

Manual of Petroleum Measurement Standards Chapter 7.1

Temperature Determination— Liquid-in-Glass Thermometers

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Introduction

This section describes how to correctly use various types of liquid-in-glass thermometers to accurately determine the temperatures of hydrocarbon liquids. Other methods, equipment, and procedures for temperature determination are described in the other subsections of *API Manual of Petroleum Measurement Standards (MPMS) Chapter 7*.

Temperature Determination—Liquid-in-Glass Thermometers

1 Scope

This section describes how to correctly use various types of liquid-in-glass thermometers to accurately determine the temperatures of hydrocarbon liquids. Other methods, equipment, and procedures for temperature determination are described in the other subsections of API *MPMS* Chapter 7.

This chapter describes the methods, equipment, and procedures for manually determining the temperature of liquid petroleum and petroleum products with liquid-in-glass thermometers. This chapter discusses temperature measurement requirements in general for custody transfer, inventory control, and marine measurements. The actual method and equipment selected for temperature determination are left to the agreement of the parties involved.

The manual method covers:

- non-pressurized tanks and non-pressurized marine vessels;
- gas-blanketed tanks and gas-blanketed marine vessels.

It does not cover hydrocarbons under pressures in excess of 21 kPa gauge (3 psi gauge) or cryogenic temperature measurement, unless equipped with a thermowell.

The requirements of this chapter are based on practices for crude oils and petroleum products covered by API *MPMS* Ch. 11.1 (ASTM D1250). Requirements in this chapter may be used for other fluids and other applications. However, other applications may require different performance and installation specifications.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 1, *Terms and Definitions*
(<https://chapter1.api.org>)

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 2 (all sections), *Tank Calibration*

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 3 (all sections), *Tank Gauging*

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 8.1, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 9.4, *Continuous Density Measurement Under Dynamic (Flowing) Conditions*

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 11.1, *Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils*

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 12.1.1, *Calculation of Static Petroleum Quantities—Upright Cylindrical Tanks and Marine Vessels*

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 12.2, *Calculation of Petroleum Quantities Using Dynamic Methods and Volumetric Correction Factors*

API Manual of Petroleum Measurement Standards (MPMS) Chapter 15, *Guidelines for the Use of Petroleum Industry-specific International System (SI) Units*

API Manual of Petroleum Measurement Standards (MPMS) Chapter 18.1, *Measurement Procedures for Crude Oil Gathered From Lease Tanks by Truck*

API Recommended Practice 500, *Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1, and Division 2*

API Recommended Practice 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*

API Recommended Practice 3000, *Classifying and Loading of Crude Oil into Rail Tank Cars*

ASTM D1250 ¹, *Standard Guide for the Use of the Joint API and ASTM Adjunct for Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils: API MPMS Chapter 11.1*

ASTM E1, *Standard Specification for ASTM Liquid-in-Glass Thermometers*

ASTM E77, *Standard Test Method for Inspection and Verification of Thermometers*

ASTM E344, *Terminology Relating to Thermometry and Hydrometry*

ASTM E2251, *Standard Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids*

NIST Special Publication 1088 ², *Maintenance, Validation, and Recalibration of Liquid-in-Glass Thermometers*

NFPA 70 ³, *National Electrical Code*

OCIMF ⁴ *International Safety Guide for Oil Tankers and Terminals (ISGOTT)*

3 Terms and Definitions

For the purpose of this document, the following definitions apply. Refer to API MPMS Ch. 1 and ASTM E344 for the definition of additional terms used in this standard.

3.1

degree

3.1.1

degree Celsius

°C

A derived unit of temperature in the International System of Units (SI).

3.1.2

degree Fahrenheit

°F

A non-SI unit of temperature used in the U.S. Customary (USC) system of units. At any temperature, an interval of one degree Fahrenheit is the same as an interval of $\frac{5}{9}$ degree Celsius.

$$^{\circ}\text{F} = (^{\circ}\text{C} * 9/5) + 32$$

¹ American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428, www.astm.org.

² National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899, www.nist.gov.

³ National Fire Prevention Association, 1 Batterymarch Park, Quincy, MA 02169, www.nfpa.org.

⁴ Oil Companies International Marine Forum, 29 Queen Anne's Gate, London SW1H 9BU, UK, www.ocimf.org

3.2

temperature discrimination

The ability to sense and record the actual temperature of a liquid to the specified temperature increments.

3.3

thermometer

A device that measures temperature using any of a variety of different principles. A thermometer has two important components: a temperature sensor in which some physical change occurs that is dependent on temperature, and some means of indicating and/or transmitting this physical change as a value.

3.3.1

liquid-in-glass thermometer

LIGT

A glass thermometer containing mercury or a low-hazard liquid that indicates the temperature being measured.

3.3.2

low-hazard liquid

A liquid that is biodegradable, non-hazardous, and considered non-toxic in quantities specified for the thermometer specification.

3.3.3

mercury-in-glass thermometer

MIGT

A glass thermometer containing mercury that indicates the temperature being measured.

3.3.4

partial-immersion thermometer

A liquid-in-glass thermometer designed to indicate temperatures correctly when the bulb and a specified part of the stem are exposed to the medium being measured.

3.3.5

total-immersion thermometer

A liquid-in-glass thermometer designed to indicate temperatures correctly when just that portion of the thermometer containing the liquid is exposed to the medium being measured.

4 General Precautions

4.1 Safety

4.1.1 General

Safety shall be considered for the specification, installation, and operation of all equipment. Refer to API 500 and NFPA 70 for guidance. When loading liquids that can accumulate static charges, refer to the precautions described in the *International Safety Guide for Oil Tankers and Terminals (ISGOTT)*, *Safety of Life at Sea*, API MPMS Ch. 3, and API 2003. Care must be taken with all liquid-in-glass thermometers to prevent breakage, which will result in a safety hazard. If the liquid in the thermometer is mercury, additional care must be taken.

4.1.2 Mercury Warning

Warning—Mercury has been designated by the U.S. Environmental Protection Agency (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 Safety Data Sheet (SDS) or Material Safety Data Sheet (MSDS) for details and the EPA website <https://www.epa.gov/mercury> for additional information. Users should be aware that selling mercury or products containing mercury, or both, in your state may be prohibited by state law.

5 Units of Measure

For custody transfer, the means of temperature determination should be agreed to among the parties involved. Temperatures referenced in this document are those defined by the International Temperature scale of 1990 (ITS-90). Temperatures may be measured and expressed in degrees Celsius or in degrees Fahrenheit. This standard presents both SI and USC, and either may be implemented. The presentations of both units are for the convenience of the user and are not necessarily exact conversions. The units of implementation are typically determined by contract, regulatory requirement, the manufacturer, or the user's calibration program. Once a system of units is chosen for a given application, it should not be arbitrarily changed. (See API MPMS Ch. 15.)

6 Equipment and Design Requirements

6.1 Liquid-in-Glass Thermometers

6.1.1 General Information

Due to the identified hazards associated with mercury-in-glass thermometers (MIGTs), its use is being phased out. API, in collaboration with the EPA, conducted a comparison study of MIGTs to other liquid-in-glass and digital thermometers in order to provide a comparison of the accuracies of each type of device. The testing indicated that alternative liquid-in-glass thermometers meeting the requirements in ASTM E2251 can be substituted for MIGTs. Annex A provides additional details of the testing that was conducted.

6.1.2 Thermometer Specifications

Glass thermometers include total-immersion thermometers and partial-immersion thermometers (see Figure 1 and refer to ASTM E344). These thermometers should conform to the specifications in ASTM E1 or E2251 for thermometers, or to the National Institute of Standards and Technology (NIST) specifications. Calibration does not have to be done by a national metrology institute (NMI) (e.g. NIST in the United States), but the certified instruments used for the calibration shall be traceable to an NMI.

ASTM thermometers are designed to be either total immersion (thermometer immersed in the medium to be measured to the top of the thermometer liquid column) or partial immersion (thermometer in the medium to be measured to a specific depth marked on the thermometer). Tank thermometers used in conjunction with a cup-case assembly are total-immersion thermometers that are completely immersed into the tank but only a portion of the thermometer is immersed in the cup when read. Testing has shown that the accuracy of the reading is not affected when read quickly after being raised out of the tank.

Operating thermometers that are used in static or dynamic measurement shall be compared on a regular basis (see Section 8) to a temperature standard. The recommended allowable tolerances between the operating thermometer and the NMI traceable thermometer are shown in Table 1 and are provided as a reference for limits considered acceptable for static and dynamic temperature determinations in custody transfer measurement of petroleum and petroleum products.

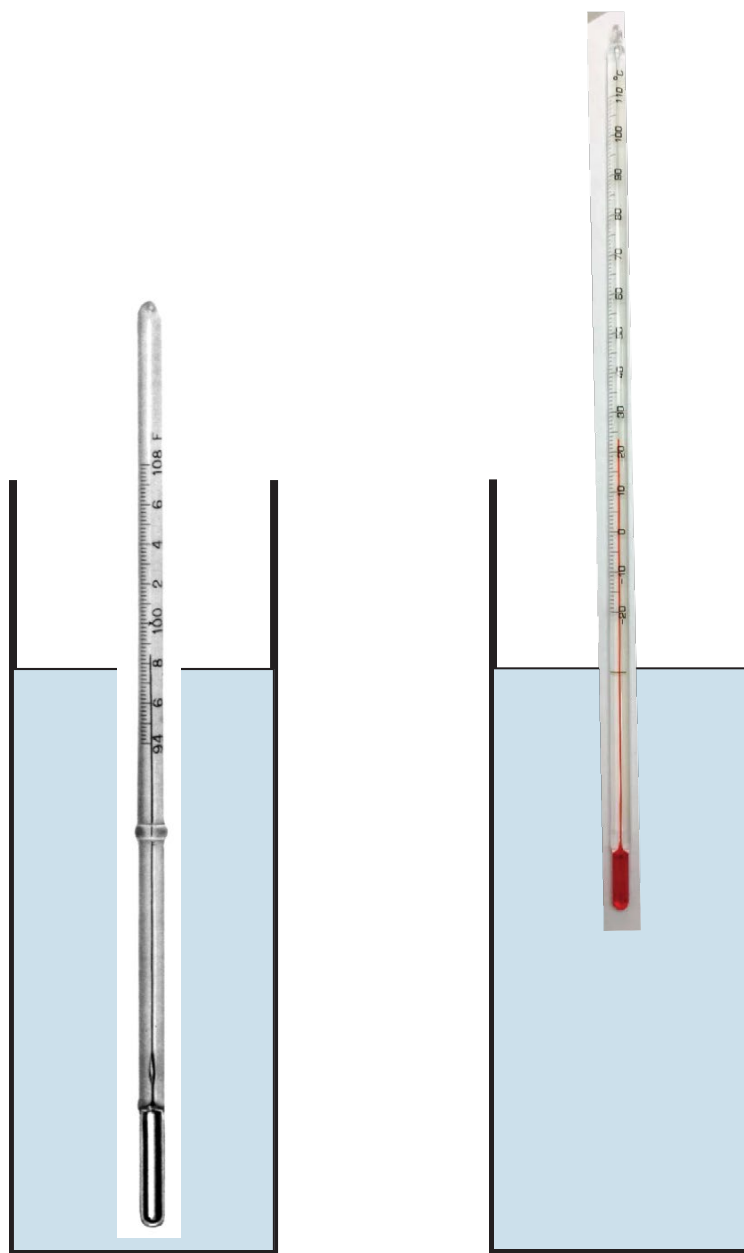
6.1.3 Permanent Glass Thermometers

Securely mount permanently installed glass thermometers in a thermowell and protect from breakage by the use of a housing. They shall have the same high-resolution scale graduation interval and tolerance as glass test thermometers. These thermometers shall be calibrated and checked using test thermometers as described in Section 8.

6.1.4 Tank Thermometers

Tank thermometers shall be of the total immersion type and shall be made in accordance with the specifications in ASTM E1 or E2251. Each thermometer shall be the liquid-in-glass type with nitrogen or another suitable inert gas filling the space above the liquid column and with graduation marks permanently

etched on its glass stem. Angle-stem thermometers may use a separate graduated scale, as discussed in 6.2.3. The thermometers listed in Table 2 shall be used.



Total-immersion Thermometer ^a

Partial-immersion Thermometer ^b

^a The thermometer is designed to indicate correctly when immersed, so that the liquid column meniscus is not more than $\frac{1}{2}$ in. (12 mm) above the liquid surface.

^b The thermometer is designed to indicate correctly when immersed to the immersion ring or mark on the stem.

Figure 1—Types of Glass Thermometers

Table 1—Allowable Tolerances: Operating Thermometer vs Temperature Standard

Service	°C	°F
Ambient temperature measurement	±1	±2
Static measurement	±0.30	±0.5
Quantity transaction record	±0.25	±0.5
Meter proving	±0.25	±0.5
Base prover volume determination	±0.05	±0.1
Density meter proving	*	*
Density meter calibration	*	*

NOTE 1 Tolerances for density meter proving and calibration are fluid and application specific. See API MPMS Ch. 9.4.

NOTE 2 Tolerances are for the specific service (from the applicable API MPMS Chapters), not the accuracy of the thermometer used.

NOTE 3 Quantity transaction record refers to a measurement ticket.

Table 2—Tank Thermometers

Name	ASTM Thermometer	Range	Graduation	Accuracy
ASTM tank	58C-86	−34 °C to +49 °C	0.5 °C	+0.3 °C
ASTM tank	58F-86	−30 °F to +120 °F	1 °F	+0.5 °F
ASTM tank	S58C-11	−34 °C to +49 °C	0.5 °C	+0.3 °C
ASTM tank	S58F-11	−30 °F to +120 °F	1 °F	+0.5 °F
ASTM tank	59C-86	−18 °C to +82 °C	0.5 °C	+0.3 °C
ASTM tank	59F-86	0 °F to +180 °F	1 °F	+0.5 °F
ASTM tank	S59C-03	−18 °C to +82 °C	0.5 °C	+0.3 °C
ASTM tank	S59F-03	0 °F to +180 °F	1 °F	+0.5 °F
ASTM tank	60C-86	77 °C to +260 °C	1 °C	+0.5 °C
ASTM tank	60F-86	170 °F to +500 °F	2 °F	+1.0 °F
ASTM tank	97C-86	−18 °C to +49 °C	0.5 °C	+0.3 °C
ASTM tank	97F-86	0 °F to +120 °F	1 °F	+0.5 °F
ASTM tank	98C-86	16 °C to +82 °C	0.5 °C	+0.3 °C
ASTM tank	98F-86	60 °F to +180 °F	1 °F	+0.5 °F
ASTM tank	130C-90	−7 °C to +105 °C	0.5 °C	+0.5 °C
ASTM tank	130F-90	20 °F to +220 °F	1 °F	+1.0 °F
ASTM tank	S130C-10	−7 °C to +105 °C	0.5 °C	+0.5 °C
ASTM tank	S130F-10	20 °F to +220 °F	1 °F	+1.0 °F
Angle-stem	—	Suitable range	1 °F	+1.0 °F
Tank thermometer ^a	—	20 °F to 220 °F	1 °F	+0.5 °F

NOTE 1 ASTM thermometer designations that start with S (e.g. S58C-11) are liquid-in-glass thermometers with low-hazard liquid (ASTM E2251).

NOTE 2 Except for the angle-stem thermometer, all of the thermometers listed in this table are the total immersion type.

NOTE 3 Length of all thermometers, except angle-stem, is 300 mm to 305 mm (12 in.).

NOTE 4 Length of angle-stem thermometer graduated portion is 300 mm to 305 mm (12 in.).

^a This thermometer does not have an ASTM designation, but it is commonly used for certain heated materials.

6.1.5 Dynamic Measurement Thermometers

ASTM E1 glass thermometers that meet the discrimination requirements for dynamic measurement are shown in Table 3. These glass thermometers are designed and calibrated for immersion to the scale level corresponding to the temperature of the liquid. These thermometers normally have scale graduations of either 0.1 °C or 0.5 °C (0.2 °F or 1.0 °F) and a tolerance of either ± 0.1 °C or ± 0.25 °C (± 0.2 °F or ± 0.5 °F). When used in a manner other than total immersion, errors may occur due to the differential expansion of the glass and liquid column in the stem.

When used for meter prover calibration and for checking and calibrating temperature devices used for meter proving, potential scale errors and stem corrections shall be analyzed and corrections should be applied. Normally, stem corrections are not significant unless the difference between the average stem temperature and liquid temperature is greater than 8 °C (15 °F). Consider the stem correction on a case-by-case basis. Annex B provides information about the methods for stem correction.

Table 3—Dynamic Temperature Thermometers

Name	ASTM Thermometer	Range	Graduation	Accuracy
ASTM tank	58C-86	−34 °C to +49 °C	0.5 °C	+0.3 °C
ASTM tank	58F-86	−30 °F to +120 °F	1 °F	± 0.5 °F
ASTM tank	59C-86	−18 °C to +82 °C	0.5 °C	± 0.3 °C
ASTM tank	59F-86	0 °F to +180 °F	1 °F	± 0.5 °F
ASTM precision	63C-86	−8 °C to +32 °C	0.1 °C	± 0.1 °C
ASTM precision	63F-86	+18 °F to +89 °F	0.2 °F	± 0.2 °F
ASTM precision	64C-86	+25 °C to +55 °C	0.1 °C	± 0.1 °C
ASTM precision	64F-86	+77 °F to +131 °F	0.2 °F	± 0.2 °F
ASTM precision	65C-86	+50 °C to +80 °C	0.1 °C	± 0.1 °C
ASTM precision	65F-86	+122 °F to 176 °F	0.2 °F	± 0.2 °F
NOTE 1 Length of all “ASTM tank” thermometers is 300 mm to 305 mm (12 in.).				
NOTE 2 Length of all “ASTM precision” thermometers is 374 mm to 384 mm (15 in.).				
NOTE 3 The name designations “ASTM tank” and “ASTM precision” are the names designated in ASTM E1.				

6.2 Liquid-in-Glass Thermometer Assemblies

6.2.1 Cup-case Assembly

The cup-case assembly, as shown in Figure 2, is constructed of either varnished hardwood or non-sparking, corrosion-resistant material. It shall have a cup with a capacity of at least 100 mL (6.1 in.³) and with dimensions such that the side of the bulb will be at least 9.5 mm (³/₈ in.) from the nearest wall and the bottom of the bulb will be 25.4 mm ± 5.0 mm (1 in. $\pm$ ³/₁₆ in.) above the bottom of the cup. The thermometer shall be a total-immersion thermometer from Table 2.

6.2.2 Armored-case Assembly

Make the armored-case assembly shown in Figure 3 of non-sparking, corrosion-resistant tubing that does not exceed 13 mm (³/₁₆ in.) in outside diameter. Either total- or partial-immersion thermometers may be used in armored-case assemblies, but care must be taken to keep the assembly immersed to the proper level in the liquid when the thermometer is read.

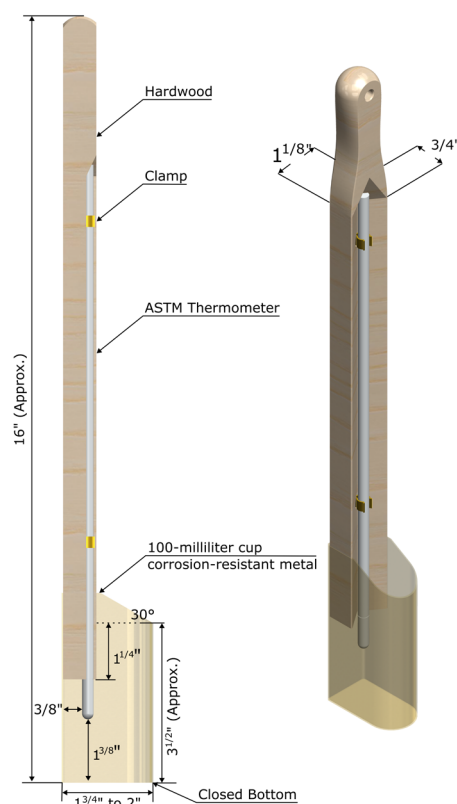


Figure 2—Typical Cup-case Assembly

6.2.3 Angle-stem Assembly

The angle-stem thermometer in Figure 4 is installed in a standard metal-separable well or socket in a tank. For vertical tanks with capacities greater than 795 m³ (5000 bbl), the glass stem of the thermometer shall be at least 0.9 m (3 ft) long, excluding the graduated portion, and shall be protected with a light metal tube. For storage tanks with capacities less than 795 m³ (5000 bbl), the stem may be 0.3 m (1 ft) long, excluding the graduated portion, and also shall be protected with a light metal tube. The sensitive portion of the thermometer shall not exceed 60 mm (2.5 in.), and the stem may have an angle of 90° or greater to conform to the contour of the tank shell.

Attach the assembly to the well by a threaded coupling. A thermometer with a separate graduated scale is acceptable as long as the markings on the scale are permanently engraved and temperature lines at approximately 27 °C (80 °F) intervals are etched on the glass stem of the thermometer to coincide with the corresponding lines on the scale.

In addition to applications discussed in this section, angle-stem thermometers may be used in pipeline metering and prover applications to measure the temperature of the proving medium but shall not be used for custody transfer measurement.

6.3 Thermowells

6.3.1 General

The use of thermowells is required in dynamic temperature measurement to isolate the liquid material from the temperature sensor. There are two general classification types of thermowells: test wells and sensor wells.

6.3.2 Test Thermowells

Test wells are thermowells installed for occasional use (temperature checking) and capped when not in use. Test wells shall be installed adjacent to sensor wells. A suggested location is within three (3) pipe diameters (maximum to be determined by company policy), between the test well and sensor well. Capping prevents foreign material from accumulating in the well bore. The test well should be the same type as the sensor well which is used for the working device, but as a minimum the test well shall have the same insertion length and a bore large enough to allow the use of a liquid-in-glass thermometer. A clogged thermowell may cause measurement errors and may damage thermometers. It is recommended that thermowells be checked periodically for an accumulation of foreign material and cleaned if needed.

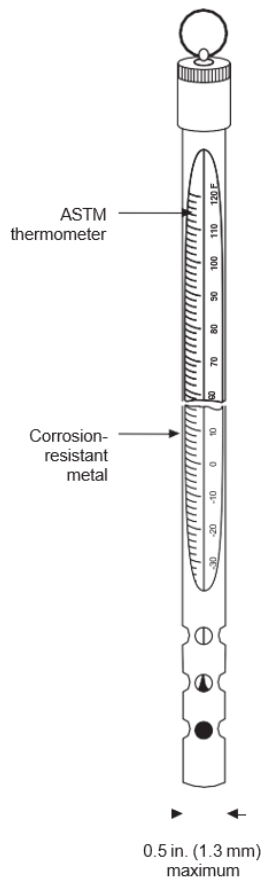
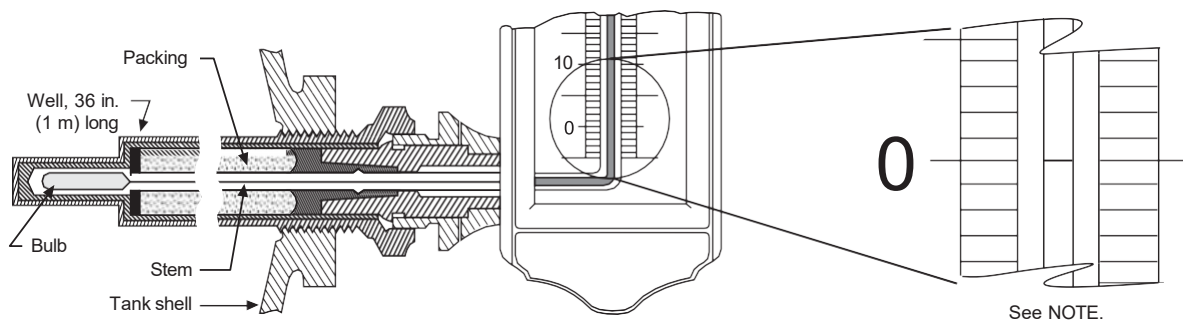


Figure 3—Typical Armored-cased Assembly



NOTE The etched reference line on the glass must be aligned with zero on the scale.

Figure 4—Typical Angle-stem Thermometer