 168 h. Allow the thermometer to cool as described in 6.4.2.2 and then repeat the procedures described in 6.4.2.1 and 6.4.2.2. It must be

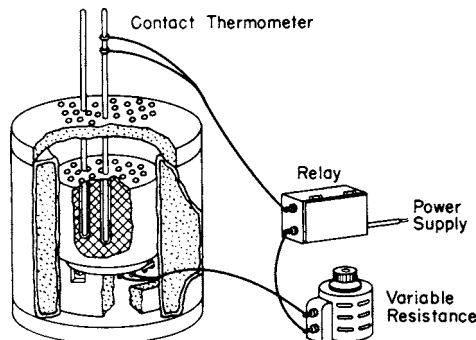


FIG. 2 Air Bath for Bulb Stability Test

emphasized that to obtain meaningful results, the procedure adopted after the 168-h period of heating must be identical to that used in the original calibration.

6.5 Verification of Scale Accuracy :

6.5.1 *Reading Thermometers to Avoid Parallax*—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.

6.5.2 *Depth of Immersion for Total-Immersion Thermometers* —Although by definition total-immersion thermometers should have the bulb and stem containing the mercury immersed both in use and in verification, it is frequently inconvenient to do so. If any portion of the stem containing mercury is exposed, the emergent mercury column correction should be determined. No correction need be applied if it is found to be less than one fifth of the verification error; otherwise, the proper correction should be applied. In some instances total-immersion thermometers may be used under conditions of complete immersion. With thermometers such as the kinematic-viscosity thermometer 30F, a significant error will be introduced unless the thermometer is verified under the same conditions as those in use. This is due to the effect of increased gas pressure above the column producing a distortion of the bulb.

6.5.3 *Depth of Immersion for Partial-Immersion Thermometers* —Thermometers of this type shall be verified by one of the methods described in 6.5.7.2, 6.5.7.3, and 6.5.7.4 using the appropriate comparators. If the thermometer is of the general-purpose type, it should be verified by immersion to the specified depth and the readings compared with those of the secondary standard.

6.5.4 Verification at the Ice Point :

6.5.4.1 Select clear pieces of ice or ice made from distilled or pure 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 the Dewar vessel with the crushed ice and add sufficient distilled, preferably precooled, water to form a slush, but not enough to float the ice. As the ice melts it will be necessary to drain off some of the water and add more crushed ice. Insert the thermometer, packing the ice gently about the stem, to a depth approximately one scale division below the 0 °C (32 °F) graduation.

6.5.4.2 After at least 3 min have elapsed, tap the stem gently and observe the reading. Successive readings taken at least 1 min apart should agree within one tenth of a division. It may be necessary to repack the ice around the thermometer because of melting.

6.5.5 Verification at the Steam Point :

6.5.5.1 If the range of the thermometer is such that the ice point is not included, the steam point at 100 °C (212 °F) can be used. For a description of the equipment and techniques best suited to the purpose, reference may be made to NIST SP250-23.²

6.5.6 Verification of Total-Immersion and General Use Partial-Immersion Thermometers at Temperatures Other Than Fixed Points:

6.5.6.1 Determine the ice point of the primary or secondary standard and the thermometer to be tested as described in 6.5.4. If the secondary standard is of the liquid-in-glass type, it should be held at room temperature for at least 72 h before this determination unless the ice point was originally determined immediately after heating to a specified temperature. The thermometer to be tested should be treated in similar manner.

6.5.6.2 Insert the thermometer to be tested and the standard in the thermometer holder, and adjust the temperature of the comparator to a value approximately 5 °C (10 °F) below the verification temperature. It may be advantageous to use two secondary standard liquid-in-glass thermometers, since observational errors of the standard may then be readily detected. Apply sufficient heat to raise the temperature at a slow uniform rate. At the verification point the rate should not exceed one scale division in 3 to 10 min. Fulfillment of this requirement will ensure that any exposed portion of the stem will have attained thermal equilibrium before readings are taken.

6.5.6.3 When the proper rate of temperature rise has been established, read the thermometers in the following order at equal time intervals: standard, thermometer or thermometers to be tested, standard, thermometers to be tested in reverse order, standard. The average of the first and third readings of the standard should agree with the second. A comparison of differences in successive readings will also indicate if the rate of rise has been uniform.

6.5.6.4 Calculate the average readings for all thermometers. Apply the appropriate corrections to the reading of the standard. Calculate the corrections to be applied to the thermometers under test.

6.5.6.5 For verification purposes, one series of readings is usually sufficient. If the thermometer is being calibrated, check determinations should be made. The results of each of at least three series should agree with the mean of the series within plus or minus one tenth of a division.

6.5.6.6 Unless otherwise specified, tests should be made not less than 40 nor more than 100 divisions apart throughout the range of the thermometer.

6.5.6.7 Comparisons may be made at constant temperature in preference to the use of slowly rising temperatures. Such a procedure is satisfactory if the bath temperature does not vary more than the precision of reading and if the thermometer is jarred, as by tapping, before taking a reading in order to overcome any sticking of the mercury to the glass. Such tapping is particularly important with thermometers having a capillary diameter of the order of 0.1 mm or less and may be employed to advantage in the rising temperature method of test as well. Sufficient time should elapse before taking readings to ensure that all portions of the