Manual of Petroleum Measurement Standards Chapter 7—Temperature Determination

Section 4—Static Temperature Determination Using Fixed Automatic Tank Thermometers

FIRST EDITION, DECEMBER 1993

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

Manual of Petroleum Measurement Standards Chapter 7—Temperature Determination

Section 4—Static Temperature Determination Using Fixed Automatic Tank Thermometers

Measurement Coordination

FIRST EDITION, DECEMBER 1993

American
Petroleum
Institute

SPECIAL NOTES

1. API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE, AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

2. API IS NOT UNDERTAKING TO MEET THE DUTIES OF EMPLOYERS, MANUFACTURERS, OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHERS EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

3. INFORMATION CONCERNING SAFETY AND HEALTH RISKS AND PROPER PRECAUTIONS WITH RESPECT TO PARTICULAR MATERIALS AND CONDITIONS SHOULD BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

4. NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

5. GENERALLY, API STANDARDS ARE REVIEWED AND REVISED, REAFFIRMED, OR WITHDRAWN AT LEAST EVERY FIVE YEARS. SOMETIMES A ONE-TIME EXTENSION OF UP TO TWO YEARS WILL BE ADDED TO THIS REVIEW CYCLE. THIS PUBLICATION WILL NO LONGER BE IN EFFECT FIVE YEARS AFTER ITS PUBLICATION DATE AS AN OPERATIVE API STANDARD OR, WHERE AN EXTENSION HAS BEEN GRANTED, UPON REPUBLICATION. STATUS OF THE PUBLICATION CAN BE ASCERTAINED FROM THE API AUTHORING DEPARTMENT [TELEPHONE (202) 682-8000]. A CATALOG OF API PUBLICATIONS AND MATERIALS IS PUBLISHED ANNUALLY AND UPDATED QUARTERLY BY API, 1220 L STREET, N.W., WASHINGTON, D.C. 20005.

FOREWORD

This standard covers the standard practice for temperature measurement of liquid hydrocarbons by automatic tank temperature (ATT) equipment. This standard supersedes all applicable sections of API Standard 2543, *Standard Method of Measuring the Temperature of Petroleum and Petroleum Products* (October 1965).

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to Measurement Coordination, Industry Services Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

COMMITTEE ON STATIC PETROLEUM MEASUREMENT
WORKING GROUP ON TEMPERATURE DETERMINATION

K. W. Mei, Chairman
Chevron Research & Technology Company
Richmond, California

C. S. Ash
BP America Incorporated
Cleveland, Ohio

F. J. Berto
Consulting Engineer
San Anselmo, California

J. R. Owen
Phillips 66 Company
Sweeny, Texas

R. S. Petersen
Texaco Trading & Transportation
Oklahoma City, Oklahoma

R. P. Piccone
Sarasota Measurement & Control
Sarasota, Florida

H. Bührmann
B.V. Enraf-Nonius Delft
Delft, Holland

G. Tyson
Beacon Electronics
Egg Harbor, New Jersey

K. Wilson
Arco Products Company
South Gate, California

CONTENTS

Chapter 7—Temperature Determination

SECTION 4—STATIC TEMPERATURE DETERMINATION USING FIXED AUTOMATIC TANK THERMOMETERS

1.0 Scope

This standard covers the static determination of temperatures of petroleum and petroleum products in stationary aboveground bulk storage tanks using fixed automatic tank temperature (ATT) systems that include precision temperature sensors, field-mounted transmitters for electronic signal transmission, and readout equipment. This standard discusses temperature measurement in general, the requirements for custody transfer, and inventory control applications. It also discusses the requirements for data collection, transmission, and receiving. Appendix A of this standard describes local reading thermometers.

This standard does not cover the determination of temperature for hydrocarbons having a Reid vapor pressure above 15 pounds per square inch absolute (101 kPa).

Safety and material compatibility precautions should be taken into consideration when using fixed ATT systems. The manufacturer's recommendations on the use and installation of the equipment should be followed. Users of fixed ATT systems should comply with all applicable codes, regulations, and API standards and the *National Electric Code* (NEC).

2.0 Referenced Publications

The following standards and codes are cited in this standard.

API

Manual of Petroleum Measurement Standards

Chapter 3.1B, "Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging"

Chapter 7.1, "Static Temperature Determination Using Mercury-in-Glass Tank Thermometers"

Chapter 7.3, "Static Temperature Determination Using Portable Electronic Thermometers"

RP 500 *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities*

RP 2003 *Protection Against Ignition Arising Out of Static, Lightning, and Stray Currents*

NFPA[1]

NFPA 70 *National Electric Code*

[1]National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

3.0 General

This section applies to all types of automatic tank temperature (ATT) systems. Safety precautions are listed separately from general precautions that affect accuracy or performance.

3.1 Safety Precautions

3.1.1 GENERAL

These safety precautions represent good practices. This list is not necessarily complete or comprehensive. Refer also to the safety precautions described in API Recommended Practice 2003.

3.1.2 PHYSICAL CHARACTERISTICS AND FIRE CONSIDERATIONS

Personnel involved with the handling of petroleum-related substances (and other chemical materials) should be familiar with their physical and chemical characteristics, including their potential for fire, explosion, or chemical reaction. They should be familiar with the appropriate emergency procedures to follow in such cases. They should comply with individual company safe operating practices and with local, state, and federal regulations, including the use of proper protective clothing and equipment. Personnel should be alert to avoid potential sources of ignition and should keep containers of materials closed when not in use.

INFORMATION REGARDING PARTICULAR MATERIALS AND CONDITIONS SHOULD BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

3.1.3 TANK ENTRY

Before a tank that has contained hydrocarbon liquids, vapor, or toxic materials is entered, all lines to the tank shall be disconnected or blinded, and a gas-free certificate should be obtained.

3.1.4 HAZARDOUS AREAS

All regulations covering entry into hazardous areas shall be observed. Electric equipment for use in electrically classified areas shall meet the area classification. Refer also to API Recommended Practice 500 and API Recommended Practice 2003 for more information.

3.1.5 MAINTENANCE

All ATT equipment shall be maintained in safe operating condition and shall be in compliance with the manufacturer's recommendations.

3.1.6 ENVIRONMENT

All ATT equipment shall be capable of withstanding the pressure, temperature, and other environmental conditions likely to be encountered in service.

3.2 General Precautions

The following general precautions affect the accuracy and performance of all types of ATT systems. These precautions should be observed where they are applicable.

3.2.1 TANK LEVELS

When tank volume information is needed, the tank level should be measured at the same time the tank temperature is measured.

3.2.2 RECORDING TEMPERATURES

Temperatures should be recorded as soon as they are taken, unless the remote readout of the ATT system automatically records the temperatures periodically.

3.2.3 OPENING AND CLOSING GAUGES

The same procedures should be used to measure a tank temperature before the product transfer (opening gauge) and after the product transfer (closing gauge).

3.2.4 SLUDGE AND WATER BOTTOMS

The temperature elements should be located so that the temperature of the sludge deposits or water bottoms in the tank is not measured.

3.2.5 COMPATIBILITY

To avoid both product contamination and equipment corrosion, all parts of the ATT equipment in contact with the product should be compatible with the product. The ATT equipment should be designed to meet the operating conditions.

3.3 Accuracy Limitations of Tank Temperature Measurements

3.3.1 GENERAL

The accuracy of petroleum temperatures taken by the ATT system should be consistent with the accuracy of the levels taken by the automatic tank gauging (ATG) system so that the overall accuracy of the standard volume measurement is not seriously degraded.

The accuracy of an ATT system depends on the following conditions:

a. The tank temperature stratification and the location of the temperature sensing elements.
b. The resistance or temperature characteristics of the resistance temperature detector (RTD).
c. The accuracy of the ATT system readout equipment.

3.3.2 SINGLE-POINT TANK TEMPERATURE MEASUREMENT

The single-point or spot tank temperature measurement should only be used when the temperature of the liquid in the tank is considered to be uniform or when the temperature stratification in the tank is considered small and, therefore, acceptable. Small tanks (less than 5,000 barrels), tanks storing a uniform temperature material, and tanks with adequate mixing equipment have less temperature stratification. Therefore, a single-point temperature measurement may be sufficiently representative.

3.3.3 AVERAGE TANK TEMPERATURE MEASUREMENT

Temperatures in large tanks (5,000 barrels or larger) are normally stratified unless the tank contents are thoroughly mixed. Vertical temperature differences of as much as 5°F or 3°C are normal, and differences of 10°F or 5°C are not uncommon. In the horizontal direction, the temperature differences are typically less than 1°F or 0.5°C for low and medium viscosity petroleum liquids. Somewhat higher differences may be expected in high viscosity petroleum liquids.

The horizontal temperature differences that occur adjacent to the tank shell do not have a significant effect on the average tank temperature.

For custody transfer measurement, when automatic tank gauges (ATGs) that measure level are used (for example, float-operated ATGs, servo-operated ATGs, or radar ATGs), an average temperature (not a single-point temperature) should be used.

In tanks with vertical temperature stratification, the temperature gradient is rarely linear. An average temperature is needed for custody transfer. The mid-level temperature of the tank contents might not give an accurate average temperature.

When hydrostatic tank gauges (HTGs) are used, which compute standard volume using pressure sensors, a single temperature sensor, located about halfway between the lower pressure sensors, may be adequate.

Note: It is possible to determine the average temperature by a single-point (spot) temperature element located on the outlet of a tank, using the ATG to calculate a volume-weighted average temperature of a parcel being loaded into or discharged out of the tank. Applications of this alternate method include loading of marine vessels from bulk storage tanks.

3.4 Use of an ATT System for Custody Transfer or Inventory Control

3.4.1 GENERAL

An ATT system may be used for either custody transfer or inventory control purposes. The use of an ATT system for custody transfer normally requires mutual contractual agreement between the buyer and the seller and may be subject to federal, state, or local regulations.

3.4.2 SELECTION OF ATT EQUIPMENT

For custody transfer temperature measurement, local direct- reading thermometers are not recommended. Copper or platinum temperature element bulbs, that is, resistance temperature detectors (RTDs), are normally used for this application.

The selection of a single point (spot), a mid-level temperature element, multiple RTDs, or an averaging temperature element should be made based on the expected tank temperature stratification and the accuracy requirements (custody transfer versus inventory control).

3.4.3 CALIBRATION PROCEDURES

The ATT system, including the temperature element or elements, the transmitter, and the readout, selected for custody transfer temperature measurement should meet the tolerances defined in 6.0.

For inventory control and accounting temperature measurements, less stringent calibration procedures and tolerances may be used depending upon the requirements of the user or the regulations.

3.4.4 REMOTE READOUT CUSTODY TRANSFER

The remote readout of an acceptable ATT system may be used for custody transfer provided the whole system, including the remote readout, complies with the required calibration tolerances.

3.4.5 SEALING CALIBRATION ADJUSTMENT

To prevent unauthorized adjustment or tampering, ATT systems used for custody transfer should provide facilities to allow sealing the calibration adjustment and should provide for data security.

4.0 Automatic Tank Temperature System Equipment

4.1 General

An ATT system typically consists of temperature element(s), fixed thermowell(s), and telemetry and readout equipment.

As described in Appendix A, most aboveground bulk storage tanks are equipped with at least one local direct-reading thermometer mounted in a fixed thermowell. This local thermometer is not considered part of the ATT system, and it is not recommended for custody transfer temperature determination.

4.2 Electronic Temperature Elements

4.2.1 RESISTANCE TEMPERATURE DETECTORS (RTD)

Copper or platinum electrical-resistance bulbs or RTDs are normally used for custody transfer temperature measurement because of their high accuracy and stability. The resistance of an RTD is measured by a Wheatstone bridge circuit or other suitable electronic package. The RTD may be a resistance wire wound on a supporting nonconductive core, a thin film type, or other type. The element should be properly encased in a stainless steel enclosure. The electronic circuits should be intrinsically safe as required. The temperature element is threaded into the thermowell. The length of the temperature sensitive portion of a single-point (spot) element should not exceed 4 inches (100 millimeters).

4.2.2 OTHER TEMPERATURE ELEMENTS

Other types of temperature elements (thermocouples, thermistors, semiconductors, and so forth) are also available. However, unless they are specially calibrated, their accuracy is normally suitable for inventory control but not for custody transfer.

4.3 Installation of Temperature Elements

4.3.1 SINGLE-POINT (SPOT) TEMPERATURE ELEMENTS

Single-point (spot) temperature elements should be installed close to a gauging hatch. The following methods of installation are in general use:

a. Installed in a metal thermowell through the tank shell, projecting at least 36 inches (900 millimeters) into the tank, at an elevation of at least 36 inches (900 millimeters) from the tank bottom.

b. Installed suspended from the tank roof in a suitable metallic or nonmetallic tube or hose secured to the tank bottom or stabilized by anchor weights. The element should be located approximately 36 inches (900 millimeters) from the tank shell and the low point at an elevation of approximately 36 inches (900 millimeters) from the tank bottom.

Adequate clearance should be provided between the sensor assembly and the thermowell for ease of installation. To prevent measurement errors due to thermal convection circu-

lation in the gap between the thermowell and the sensor assembly, the well may be filled with a heat conductive fluid. Adequate thermal expansion for the fill fluid should also be provided.

c. Installed by either attaching the temperature element to the flexible elbow of the swing suction line or by suspending the element on a pulley arrangement from the floating roof (see 4.3.2.4).

4.3.2 MULTIPLE SPOT AND AVERAGING TEMPERATURE ELEMENTS

The installation of the temperature elements for fixed averaging temperature equipment should conform to the same requirements as those for single-point or spot temperature elements. The configurations described in 4.3.2.1 through 4.3.2.4 are in general use.

4.3.2.1 Upper, Middle, and Lower Temperature Elements

The upper temperature element is suspended about 3 feet (1 meter) below the liquid surface. The mid-level temperature element is suspended at the mid-point of the liquid. This can be accomplished either by attaching the element to the flexible elbow of the swing suction line or by suspending the element on a pulley arrangement. The lower temperature element is installed about 3 feet (1 meter) from the tank bottom. The resistances of the three elements are electrically combined, or their readings averaged, to give the average temperature.

4.3.2.2 Multiple Spot Temperature Elements

Multiple spot temperature elements are installed at approximate 10-foot (3-meter) intervals with the lowest element approximately 3 feet (1 meter) from the bottom of the tank, as shown in Table 1.

In fixed-roof tanks, the elements may be installed in thermowells extending through the tank shell. In floating-roof or internal floating (pan-roof) tanks, the elements may be installed in a special slotted temperature standpipe or similar device passing through a proper sleeve or bushing. All temperatures are generally measured and transmitted to a central temperature readout device with computing ability integral to the ATG system. The temperature readout device averages only the submerged elements. Alternatively, the device may transmit the individual temperatures of the submerged elements to provide a vertical profile of the temperature. A typical multiple point temperature element installation is shown in Figure 1.

Table 1—Elevation of Temperature Elements

Tank Heights	Number of Elements	Element Elevation
<30 ft (9 m)	4	3 ft (1 m), 40%, 60%, 80%
30 ft (9 m) to 50 ft (15 m)	5	3 ft (1 m), 20%, 40%, 60%, 80%
>50 ft (15 m)	6	3 ft (1 m), 20%, 35%, 50%, 65%, 80%

Note: The number of temperature elements and the locations shown are a suggested minimum. This minimum generally meets the criteria of providing a single mid-level temperature where the oil level is 10 feet (3 meters) or less and providing an upper, middle, and lower temperature where oil levels are greater than 10 feet (3 meters). This information is also given in Table 3 of API Chapter 7.1.

4.3.2.3 Variable Length RTD Temperature Elements

A number of RTDs of varying lengths, all of which extend from the bottom of the tank, are encased in a flexible sheath. Only the longest, fully submerged RTD is used to determine the average temperature of the liquid in the tank. The correct RTD is selected either by a switching device in the ATG or by software in the ATG system's remote readout device (typically a computer). The multiple element assembly can be installed in the tank in a closed thermowell that is filled with heat conductive oil or directly immersed in the liquid and suspended from the tank roof or gauging platform. A typical variable length RTD temperature element installation is shown in Figure 2.

Table 2 shows the nominal lengths of elements in a typical variable length RTD temperature element system. The number of elements contained in the RTD should be such that the longest element is less than the maximum liquid level in the tank.

4.3.2.4 Mid-Level Temperature Element

A mid-level temperature element is a single temperature element suspended at the mid-point of the liquid. This can be accomplished either by attaching the element to the flexible elbow of the swing suction line or by suspending the element on a pulley arrangement from the floating roof.

Note: The mid-level temperature might not be the tank average temperature.

Calibration of a mid-level temperature element-based ATT system is the same as for a single-point temperature element-based ATT system.

Table 2—Nominal Lengths of Elements of a Typical Variable Length RTD Temperature Element System

0–3 feet (0.91 meters)	0–20 feet (6.1 meters)
0–5 feet (1.52 meters)	0–26 feet (7.92 meters)
0–7 feet (2.13 meters)	0–32 feet (9.75 meters)
0–10 feet (3.0 meters)	0–40 feet (12.19 meters)
0–14 feet (4.27 meters)	0–50 feet (15.24 meters)

Note: In practice, the sensitive portion of the element is 6 inches less than shown above so that the lowest 6 inches in the tank is not measured.

4.4 Thermowells for Fixed Electronic Temperature Elements

Thermowells for fixed electronic temperature elements should extend through the tank shell for at least 36 inches (900 millimeters) to reduce errors due to temperature differences between the liquid in the tank and the ambient conditions. The thermowell material should be compatible with the liquid product. Usually Type 304 or 316 stainless steel is specified.

The thermowells should be located near the ladder or stairway to facilitate maintenance and located as far as possible from the heating coils and the tank inlet and outlet.

Thermowells extending through the tank shell cannot be used on floating-roof or pan-roof tanks above the minimum roof height. Various proprietary thermowells are available to support averaging temperature elements in floating-roof or pan-roof tanks.

4.5 Telemetry and Readout Equipment

The same kind of electronic temperature readout equipment and wiring practices used for the refinery process unit temperatures can be used for tank temperature readouts. However, in a large tank farm, the cost of direct wiring the elements to the tank farm central control house may be excessive. Normal practice is to transmit temperature information using the wiring network provided for the remote reading ATG level transmitters.

The majority of the commonly used ATG equipment provides field converters to convert RTD resistances into data transmission codes of various formats. These field converters permit the ATG field multiplexers or field selectors to transmit both level and temperature information.

The temperature elements, field converters, field multiplexer or selectors, and ATG readout equipment are all proprietary to the ATG systems.

Commonly used modern ATG equipment provides readout equipment to display and log both levels and temperatures. This readout equipment can determine average temperatures either by selecting the appropriate longest, fully submerged variable length RTD or by averaging the appropriate submerged spot elements.

This readout equipment can usually be programmed to alarm on high or low temperatures. It can also look up the tank capacity table, apply the appropriate expansion coefficients, and calculate the standard volumes.

5.0 Procedures

5.1 Timing

When tank volume information is needed, tank temperatures should be measured at the same time the liquid level is measured.

5.2 Reporting Temperatures

5.2.1 LOCAL READING THERMOMETERS

For every custody transfer, the fixed dial thermometer or mercury-in-glass thermometer described in Appendix A should be read and recorded to the nearest 1°F or 0.5°C. This temperature provides a rough check against major errors.

5.2.2 FIXED ATT SYSTEM RTD THERMOMETERS

Fixed remote-reading RTD thermometers should be read and recorded to the nearest readout graduation (typically 0.1°F or °C). If the ATT readout equipment does not perform temperature averaging, then average tank temperatures should be calculated from the multiple readings.

6.0 Calibration

6.1 General

The precision electronic temperature elements and field transmitters used for fixed automatic tank temperature measurement are factory calibrated. The transmitters normally do not provide field calibration adjustments.

The purpose of the following calibration procedures is to verify the adequacy of the factory calibration and the accuracy of the ATT system (including the temperature elements, the transmitter, and the local or remote readout equipment) as installed.

The accuracy of each component in an ATT system (that is, the temperature elements, the transmitters, and the remote readout equipment) is normally better than the accuracy of the calibration device or test equipment used for field verification. The calibration tolerances set forth in this standard reflect the accuracy limitations of this field verification equipment.

The calibration reference for an ATT system should be certified by or traceable to the National Institute of Standards and Technology (NIST).

6.2 Calibration of Single-Point or Mid-Level Temperature Element ATT Systems

6.2.1 FACTORY CALIBRATION

Single-point or mid-level ATT systems should be calibrated in one of the following ways:

a. The ATT system (including the temperature sensors, the temperature transmitter-converter, and the readout) as a whole is calibrated with constant temperature baths, at three or more temperatures covering the operating range. The temperature measured by the ATT system and the bath temperature that is measured by reference thermometers should be calibrated to within ± 0.50°F or 0.25°C at each temperature.

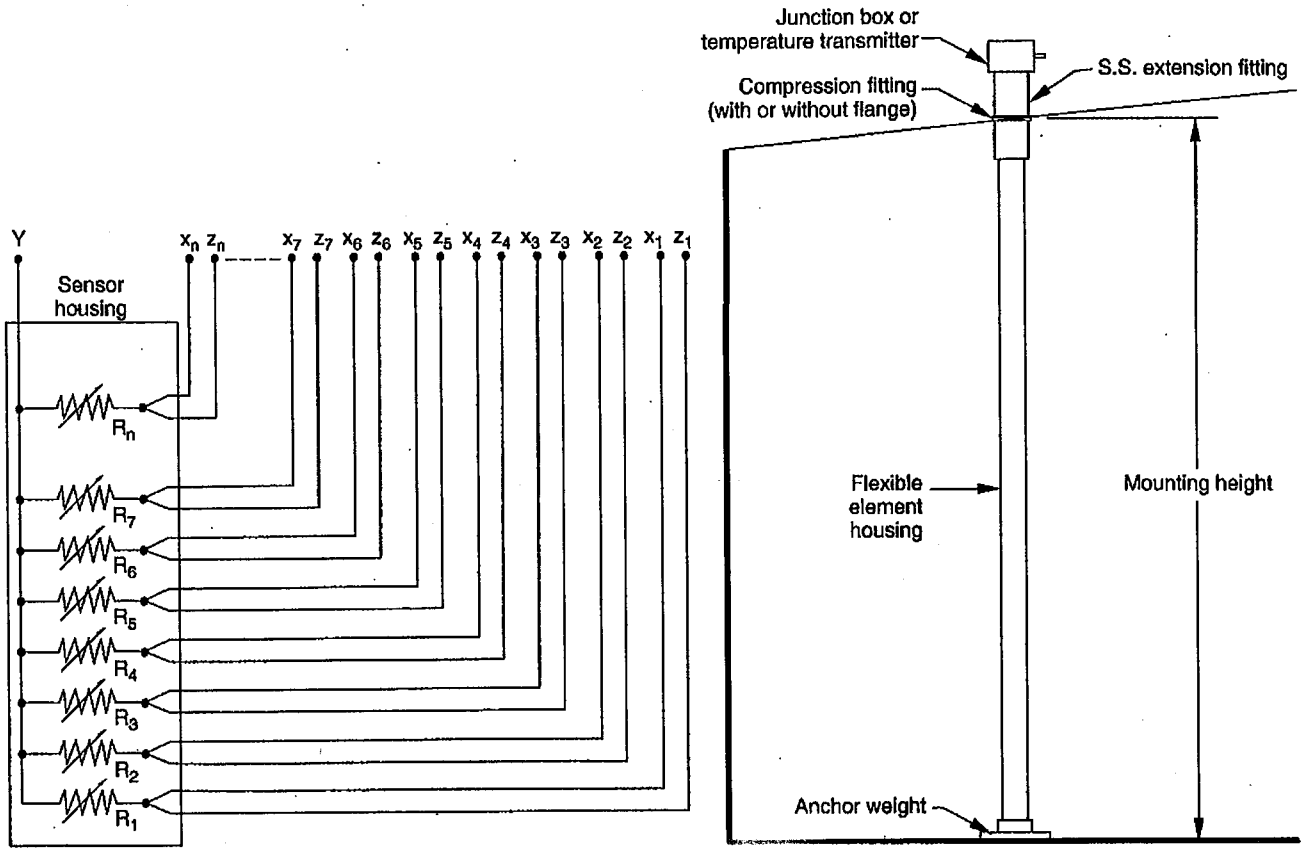

Figure 1—Multiple Spot Temperature Element Installation

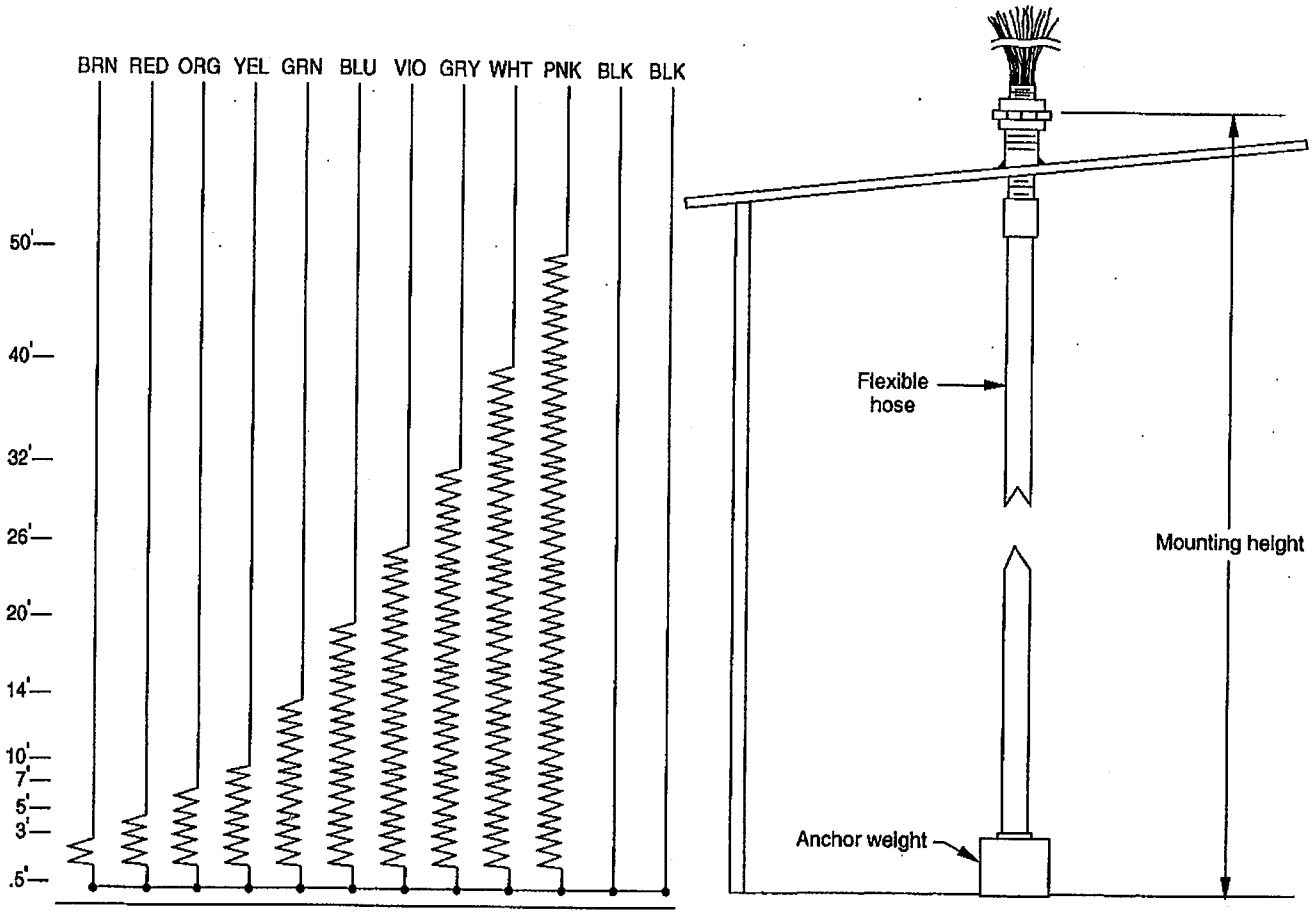

Figure 2—Variable Length RTD Temperature Element Installation

b. Alternately, the components of the ATT system are separately calibrated. Measure the resistance of the temperature element in the bath. The bath temperature and the temperature equivalent to the resistance should be within ±0.25°F or 0.15°C at each temperature. Separately, use precision resistors or a thermal calibrator (recently calibrated against a reference traceable to NIST) to simulate temperature input to the temperature transmitter-converter and to the readout of the ATT system. The temperature measured and displayed by the ATT system and the temperature input should be calibrated to within ±0.25°F or 0.15°C at each temperature.

6.2.2 INITIAL FIELD VERIFICATION

6.2.2.1 Verification by Components

Separate calibration checks of the temperature element and the temperature transmitter are performed as follows:

a. Temperature element: Use a recently calibrated electronic digital thermometer to provide a rough check of the measurement by the temperature element. Lower the thermometer to the depth at which the element is located. The temperature measured by the thermometer and by the element should be within ±1°F or 0.5°C. Refer to API Chapter 7.1 and API Chapter 7.3 for more information.
b. Temperature transmitter: The ATT system, excluding the temperature element, can be verified by using a temperature calibrator (for example, precision resistors or a thermal calibrator) to simulate temperature input at three or more temperatures covering the expected tank operating temperatures. The ATT output or display should agree with the calibrator within ±0.5°F or 0.25°C at each temperature. The temperature calibrator and precision resistors should be previously calibrated against a reference certified by NIST.

6.2.2.2 Verification as a System

As an alternate to separate calibration checks of the temperature element and the transmitter, a portable electronic digital thermometer, calibrated immediately prior to verification, may be used to verify the entire ATT system. Because it may not be possible to position the thermometer close to the temperature element and because a slight horizontal temperature stratification may exist, the measurement by the thermometer may not agree completely. Generally speaking, for ambient storage tanks, if the sensing element of the portable electronic thermometer can be placed within 3 feet (1 meter) of the fixed temperature element, calibration by a portable electronic thermometer is acceptable. If the temperature measured by the thermometer and by the fixed temperature element is within ±1°F or 0.5°C, the ATT system is considered within calibration.

This method may generate erroneous results and therefore should not be used in heated tanks where uneven heating by heating coils is often encountered.

6.3 Calibration of Upper, Middle, and Lower or Multiple Point ATT Systems

6.3.1 FACTORY CALIBRATION

Refer to the factory calibration procedure for single-point or mid-level ATT systems. Each point (that is, temperature element) of the ATT system should be checked following the factory calibration procedure described in 6.2.1.

6.3.2 INITIAL FIELD VERIFICATION

6.3.2.1 Verification by Components

Separate calibration checks of the temperature element and the temperature transmitter are performed as follows:

a. Temperature element: Use a recently calibrated electronic digital thermometer to provide a rough check of the measurement by the temperature element. Lower the thermometer to the depths at which the RTDs are located. For each temperature element, the temperature measured by the thermometer and by the element should be within ±1°F or 0.5°C.
b. Temperature transmitter: Refer to 6.2.2.1, Item b, for the field verification procedures for the temperature transmitter.

6.3.2.2 Verification as a System

As an alternate to separate calibration checks of the temperature element and the transmitter, a portable electronic digital thermometer, calibrated immediately prior to verification, may be used to verify the entire ATT system.

The tank should preferably be nearly full, with all temperature elements submerged. Take ten temperature readings evenly spaced, or every 2 feet, covering the entire liquid level. The manual average temperature by the portable thermometer is the average of the readings. The average temperature by the ATT system is the average temperature of all temperature elements submerged in the liquid. If the difference between these two average temperatures is within ±1°F or 0.5°C, the ATT system is considered within calibration.

Note: An "Upper-Middle-Lower" ATT system, which automatically adjusts according to the liquid level, does not require the tank to be full.

6.4 Calibration of Variable Length ATT Systems

6.4.1 FACTORY CALIBRATION

Refer to the factory calibration procedure for single-point or mid-level ATT systems. The average temperature read by each element (consisting of multiple RTDs) of the ATT system should be checked following the factory calibration procedure described in 6.2.1.

6.4.2 INTITAL FIELD VERIFICATION WITH A PORTABLE ELECTRONIC THERMOMETER

This procedure is used to verify the variable length averaging ATT systems that automatically select the longest, fully submerged element to determine the average tank temperature. A portable electronic digital thermometer, calibrated immediately prior to verification, should be used to verify the entire ATT system.

The tank should preferably be nearly full, with all temperature elements submerged. Take ten temperature readings evenly spaced, or every 2 feet, covering the entire liquid level. Manually select each temperature element (either by a software or a hardware switch). Compare the average temperature calculated from the appropriate portable thermometer readings against the average temperature measured by the temperature element selected and displayed by the ATT readout. For each temperature element, if the difference between the average temperature calculated from the portable thermometer and the average temperature read by the ATT system is within ±1°F or 0.5°C, the ATT system is considered within calibration.

For small tanks (that is, the tank height is 10 feet or lower), three temperature readings (at upper, middle, and lower levels) may be used to calculate the average temperature.

6.5 Subsequent Verification of ATT System Accuracy

6.5.1 FREQUENCY OF SUBSEQUENT VERIFICATION

A regular verification program should be established for custody transfer ATT systems. All essential components of the ATT system installation should be checked as recommended by the manufacturer's instructions. Every 3 months each ATT system should be inspected and its calibration verified using the same procedures described in the initial field calibration paragraphs in this standard.

6.5.2 RECORDKEEPING

Full records should be kept of the initial calibration and the periodic verifications of each ATT system used for custody transfer.

7.0 Requirements for Data Collection, Transmission, and Receiving

7.1 General

The requirements for data collection, transmission, and receiving vary with the type and the make of the ATT system, which is often part of the ATG system. The manufacturer's recommendations should be followed. Additional requirements may be necessary to provide proper security and protection of the measured data. The installation should conform to all applicable codes and regulations.

7.2 Data Collection Unit

7.2.1 GENERAL

A data collection unit collects the measured data (for example, level and temperature) from one or more tanks. The unit may be in the transmitter, or it may be a microprocessor-based field unit separate from the transmitter or transmitters. Data collected by the unit will be transmitted, preferably in digital format, to a remote receiving unit, which may be a host computer.

7.2.2 ELECTRICAL CLASSIFICATION

Data collection units should be designed to meet the area's electrical classification requirements. Since the units are usually located outdoors, weatherproof or rain-tight enclosures (or junction boxes) should be the minimum provided.

7.3 Data Transmission

7.3.1 INTERFERENCE FROM THE AC POWER WIRING

All AC power wiring should be run with at least 3 feet or 1 meter of separation distance from the signal wiring. Most ATG and ATT systems do not require electromagnetic shielding of the power wiring if the current is less than 10 amperes.

7.3.2 RADIO FREQUENCY INTERFERENCE

Particular attention should be made to avoid interference from radio frequencies (RF). Cable shielding and cable routing should be designed to minimize RF interference. Filtering may be required at equipment inputs.

7.3.3 SIGNAL WIRING

Signals are typically transmitted in pairs of twisted, shielded conductors in an insulated multipair cable installed in conduits or buried. The line impedance should be calculated to stay within the maximum impedance specified by the ATG and ATT equipment manufacturer. Digital signals are recommended over analog signals, especially if long distance transmission or high impedance is expected.

Alternatively, signals may be transmitted via other media (for example, fiber optics, or coaxial cables) as recommended by the ATG and ATT equipment manufacturer.

7.3.4 GROUNDING

Proper grounding is important to protect the ATG and ATT equipment from damage due to transients or surges, which can result in loss of measurement data.

Grounding requirements vary by type and make of the ATG and ATT equipment. Therefore, the manufacturer's recommendations should be explicitly followed.

In aerial installations, the supporting messenger should be bonded to ground. In buried cable installations, only cable suitable for direct burial should be used. In conduit systems, continuity of ground through conduit joints should be ensured either by proper makeup of joints or by bonding connections around each joint.

7.3.5 WIRING SHIELDS

The wiring shields may be copper, aluminum, or steel in accordance with the manufacturer's recommendations. The overall shielding should be bonded together at all junction boxes and properly grounded on only one end either to a power line grounded neutral or to a driven ground rod.

7.3.6 SIGNAL-TO-NOISE RATIO

The requirements covered in 7.3.2 through 7.3.4 should be followed to provide immunity to noise pickup.

7.4 Receiving Unit

The receiving unit may be an integral part of the receiving unit for an ATG system. The unit is usually located in the tank farm control house or some other remote location. Refer to API Chapter 3.1B for the functionality of the receiving unit. The remote temperature readout unit should be able to do the following:

a. Scan all tanks monitored by the ATG and ATT system in a manner that meets the data acquisition requirements.
b. Display temperatures on a real-time basis.
c. Perform data validity checks and alert the operator if errors are detected.
d. Display alarms such as high temperature, low temperature, and so forth.

7.5 Transient and Lightning Protection

7.5.1 TRANSIENT PROTECTION

7.5.1.1 Definition

The term *transient,* as used in this standard, refers to high-voltage, fast-rising, lower-energy pulses. The disturbances caused by transients usually have a duration of 0.2 seconds.

7.5.1.2 Protection Against Transients

Protection against transients should be provided to protect the level and temperature transmitter and to provide secure transmission of the measurement data. The shields and proper grounding described in 7.3 often provide adequate protection. However, the manufacturer's recommendations should be followed if they are more restrictive.

7.5.2 LIGHTNING PROTECTION

7.5.2.1 Definition

Lightning or *surge* is a high-energy, fast-rising voltage pulse that temporarily causes an increase in line voltage over the operating tolerances normally permitted.

7.5.2.2 Basic Requirements

In areas where there is a high incidence of lightning and, in particular, where the tanks are spread over a wide area remote from the central readout equipment, additional precautions against lightning should be provided. The lightning protection system should absorb the lightning surge energy in the signal or power lines.

The surge protective level should not interfere with the normal operation of the ATG and ATT equipment. Surges that can damage the ATG and ATT equipment should not pass through the system. The lightning protection devices should be maintenance free and self-restoring. The selection and installation of protective devices should be based on the recommendations of the manufacturers of the ATG and ATT equipment.

7.5.2.3 Installation of Surge Protectors

The lightning surge protectors should be installed at both ends of the signal transmission lines to protect the signal source and its receiving unit from electrical surges propagating in both directions from the induction point.

Alternatively, lightning protection can also be provided by the galvanic separation technique.

7.5.3 GROUNDING LIGHTNING SURGE PROTECTORS

Ground wires for transient and surge protectors should be connected to a good earth ground, such as a metal cold water pipe. If a reliable earth ground is not available, a driven ground rod should be provided. Five (5) ohms is an acceptable ground resistance.

APPENDIX A—LOCAL DIRECT-READING THERMOMETERS

A.1 General

Most aboveground bulk storage tanks are equipped with at least one local direct-reading thermometer mounted in a fixed thermowell. This local thermometer is not recommended for custody transfer temperature determination because it is usually inaccurate and it does not provide an average tank temperature unless the tank contents are at a uniform temperature. Rather, it provides a rough check on the custody transfer temperature measurement.

Table A-1 describes thermowell and location for tank temperature measurement.

A.2 Thermowells for Local Reading Thermometers

The thermowell for the fixed direct-reading thermometer should extend through the tank shell for at least 12 inches (300 millimeters). A longer immersion length (24 to 36 inches or 600 to 900 millimeters) will reduce ambient temperature error. The thermowell material should be compatible with the liquid. Usually Type 304 or 316 stainless steel is specified.

The thermowell and the thermometer should be located for convenient reading near the stairway, ladder, or ATG. The thermowell should be located approximately 3 to 4 feet (900 to 1200 millimeters) above grade for ease of reading and to lessen bottom effects. However, the thermowell must be low enough to clear the landed roof of a floating-roof or pan-roof tank.

A thermowell fill fluid will reduce the thermometer's response time to react to temperature changes. Fill fluids should have a low volatility and freeze point. If the thermowell is sloped down from the horizontal, it will retain the fill fluid better; however, thermowells designed for the angle-stem, industrial-type glass thermometers should be horizontal.

Table A-1—Tank Appurtenances for Temperature Measurement

Tank Type	Fixed Temperature Measurement	Portable Temperature Measurement
Fixed-roof tanks	Thermowell for local thermometer Thermowell for remote readout Thermowells or vertical temperature well for average temperature assemblies	Roof hatch
Floating- roof or internal floating-roof tanks	Thermowell for local thermometer Thermowell for remote readout Vertical temperature well for average temperature assemblies	Gauging hatch and slotted gauging well

A.3 Local Direct-Reading Thermometers

A.3.1 ANGLE-STEM, INDUSTRIAL-TYPE GLASS THERMOMETERS

Angle-stem, industrial-type glass thermometers are installed in standard metal separable thermowells in the tank. The glass stem of the thermometer must be at least 12 inches (300 millimeters) long and must be protected with a light metal tube. The sensitive portion of the thermometer should not exceed 2.5 inches (60 millimeters). The assembly should be attached to the well by a threaded coupling. A thermometer with a separate graduated scale is acceptable provided that the markings on the scale are permanently engraved and the markings are etched on the glass stem of the thermometer, near the ends of the range, to coincide with the corresponding lines on the scale.

A.3.2 BIMETAL-ACTUATED DIAL THERMOMETERS

Bimetal-actuated dial thermometers are installed in standard metal separable thermowells sloping downward into the tank. The stem of the thermometer should be at least 12 inches (300 millimeters) long, and the sensitive portion of the thermometer should not exceed 2.5 inches (60 millimeters). The assembly should be attached to the well by a threaded coupling.

A.3.3 MERCURY-ACTUATED DIAL THERMOMETERS

Mercury-actuated dial thermometers are installed in standard metal separable thermowells sloping downward into the tank. The stem of the thermometer should be at least 12 inches (300 millimeters) long. The assembly should be attached to the well by a threaded coupling.

Order No. 852-30145

1-01102—12/93—1M ( )

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005