Manual of Petroleum Measurement Standards Chapter 17—Marine Measurement

Section 2A—Closed and Restricted Systems

FIRST EDITION, NOVEMBER 1995

American Petroleum Institute

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Measurement Coordination

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Chapter 17—Marine Measurement

SECTION 2A—CLOSED AND RESTRICTED SYSTEMS

17.2A.1 Introduction

Government and regulatory agencies worldwide have imposed safety and environmental regulations that prohibit tank vessel operations from releasing hydrocarbons into the atmosphere. This has resulted in the restriction and, in some cases, the prohibition of traditional methods of obtaining cargo measurements. Consequently, numerous measurement methods and technologies are now being used and developed that allow the necessary cargo measurements and samples to be taken while the vessel's cargo tanks remain closed to the atmosphere.

Tank vessels are using closed and restricted measurement devices when operational, safety, and environmental considerations mandate all systems be closed to vapor releases to the atmosphere. These devices are used during various vessel operations including, but not limited to, tank-to-tank transfers, loading, discharging, crude oil washing, and ballasting. Closed and restricted devices are designed to provide liquid levels temperature measurement. Samples may be taken under closed or restricted conditions using specially designed equipment through vapor control valves (VCVs).

17.2A.2 Scope

This standard covers the use of manual portable measurement units (PMUs) through deck-fitted VCVs and fixed automatic tank gauge (ATG) systems when a marine vessel's cargo tanks may not be opened to the atmosphere. It establishes the procedures for obtaining the level measurements of cargo, free water, and onboard quantity/remaining onboard (OBQ/ROB) as well as taking the temperatures and samples required for the marine custody transfer of bulk liquid petroleum cargoes under closed or restricted system measurement conditions. It does not address in detail the technologies of the equipment used. This standard is not intended for use with pressurized or refrigerated cargoes such as LPG and LNG.

17.2A.3 References

The following standards contain provisions that, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

API

Manual of Petroleum Measurement Standards

Chapter 1, "Vocabulary"

Chapter 2, "Tank Calibration"

Chapter 2.8B, "Recommended Practice for the Establishment of the Location of the Reference Gauge Point and the Gauge Height of Tanks on Marine Vessels"

Chapter 3, "Tank Gauging"

Chapter 3.1A, "Standard Practice for Manual Gauging of Petroleum and Petroleum Products"

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

Chapter 3.4, "Standard Practice for Level Measurement of Liquid Hydrocarbons on Marine Vessels by Automatic Tank Gauging (Under Development)"

Chapter 7, "Temperature Determination"

Chapter 7.3, "Static Temperature Determination Using Portable Electronic Thermometers (PETs)"

Chapter 7.4, "Static Temperature Determination Using RTDs (Under Development)"

Chapter 8, "Sampling"

Chapter 8.1, "Manual Sampling of Petroleum and Petroleum Products" (ANSI[1]/ASTM[2] D 4057)

Chapter 8.2, "Automatic Sampling of Petroleum and Petroleum Products" (ANSI[1]/ASTM[2] D 4177)

Chapter 17.1, "Guidelines for Marine Cargo Inspection"

Chapter 17.2, "Measurement of Cargoes on Board Tank Vessels"

Chapter 17.4, "Method for Quantification of Small Volumes on Marine Vessels (OBQ/ROB)"

Publ 2217 *Guidelines for Confined Space Work in the Petroleum Industry*

Publ 2026 *Safe Dissent Onto Floating Roof of Tanks in Petroleum Service*

ICS[3]/OCIMF[4]/IAPH[5]

International Safety Guide for Oil Tankers and Terminals (ISGOTT)

[1]American National Standards Institute, 1430 Broadway, New York, New York 10018.

[2]American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

[3]International Chamber of Shipping, 30/32 Mary Axe Street, London EC3 A8ET England.

[4]Oil Companies International Marine Forum, Portland House, Stag Place, London SW1E SBH England.

[5]International Association of Ports and Harbors, Kotohira-Kaikan Building, 2-8 Toranomon, 1-Chom Minato-Ku, Tokyo 105, Japan.

IMO[6]

Inert Gas Systems

OSHA[7]

29 *Code of Federal Regulations* Part 1910.1000, Occupational Safety and Health Standards

17.2A.4 Definitions and Abbreviations

17.2A.4.1 DEFINITIONS

For the purpose of this standard, the following definitions apply:

An *automatic tank gauge* (ATG) is an instrument that automatically measures and displays liquid levels or ullages in one or more tanks continuously, periodically, or on demand. It also refers to the liquid level in a tank as measured using an ATG system.

An *automatic tank thermometer system* (ATT) is a system that automatically measures and displays temperatures of liquids in one or more vessel tanks continuously, periodically, or on demand.

An *automatic vessel tank gauge system* is a system that automatically measures and displays liquid levels or ullage in one or more vessel tanks continuously, periodically, or on demand (see API MPMS Chapters 1 and 17.2).

A *closed system* exists when a marine tank vessel does not permit the direct exposure and/or release of the tank contents into the atmosphere under normal operating conditions. (See definition of restricted system.)

Closed system measurement (CSM) is the measurement of petroleum cargoes on a closed system marine tank vessel performed using closed measurement devices. (See definition of restricted system measurement.)

Closed measurement devices are those that penetrate the cargo tank but form part of a closed system and keep the cargo from being released, such as float gauge systems, electronic probes, magnetic probes, bubble tube indicators, and vapor/gas-tight portable measurement or sampling units. (See definition of restricted measurement devices.)

A *portable measurement unit* (PMU) is an intrinsically safe device used in conjunction with a VCV to obtain required liquid level and temperatures under closed and restricted system conditions.

A *portable manual sampling unit* (PSU) is an intrinsically safe device used in conjunction with a VCV to obtain required cargo samples under closed and restricted system conditions.

A *restricted system* exists when a marine tank vessel allows some vapors from its cargo tank contents into the atmosphere under normal operating conditions. (See definition of closed system.)

Restricted system measurement (RSM) is the measurement of petroleum cargoes on a restricted system marine tank vessel using restricted measurement devices. (See definition of closed system measurement.)

Restricted measurement devices are those that penetrate the cargo tank, but form part of a restricted system and keep the vapors from cargo from being released to the atmosphere to a minimum, such as restricted PMUs and PSUs. (See definition of closed measurement devices.)

A *standpipe* is a vertical pipe installed on the deck of a marine tank vessel to which the VCV may be fitted.

A *vapor control valve* (VCV) is a valve fitted on a standpipe, expansion trunk, or the deck, which permits use of the portable hand-held gauging instruments while restricting the release of vapors into the atmosphere.

17.2A.4.2 ABBREVIATIONS

ATG: automatic tank gauge
ATT: automatic temperature system
CSM: closed system measurement
FTG: float-operated automatic tank gauge
IMO: International Maritime Organization
HTG: hydrostatic tank gauge
ISGOTT: International Safety Guide for Oil Tankers and Terminals
IGS: inert gas system
ITG: inductive tank gauge
MCTM: marine custody transfer measurement
MIST: National Institute of Standards and Technology
OBQ: onboard quantity
OCIMF: Oil Companies International Marine Forum
PET: portable electronic thermometer
PMU: portable measurement unit
PSU: portable sampling unit
P/V: pressure vacuum (valve)
ROB: remaining onboard
RSM: restricted system measurement
RTG: radar tank gauge
SOLAS: Safety of Life at Sea Convention
STG: servo-operated automatic tank gauge
UTI: ullage, temperature, interface (also a portable measurement unit capable of measuring these three parameters)
VEF: vessel experience factor
VCV: vapor control valve

17.2A.5 General Safety Precautions

This section applies to all types of closed or restricted measurement on board marine tank vessels. However, while the safety precautions represent good operating practices, they should not be considered necessarily complete or comprehensive. In addition to those listed herein, reference should be made to all safety precautions contained in any relative governmental, local, or company operating guidelines.

[6]International Maritime Organization, London, England.
[7]Occupational Safety and Health Administration, U.S. Department of Labor. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

Note: Anyone working with the vessel's closed or restricted system measurement equipment, including vapor valve assemblies, must be at all times under the direction and supervision of the officer in charge of the vessel.

17.2A.5.1 ELECTRICAL AND OPERATING SAFETY

All marine measurement equipment shall be designed and installed to meet applicable national and international marine safety codes and regulations.

17.2A.5.2 MAINTENANCE

All marine measurement equipment shall be maintained in safe operating condition and in compliance with the manufacturers' instructions.

17.2A.5.3 SEALING

All ATGs and VCVs shall be sealed to withstand the vapor pressure of liquid in the tank. ATGs and VCVs mounted on vessels with an inert gas system (IGS) must be designed to safely withstand the full range of operating and possible extreme pressures of the vessel's pressure vacuum (P/V) valve.

17.2A.5.4 VAPOR CONTROL VALVE INSTALLATION

The VCV shall be installed as per specifications of design and appropriate governing body such as the U.S. Coast Guard or Classification Society.

17.2A.6 Description of Equipment

The two basic categories of closed and restricted system measurement equipment used on marine tank vessels are "portable manual" and "fixed automatic." Manual equipment can be used to obtain levels of liquid cargo, free water, cargo temperatures, and samples whereas automatic systems are primarily used to obtain the levels and temperatures of liquid cargo only. While either type of equipment can be used for custody transfer measurements, it must be understood not all automatic equipment was designed and installed on vessels for that purpose. Some systems were designed to be used for shipboard operational purposes only (for example, for determination of proper trim and stability and cargo loading and discharging).

Accordingly, both parties should be aware of the limitations of any shipboard measurement system and agree on the method of measurement to be used to determine the "official" custody transfer volumes.

If a closed or restricted measurement system is to be used for marine custody transfer measurements (MCTM), the accuracy of the equipment used should fall within the tolerances set forth in API MPMS Chapters 2.8, 3.1A, 3.4, 7.3, and 7.4. However, because of various vessel designs and physical installation of the equipment used, accuracies other than those described therein may be the maximum achievable. The measurement accuracies designed into the system must be warranted by the manufacturer.

17.2A.6.1 MANUAL EQUIPMENT

Manual equipment consists of a PMU that must be carried from tank to tank to obtain the appropriate measurements through a VCV located at each tank. Generally, PMUs and VCVs made by the same manufacturer are designed to be used together. However, equipment made by different manufacturers may be used together with an appropriate adapter.

17.2A.6.1.1 Vapor Control Valve

These valves are generally found on standpipes, flanges, existing ullage hatches, and expansion trunks or fitted flush to the vessel's deck. (See Figures 1, 2A, and 2B. Note that Fig. 2B is an illustration of when a vessel has been retrofitted for a PMU gauge location using existing gauge tables for "open" measurements.) They are designed to allow attachment of the portable measurement or sampling device using a securing device or adapter. By operating the VCV according to its manufacturer's instructions, the PMU probe, sampler tape, and/or sampler can be lowered into the tank through the VCV whether the vessel's IGS is putting positive pressure into the tanks or not.

VCVs come in varying diameters from 1 inch (25.4 millimeters) to 4 inches (101.6 millimeters). The valve sizes and types are specified by the manufacturer and the vessel owner. However, if the VCV is too narrow, it will not allow adequate sampling to be conducted. (See Appendix B.11.)

The VCV's location and size are critical to the ability to be able to measure tank contents and to take sufficient samples. To measure small quantities in a tank when the vessel is not on an even keel, a VCV must be located as close as possible to the bulkhead that is in the direction of the vessel's normal operating trim and list when the vessel is in an OBQ/ROB condition. In placing the VCV, care must be given to ensure its location will not cause the measurement equipment to touch the tank bulkhead when in use. For more information, see Appendix B.11, API MPMS Chapters 2.8B and 3.4.

Note: Since many vessels have been retrofitted with VCVs that are not in the exact location as the existing "open" gauge points, tank capacity tables should be adjusted to take in consideration any new gauge location for PMU equipment. Also, the VCV locations should be placed in accordance with API MPMS Chapter 2.8B. If the tables have not been adjusted for these location changes, some corrective action may have to be taken to obtain correct measurements. Such corrective action must take into consideration the use of adapters that allow the use of different manufacturers' PMUs with varying vapor control configurations.

17.2A.6.1.2 Portable Measurement Unit

The PMU is designed to measure oil levels, water levels, and temperatures of cargo in a tank. The unit may be designed to perform one, two, or all three of the foregoing functions. Multifunction units are sometimes referred to as UTIs (ullage,

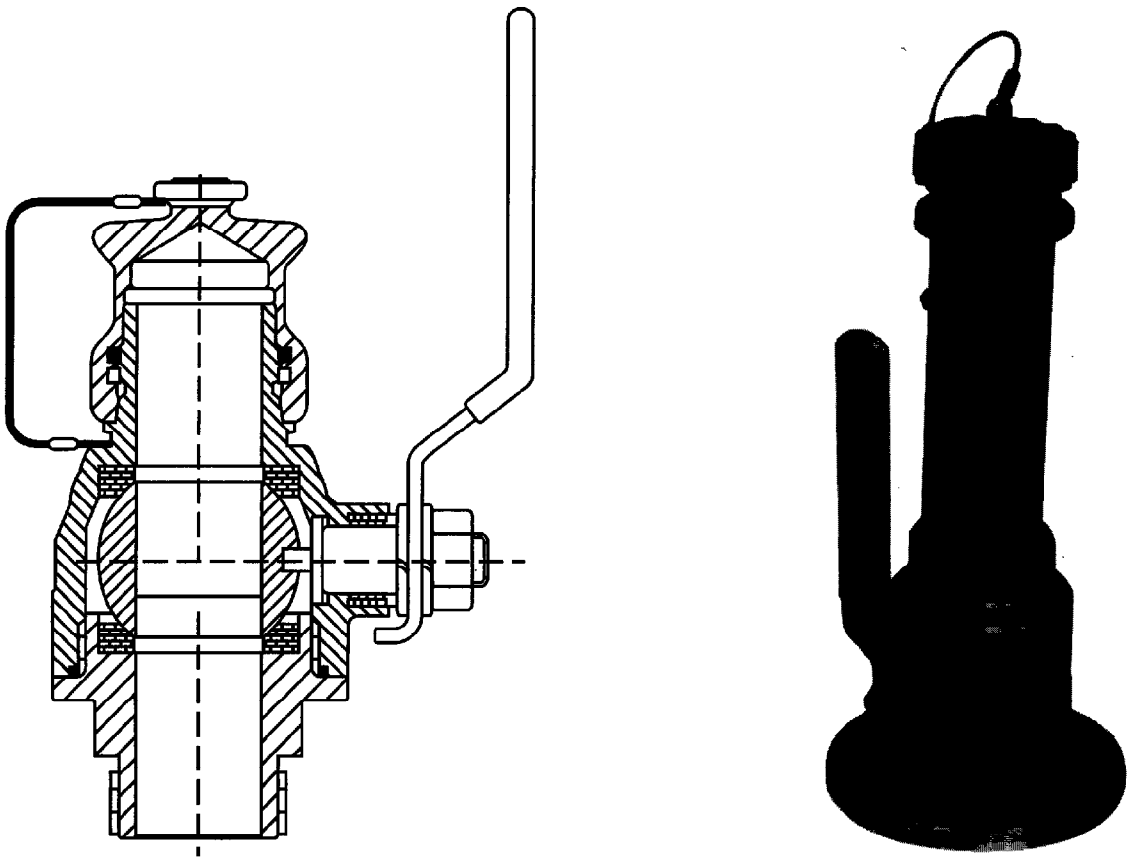


Figure 1—Typical Vapor Control Valves (VCVs)

temperature, interface). Most PMUs use an electronic sensing device integrated into a measuring tape. (See Figure 3.)

Each PMU must be fitted with a means to provide a tight seal on the VCV. For a detailed description of the systems, consult the manufacturer's instructions. Before using a PMU, verify its design capabilities and refer to the manufacturer's instructions for proper use and warranted accuracies.

17.2A.6.1.3 Portable Sampling Unit (PSU)

The PSU is designed to obtain samples under closed and restricted system conditions and to be compatible with VCVs fitted on the vessel. Some PSUs are capable of accepting various types of samplers and of taking the various types of samples in accordance with API MPMS Chapters 8.1 and 17.2. (See Figure 4.)

17.2A.6.1.4 Maintenance/Verification

When measurement equipment is first put into service, it must be carefully inspected and checked for any signs of damage or construction flaw. The measurement tapes of all PMUs should be compared against a verified steel gauge tape to be certain the linear markings on the tape are correct in accordance with API MPMS Chapter 3.1A. PSUs should be checked for proper size, operation, seating, and any signs of wear before each use.

The manufacturer's instructions and warranties should be carefully reviewed and followed throughout the use of the equipment and, if required, sufficient replacement batteries kept available. In addition, the manufacturer's maintenance schedule and verification procedures must be followed and a log kept of all maintenance and verifications performed. UTIs and single function portable electronic thermometers (PETs) must be verified and records kept in accordance with API MPMS Chapter 7.3.

CAUTION: Although UTIs and single function PMUs have been designed to withstand the rigors of shipboard operation, they are sensitive electronic measurement devices. As such they must always be handled with care and properly maintained throughout their use.

17.2A.6.2 AUTOMATIC EQUIPMENT

Automatic measurement equipment consists of permanently installed, fixed devices in a vessel's tanks to determine liquid levels and temperature. (See Figure 5.)

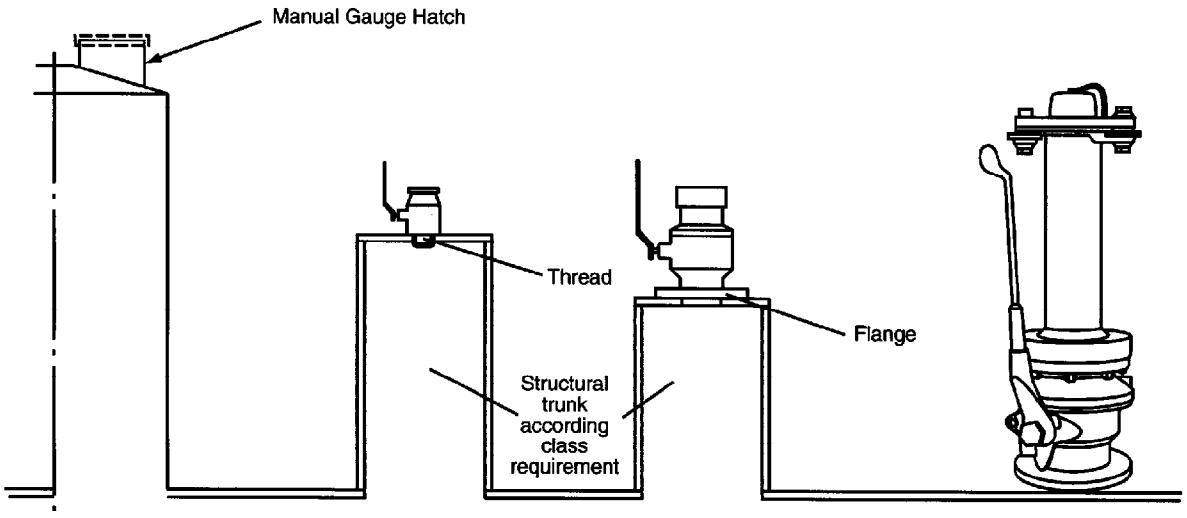


Figure 2A—Typical Deck Mountings of Vapor Control Valves
PMUs not Attached

Automatic sampling equipment used on tank vessels may be fixed or portable.

17.2A.6.2.1 Automatic Measurement Equipment

Automatic measurement equipment, also known as remote or fixed measurement equipment, is built into the vessel. Such measurement systems on tank vessels normally have automatic level and temperature measurement capability with readouts located at the compartment or at a remote point, such as the cargo control room. It includes ATG equipment, which consists of, but is not limited to, the following types of liquid level measurement technologies:

a. Float-operated tank gauge (FTG).
b. Hydrostatic tank gauge (HTG).
c. Inductive-level tank gauge (ITG).
d. Radar tank gauge (RTG).
e. Resistive or electro-ohmic tank gauge.
f. Servo-operated tank gauge (STG).

Additionally, many of these systems are designed so that liquid level and temperature measurements are transmitted to an on-board computer and automatically converted to volumes. In all cases, the tank capacity tables should be specifically developed and issued for the automatic gauging system used. For more information, see API MPMS Chapters 2.8B and 3.4.

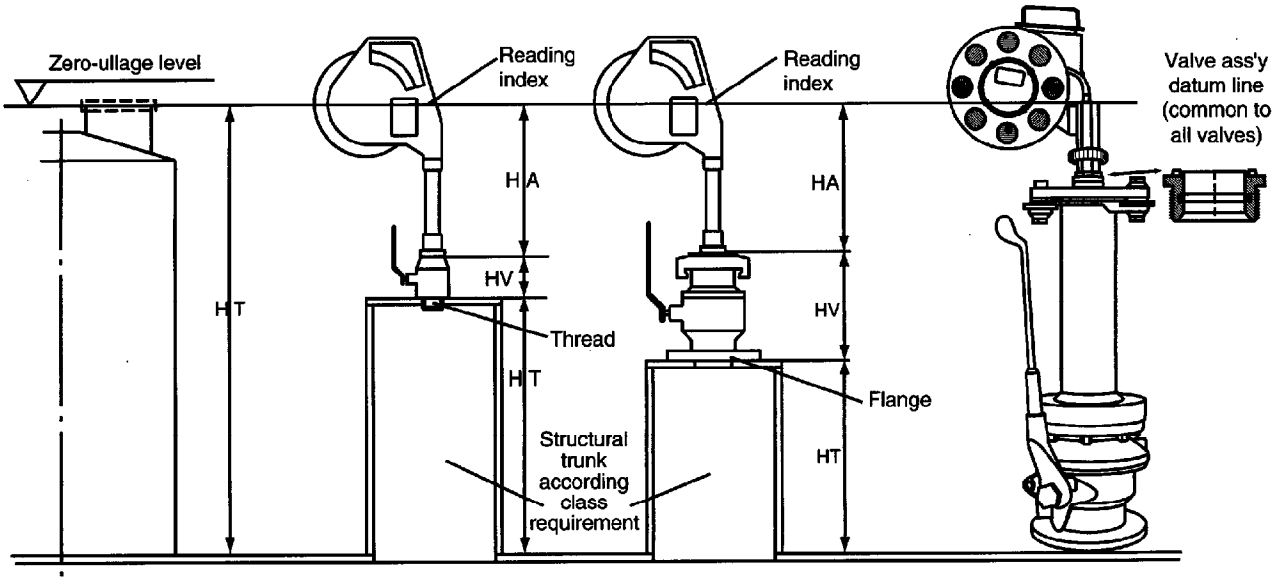
The operation and capabilities of these systems vary greatly by technology and manufacturer. Some can only measure liquid levels in the tank while others have the capability to measure free water, temperature, and OBQ/ROB. Fixed automatic measurement equipment does not generally measure free water and the level of OBQ/ROB if the liquid level falls beyond the measurement range or is not detectable by the sensor. Therefore, automatic measurement equipment is usually used for vessel operations' purposes rather than MCTM. If the overall accuracy of the ATG system and temperature-taking system described in API MPMS Chapters 3.4 and 7.4 are met, however, this information can be used to determine cargo level and temperature for marine custody transfers.

A detailed description of the technologies used in each of these types of equipment can be found in API MPMS Chapters 3 and 7 and in the manufacturers' instructions. These and other types not described herein may be used if they can perform as well as or better than the measurement parameters set out in Section 17.2A.7.

17.2A.6.2.2 Automatic Temperature Equipment

Temperatures can be taken automatically if a shipboard automatic temperature measuring system (ATS) is available.

An ATS should contain sufficient temperature sensors to enable the calculation of a representative average cargo temperature in accordance with API MPMS Chapter 7.4. The manufacturer's operating specifications and installation literature must indicate location of sensors and if automatic averaging of temperature is provided by immersed sensors.



HT = Height of Trunk
HA = Height of Adaptor
HV = Height of Vapor Control Valve (VCV)

Figure 2B—Typical Deck Mountings of Vapor Control Valves PMUs Attached

Temperatures taken using automatic measurement equipment should indicate the levels at which temperature measurements are taken in each tank or if average temperatures are used. The vessel should provide data indicating the last date of verification of automatic temperature measurement equipment against the National Institute of Standards and Technology (NIST) (or equivalent) standards. A log of temperature verification against a certified thermometer traceable to NIST must be maintained by the vessel. In all cases, the manufacturer's description of each system and its capabilities must be fully reviewed and understood before use.

17.2A.6.2.3 Automatic Sampling Equipment

Most automatic sampling equipment used for MCTM purposes is located ashore. While some vessels have automatic samplers permanently installed on deck, most automatic samplers used on board vessels are of the portable type that are attached to the vessel's manifold at the time of hose connection. (See Figure 6.) In either case, design and performance of all automatic sampling equipment shall be in accordance with API MPMS Chapter 8.2.

17.2A.6.2.4 Maintenance/Verification

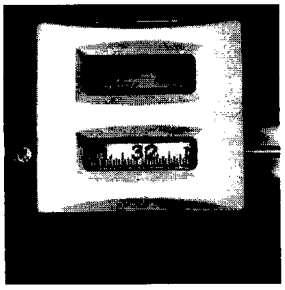
In all cases, the maintenance instructions and verification schedules as described by the manufacturer and in accordance with the requirements described in the respective referenced standards must be observed by the owner of the equipment.

17.2A.7 Procedures for Manual Closed or Restricted System Measurement

When vessels are fitted with VCVs, portable electronic gauging equipment can be used to measure free water, petroleum liquid levels, and temperature. It may also be used for measuring liquid OBQ/ROB. Special PMUs and techniques may be used for taking samples and for measuring nonliquid OBQ/ROB. Use of this equipment requires observance of safety procedures described in the manufacturer's instructions and as outlined in the *International Safety Guide for Oil Tankers and Terminals* (ISGOTT), *Inert Gas Systems*, and other applicable publications or procedures issued by the International Maritime Organization (IMO), International Chamber of Shipping (ICS), the Oil Companies International Marine Forum (OCIMF), and any other relevant governing body or organization.

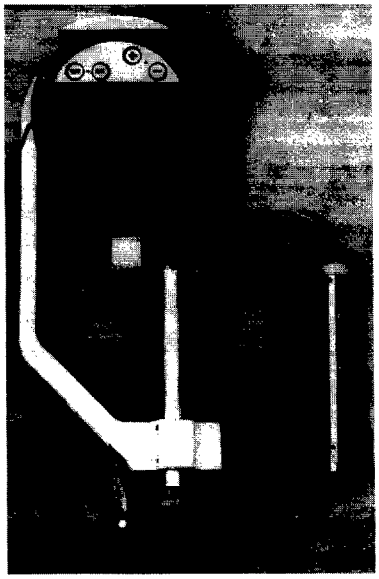
Prior to boarding a vessel equipped with VCVs, an attempt should be made to determine the manufacturer and size of the VCVs so that compatible equipment or adapters can be taken on board.

Before gauging, the following should be verified:



Detail display

Detail sensor



Type of sensor probe and measuring instrument

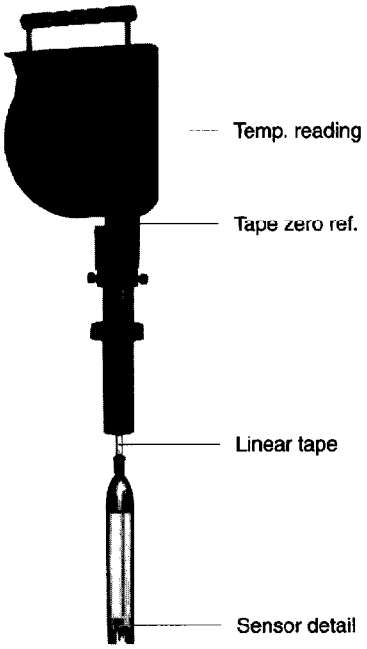


Figure 3—Two Types of Portable Measurement Units (PMUs)

a. All cargo operations have been stopped and no cargo is being transferred.
b. The IGS pressure in the cargo tanks has been lowered sufficiently to minimize vapor loss.
c. The gauging equipment has been calibrated and the calibration/verification log reviewed.
d. The equipment is free of breaks, kinks, and signs of wear that might affect measurement accuracy.
e. The equipment is suitably clean for the product to be measured—all numbers and graduations on the tape are legible.
f. The batteries are charged. (They should be replaced, if necessary.)

Note: For best accuracy, trim and list should be eliminated. When both conditions exist, every effort should be made to eliminate at least one condition, preferably list. Conditions of trim and list must be noted and corrections made for their effect on measurements and volumes.

17.2A.7.1 MANUAL SAMPLING

Since closed or restricted sampling is performed through VCVs, refer to Section 17.2A.6.1.1. If samples are to be taken using the same VCV as the one to be used to obtain the other tank measurements, sampling should be done first. To obtain the best cargo samples from each tank, they must be taken in accordance with API MPMS Chapters 8 and 17.2.

When spot samples are taken, the upper samples should be taken first and succeeding samples taken at each next-lower level, taking the lowest sample last to cause minimum disturbance or contamination in the column of oil being sampled. A minimum of one upper, middle, and lower sample must be taken. Cargoes suspected of stratification or containing emulsions will require a larger number of spot samples. Such additional samples must be taken at regularly spaced intervals, with the lowest sample taken at least 1 foot above any measured level of free water. The manufacturer's description of equipment should be reviewed to determine the design capabilities and limitations of the units.

It may be necessary to obtain a line or manifold sample for quality control purposes. This is especially true when clean products are being transferred and the specification of the product must be determined at the beginning of the transfer or during any part of it. In those cases, it must be

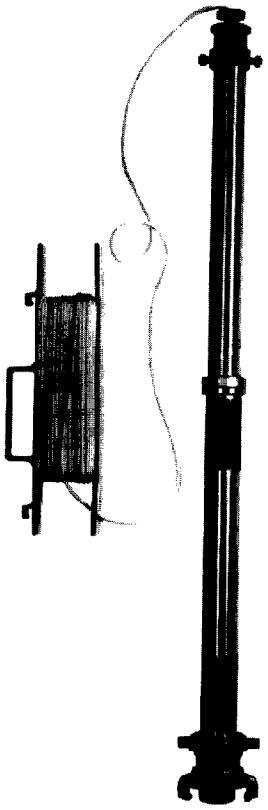


Figure 4—Type of Portable Sampling Unit (PSU)

understood that the manifold sample so obtained is only a type of spot sample and as such should not be considered a representative sample of the entire cargo.

17.2A.7.2 LIQUID LEVEL/FREE WATER GAUGING

The level of cargo, free water, or both in a vessel's tanks may be obtained using closed or restricted PMVs and VCVs if the vessel is so fitted. Such equipment should be checked or verified, or both, before each use according to the manufacturer's instructions.

a. Examine tank calibration tables to verify they correspond to the VCV locations and to the gauging equipment being used. If discrepancies are identified, notify the appropriate parties and highlight the effect of any discrepancy in the gauging report. (See API MPMS Chapters 2 and 3.4.)

b. Record the reference gauge height indicated for each vessel's tank on the vessel's calibration tables. Note any corrections for individual standpipes and adapters and calculate the actual reference height for the reference gauge point used.

c. Determine if tank capacity tables include volumes within vessel lines in each tank. If they do not, so note and record.

d. Prior to gauging, verify with the vessel's officer that no cargo is being transferred and request an estimate of the cargo level in each tank.

e. Verify that the VCV is closed.

f. Place the gauging tape assembly onto the VCV and screw it down tightly (or lock firmly if it is a quick-release type).

g. To measure oil, open the VCV and slowly unwind the tape until the oil-indicating tone is heard. When the sensor on the probe indicates an oil level according to the manufacturer's operation instructions, read the tape at the reference gauge point to the nearest tape graduation (⅛ inch, 1 millimeter, 100th of foot). (See API MPMS Chapter 3.1A and this document.)

h. Repeat the gauging procedure until two identical readings are obtained out of three consecutive gauges. If three gauges are required to obtain two alike, all three must fall within a ⅛ inch (3mm) span. (See API MPMS Chapters 3.1A and 17.2.)

Note: Persistent variance between gauges usually indicates movement of the tank contents. If cargo movement in a tank is unavoidable, at least five measurements should be taken, the highest and lowest readings dropped, and the remaining three averaged. (See note in Section 17.2A.8.1.d.)

i. When cargo level measurement is complete, determine the free water ullage by lowering the sensor to approximately 1 foot (300 millimeters) above the bottom of the tank. Determine the oil and water interface by lowering and raising the sensor until the water interface is found according to the manufacturer's operation instructions. For added evaluation, water finding paste may be applied to the probe. See Appendix B.10 for alternate procedures.

Note: The detection of cargo and free water at the specific gauge locations on a vessel are not always possible due to varying gauge locations and trim conditions. For more information on gauge point location, see API MPMS Chapters 2.8B and 3.4.

Note: If such soundings indicate emulsion or if emulsion is expected to exist, alternate methods of water measurement such as bottom sampling may be used (see API MPMS Chapter 8.1).

j. Lower the probe slowly to the bottom of the tank. Record the gauge at which the bottom of the tank is found to the nearest whole tape graduation . This is the observed reference height of the tank. (The difference between the ullage of the free water interface and the observed reference height is the free water innage.) Refer to API MPMS Chapter 3.1A, paragraph 11.2.3, for guidance when the observed or published reference height (as stated on the tank capacity table) is either exceeded or not reached.

Note: Because of the design of the probe used, the tip of the probe may not be the zero point of the gauge tape. (See Figure 7.) In that situation, an adjustment to the gauge must be made to convert the observed reference height to the corrected reference height.

Note: Heavy bottom sludge may make the tank bottom difficult to be felt necessitating the use of a specially designed weighted bob. (See Figure 8.) In addition, the probe end of the PMU can become blocked by the sediment, which can seriously affect the sensitivity of the probe.

k. Raise the probe back into the oil and recheck the interface level. Once the interface level is verified, record the free

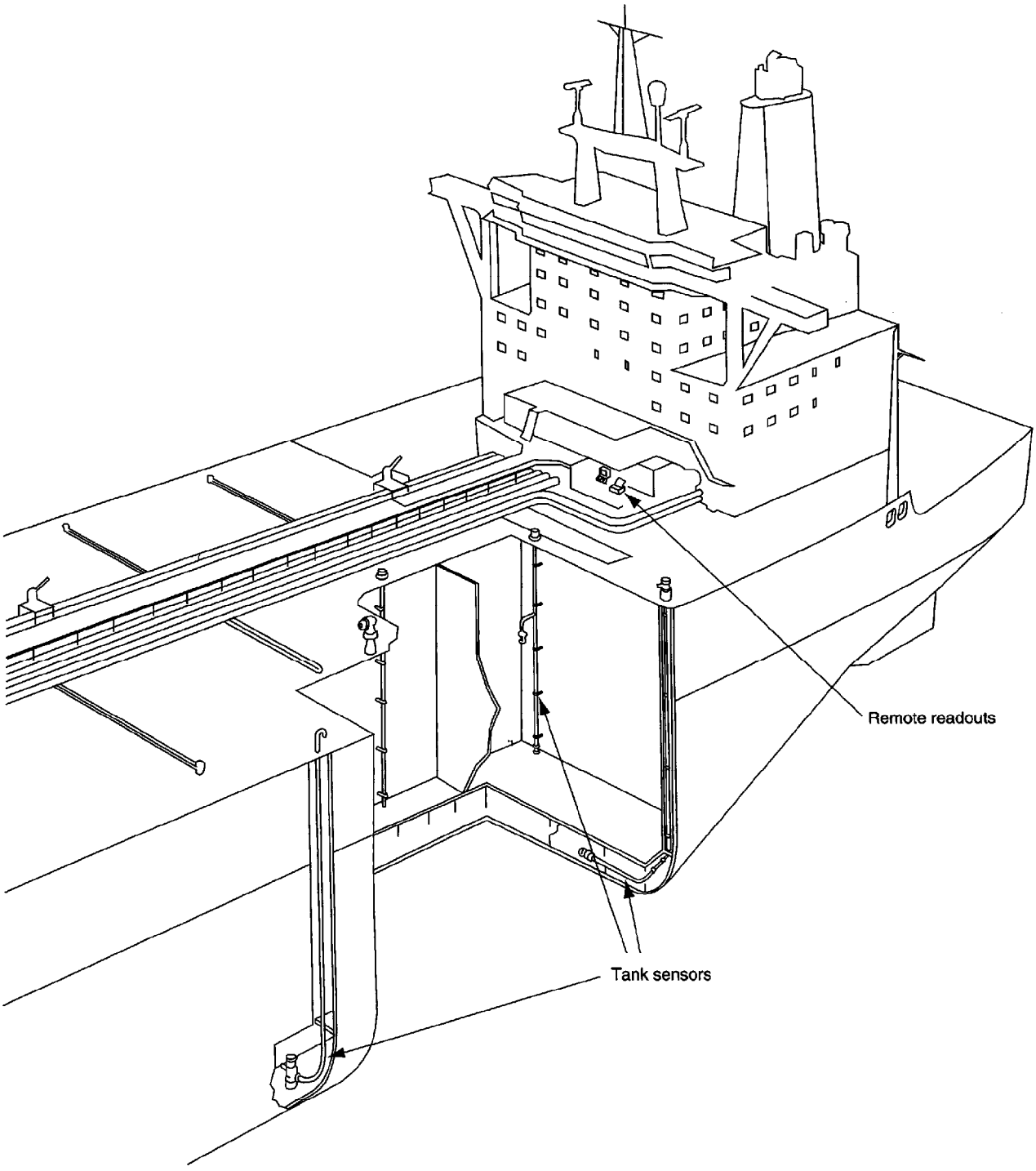


Figure 5—A Type of Automatic Fixed Measurement System Permanently Installed on a Vessel

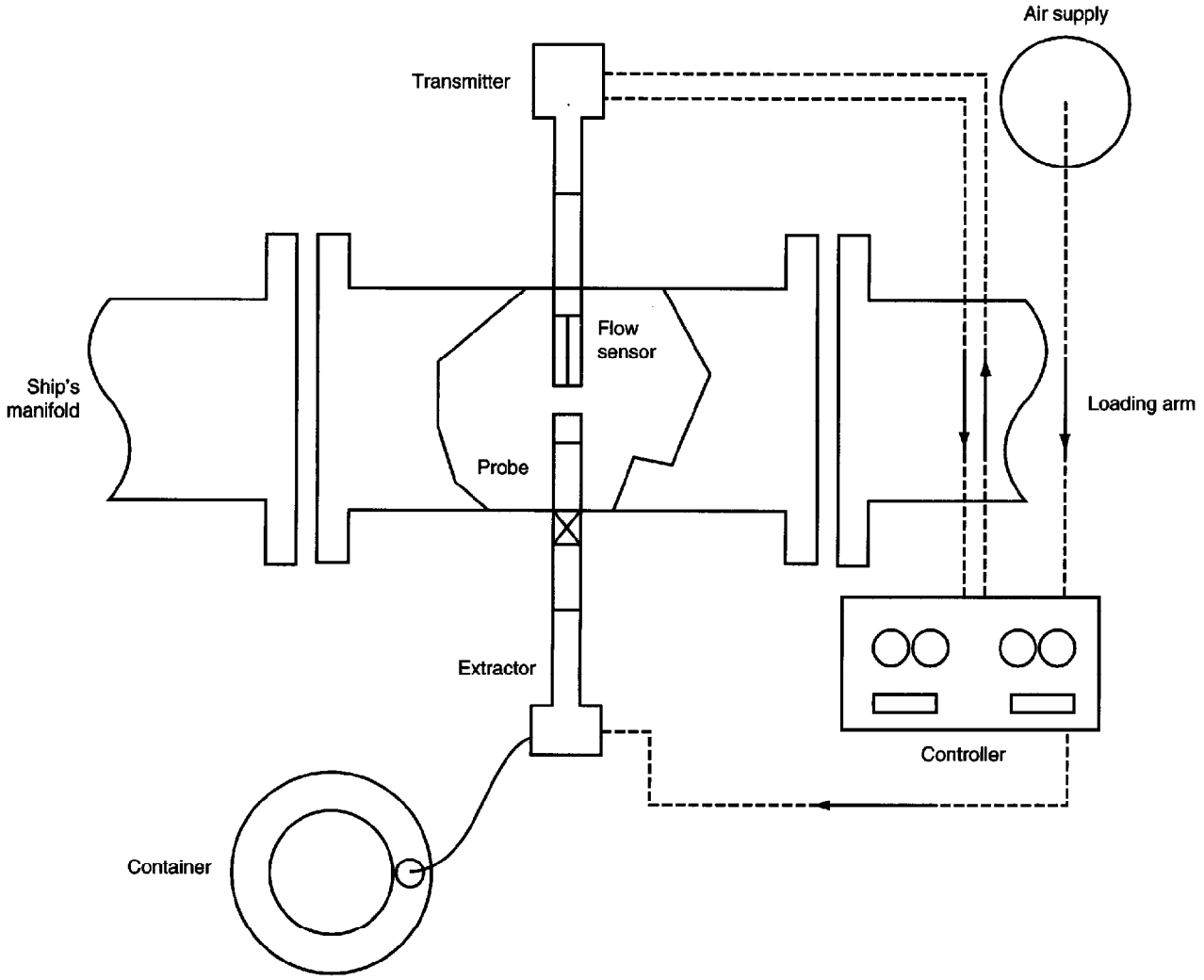


Figure 6—Type of Automatic Sampler Designed for Shipboard Use

water ullage reading to the nearest tape graduation (⅛ inch , 1 millimeter, 100th feet) at the reference gauge point.

l. When all measurements are complete, wind the tape until the bob is fully retrieved above the valve. Then close the VCV and disconnect the gauging equipment from the valve.

m. Verify that batteries are still charged after each tank is gauged.

17.2A.7.3 TEMPERATURE MEASUREMENT

PMUs that can take temperatures are special types of PETs designed to be used in conjunction with VCVs. Such PMUs may be of the single function type or integrated into a multifunction measurement unit. As such, temperatures are to be obtained in conjunction with the measurement of liquid levels in the tank. (See 17.2A.7.2.)

Temperatures measured with these units should be obtained following the requirements of API MPMS Chapters 7.3. and 17.2. All temperatures should be read to the nearest 0.1°F and recorded to the nearest 0.5°F. A sufficient number of temperatures must be taken of each tank to satisfy the minimum requirements as outlined in Table 1 of this document.

17.2A.7.4 MEASURING SMALL QUANTITIES

Measurement of small quantities on board marine tank vessels, including OBQ and ROB volumes, is performed in the same manner as that of gauging liquid levels described in

Section 17.2A.7.2. However, unless reference gauge points are properly located on the cargo tanks, small quantities may not be detectable under all conditions of trim and list. To handle varying trim conditions, gauge points must be located as close to the aft and forward bulkheads as possible. In placing such gauge points, care must be given to ensure their location will not cause the measurement equipment to touch the tank bulkhead when in use. On vessels where only a single trim condition (aft or forward) is experienced, the vessel need only have a single gauge point located in the direction of the normal operational trim of the vessel. For more information on gauge point location, see API MPMS Chapters 2.8B and 3.1A. Also see Appendix B.11.

The following actions should be considered when the existence of ROB, OBQ, or free water is likely but not detectable at the reference gauge point because of the location of the VCV but only when they can be done safely and when operating regulations permit:

a. Request the vessel's officer to reduce tank pressure to a safe level at which the tank can be opened at a point closer to the aft bulkhead.
b. File a protest against the vessel for having a VCV in a location not suitable to allow proper MCTM.

Note: Because of the design of the probe used, the tip of the probe may not be the zero point of the integrated gauge tape (see Figure 7); therefore, in that situation, an adjustment to the gauge must be made.

Procedures outlined in API MPMS Chapter 17.4 should be followed for calculating small quantities on board vessels.

17.2A.8 Procedures for Automatic Closed System Measurement

When vessels are fitted with automatic measurement equipment, the equipment may be used to measure petroleum liquid levels and in some cases temperature. Use of this equipment requires observance of safety procedures outlined in ISGOTT, the IMO *Inert Gas Systems*, and other applicable ICSG and OCIMF publications as well as manufacturer's instructions.

Before taking automatic measurements, verify the following:

a. All cargo operations have been stopped and no cargo is being moved into, out of, or within the vessel
b. The gauging equipment has been calibrated per API MPMS Chapters 3.1B and 3.4.

Note: For best accuracy, trim and list should be eliminated. When both conditions exist, every effort should be made to eliminate at least one condition, preferably list. Conditions of trim and list must be noted and corrections made for their effect on measurements and volumes.

17.2A.8.1 LIQUID LEVEL GAUGING

Before commencing level measurement, the manufacturer's specific operating procedures should be consulted, as well as appropriate vessel personnel, for operational instruction on the particular system aboard the vessel. The manufacturer's instruction should always be used to supplement the following generic guidelines:

a. Confirm the vessel's automatic gauge system is working and determine whether the system calculates volumes automatically or requires the input of measurement data to generate calculated volumes.

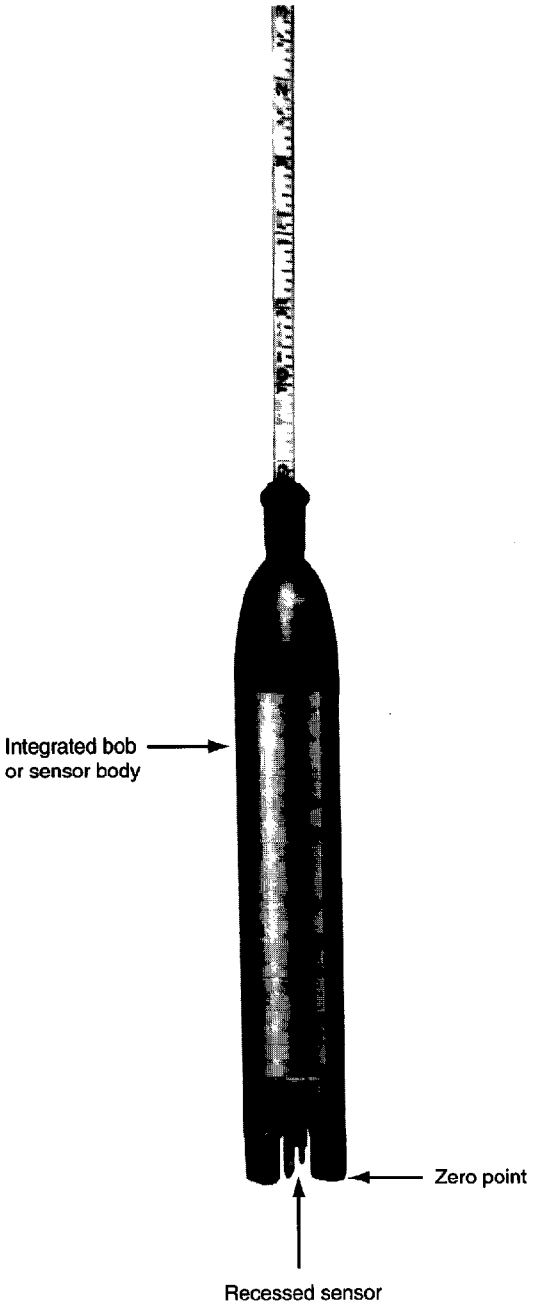


Figure 7—Typical Recessed Sensor

b. Verify that measurements are being taken from the reference points specified by capacity tables.
c. Determine if tank capacity tables include volumes within vessel lines. If they do not, so note and record.
d. Read and record level gauge to the nearest graduation (⅛ inch, 1 millimeter, 100th of foot). (See API MPMS Chapters 3.1B and 3.4.) If the system automatically converts gauges to volumes, record them also.

Note: If the cargo is moving because of swells or waves, at least five measurements should be taken, the highest and lowest readings dropped, and the remaining three averaged. Such adverse conditions should be noted on the ullage report.

e. Repeat step d until all tanks are completed.

17.2A.8.2 TEMPERATURE MEASUREMENT

Review the temperature system verification log and record the last calibration date. Read and record the temperature at the tank or in the cargo control room for all tanks being temperatured. Indicate if temperatures are automatically averaged for each tank. If so, report temperatures to the nearest .5°C or F. If not, temperatures at each tank level should be recorded to the nearest 0.1°C or F and then the level temperatures of each tank manually averaged to .5° and so reported. See Table 1.

17.2A.8.3 DYNAMIC SAMPLING

If a shore or a portable shipboard automatic in-line sampler is used for the custody transfer, follow as closely as possible the guidelines outlined in API MPMS Chapter 8.2. While only static sampling techniques can be used to obtain a sample of what is in the vessel's tanks at any given time, dynamic sampling is used to obtain representative samples of the cargo going onto or being discharged from the vessel.

Since flow rates can vary a great deal during marine vessel loadings/discharges, time proportional sampling is normally not appropriate and a pacing device should be used to ensure flow proportional sampling. Generally speaking, static elements (such as piping elbows) provide better upstream mixing at higher velocities. Therefore, it is recommended that the initial startup of a marine vessel discharge be conducted from a tank that is relatively free of water as determined by the pretransfer inspection. Once the flow rate has reached a steady maximum flow rate, it is recommended to empty the bottoms from each of the vessel's tanks to be discharged.

When shipboard samplers are used at the ship's manifold, the sampler operator should attempt to get the vessel's chief mate to agree to use the minimum number of manifold lines at any given time in order to keep the velocity for each line in a higher range.

17.2A.8.3.1 Inspect the sampler for integrity and cleanliness. When a sampler is used intermittently (as a portable sampler is often used), the sample probe, extractor, and flow sensor (especially in the case of a pilot probe) should be cleaned after every use to prevent plugging. Sediment buildup in the sampler head can cause problems with the o-ring seals and the proper operation of internal check valves, thereby compromising its grab size. If more than one line is to be sampled into one receiver, be sure that the sampling

Table 1—Liquid Temperature Measurement Location Requirements
Portable Electronic Thermometer

Atmospheric Storage Tanks Tank Capacity/Liquid Level	Required Temperature Measurement Locations		
	Upper	Middle	Lower
Tank Capacity Less Than or Equal to 5,000 Bbls		X	
Tank Capacity Greater Than 5,000 Bbls			
Level < 10 ft		X	
10 ft ≤ Level	X	X	X

Note: Each temperature measurement shall be taken within ±1 foot of the specified location.

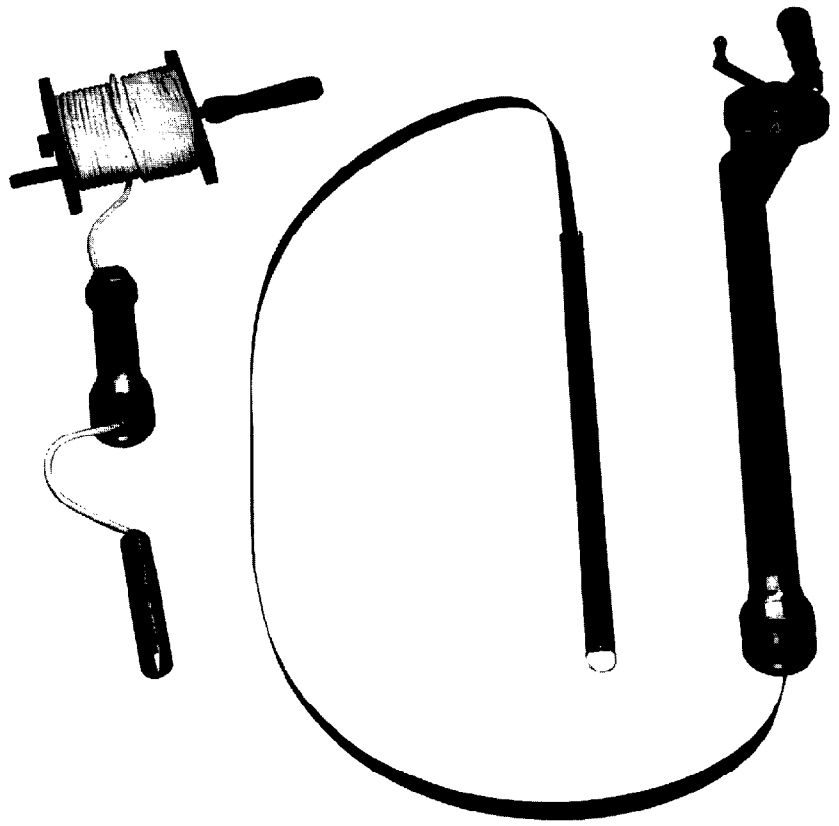


Figure 8—Typical Special Weighted Bar and Bob Units

grab size is essentially the same for each of them to ensure that the lines are sampled in a volume proportional manner.

17.2A.8.3.2 Check to be sure the power source is activated.

17.2A.8.3.3 Prepare the sample system for the transfer. This includes the following:

a. Drain and clean container(s).
b. Verify that valves are in proper position.
c. Verify that the sample lines are drained. (This should have been performed at the end of the last sampling exercises.)
d. Ensure containers are securely closed.
e. Hook up container(s) if necessary.

17.2A.8.3.4 Seal container(s) and record seal numbers if receiver is left unattended.

17.2A.8.3.5 Set up controller. Since flow rates can vary widely during marine vessel loading/discharges, time proportional sampling is normally not appropriate and a pacing device should be used to ensure flow proportional sampling.

Assuming the system is flow proportional and is equipped with a computer, verify or enter as appropriate to the system the setup constants or variables:

a. Expected Parcel Volume (TOV) to be transferred	PVe
b. Expected extractor grab size (ml)	b
c. Expected sample volume (normally 80 percent of receiver capacity)	SVe
d. Expected number of sample grabs	n
e. Frequency of sampling, transfer volume units per grab	B

Note: Setting up the sampler is extremely important, so one must have a complete understanding of the system being used.

17.2A.8.3.6 When flow starts, verify by sight glass, weigh scale, or other appropriate means, that there is flow through each line being sampled and that each line being sampled is in fact delivering sample bites into the receiver(s). This audit function should be done at the approximate midpoint of the transfer and at the end.

17.2A.8.3.7 After the transfer is complete, check the security seals on the sampler container(s) for integrity, secure the system, and label container(s). Then either mix the

sample and distribute as required, or take the entire sample receiver to the laboratory for testing. Follow API MPMS Chapter 8.2 guidelines to evaluate the performance of the sampler.

17.2A.8.3.8 Manifold Samples

In addition to those samples noted in Section 17.2A.8.3, it may be necessary to obtain a line or manifold sample for quality control purposes. This is especially true when clean products are being transferred and the specification of the product must be determined at the beginning of the transfer or at any part of it. In those cases, it must be understood that the sample so obtained is not to be used as a representative sample of the entire cargo but rather as a verification of the parcel's quality.

17.2A.8.4 MEASURING OF SMALL QUANTITIES/FREE WATER

Most ATG systems do not have the ability to accurately measure free water under oil or small amounts of OBQ/ROB, especially if the surface of the OBQ/ROB cannot be detected due to the trim or list. With those systems that can perform such measurements, the sensing devices used must be located so that measurements can be taken under all conditions of trim. To handle varying trim configurations, sensors must be located as close to the aft and forward bulkheads as possible. On vessels that normally operate with only a single trim condition (aft or forward), the vessel need only have sensors located in the direction of its normal operational trim of the vessel. For more information on gauge point location, see API MPMS Chapters 2.8B, 3.1B, and 3.4.

APPENDIX A—PHYSICAL CHARACTERISTICS AND FIRE CONSIDERATIONS

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

API Publication 2217 and API Publication 2026 and any applicable regulations should be consulted when sampling requires entry into confined spaces.

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.

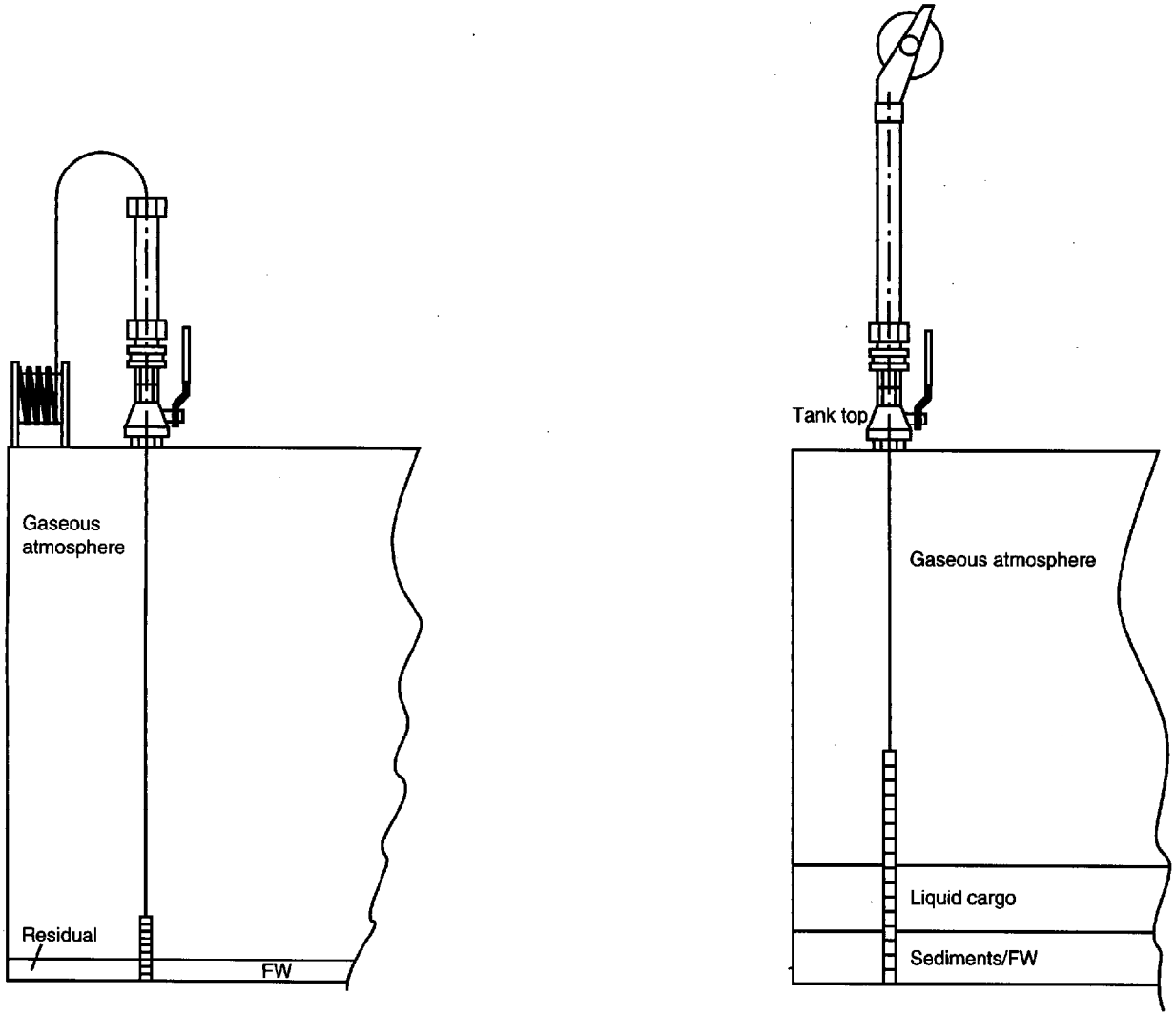


Figure A-1—Taking Water Cuts Through a VCV Using a Special PMU and Brass Bob/Bar

APPENDIX B—ADDITIONAL INSTRUCTIONS AND CAUTIONARY NOTES

B.1 General

This appendix contains additional instructions and cautionary notes regarding measurement accuracy and determination of vessel volumes.

B.2 Training

Many aspects of measurement on board vessels require thorough knowledge and experience so that an accurate survey can be produced. Without adequate and recurrent training of personnel, many errors may be introduced during the measurement and sampling process.

Inaccuracies in the survey obviously have an economic impact on the seller and buyer, and periodic training and review is required to maintain measurement skills. Training and review are essential in maintaining awareness of improved techniques and equipment that allow better cargo measurement and sampling of cargoes on marine tank vessels.

Although this publication describes practices for proper measurement and sampling of liquid cargoes on board vessels, it is not intended to be a training manual. Additional training should be provided to those involved in measurement activities and should be based on current API material. Appropriate training in shipboard operations and safety practices should be provided to all personnel working on board any vessel.

B.3 Discrepancies in Reference Height

The reference height is the distance from the tank bottom or datum plate to the established reference point. Accurate ullages can be taken only when the observed referenced height is the same as the reference height printed in the calibration tables. If a reference height is not specified in the calibration tables, a note should be included in the cargo documents indicating how the reference height was obtained.

Some gauging hatches are situated on hinged manways. If these manways are not properly secured, the reference height will change, which could affect the accuracy of ullages.

To establish good practices and reliable measurements, the reference point should be clearly marked. The reference height should also be clearly marked near the reference point.

When OBQ, ROB, or water cuts are made, the reference height of the gauge point should be confirmed. In the event that a difference is found, it must be established whether the variance is caused by hard residue on the bottom of the tank, an improperly secured manway or hatch, or another observable cause. The decision to use the ullage or the innage method of gauging will depend on the cause of the discrepancy in the reference height. For example, if the difference in reference height is due to a buildup of residue on the tank floor, the ullage method should be used. If the difference is the result of an increase in reference height as a result of the improper setting of the tank top, the innage method should be used.

If it is established that the tank configuration has changed, the official calibration tables should be amended.

B.4 Certification of Calibration Tables

Some vessel owners or operators may use a set of calibration tables prepared for a class of vessels based on one sister vessel. Calibration tables used to determine cargo volumes should be certified, preferably by the shipbuilder, for accuracy of use on board the particular vessel for which they are issued; however, if the only tables available are not certified, they may be used. In all cases, the innage/ullage report should note the name of the vessel the calibration tables were prepared for, the name of the vessel they were used on, the name of the certifying shipbuilder, and if the tables were only certified by the vessel owner or operator, an explanation of why there was no shipbuilder certification, as well as the name of the shipbuilder.

B.5 Missing Calibration Tables

All parties involved, including the vessel's owners, should be notified immediately when the calibration tables cannot be located. A letter of protest should be issued immediately. Copies of the tables should be obtained at the earliest possible opportunity. In such situations, measurement data must be obtained as usual and retained until the tables become available and calculations can be performed.

B.6 Lack of and Poor Maintenance of Equipment

Before any custody transfer occurs, vessel operators, gaugers, inspectors, and others involved in marine bulk cargo transactions must be aware of the specific requirements for and the condition of all measuring equipment and devices used in the transfer. Equipment that is known to be defective, out of calibration, or in poor operating condition must not be used. All equipment, whether automatic or manual, must conform to the API *Manual of Petroleum Measurement Standards*, unless all parties involved in a specific measurement activity have previously agreed on an alternative.

B.7 Draft Readings and Trim and List Corrections

B.7.1 GENERAL

Draft readings must be taken before and after loading and discharging. Draft readings are used to determine the following:

a. The depth of the vessel in the water.
b. The trim and list of the vessel.
c. Whether the vessel is loaded correctly.

Draft readings can also be used as an alternative method for determining the weight of the cargo loaded on board the vessel, by means of a dead-weight survey. With this method, the mean, fore, aft, and amidships draft must be taken and recorded, and the salinity of the water in which the vessel is floating must be determined.

Draft marks are displayed in customary or metric units. The numerals for customary units are 6 inches high and are spaced 6 inches apart. Readings are made from the bottom of the numerals and estimated to the inch (see Figure B-1). The numerals for metric units are displayed in even decimeters, are 10 centimeters high, and are spaced 10 centimeters apart. Readings are made from the bottom of the numerals and estimated to the centimeter (see Figure B-2).

B.7.2 DETERMINATION OF LIST

A vessel's list can be accurately determined in two ways:

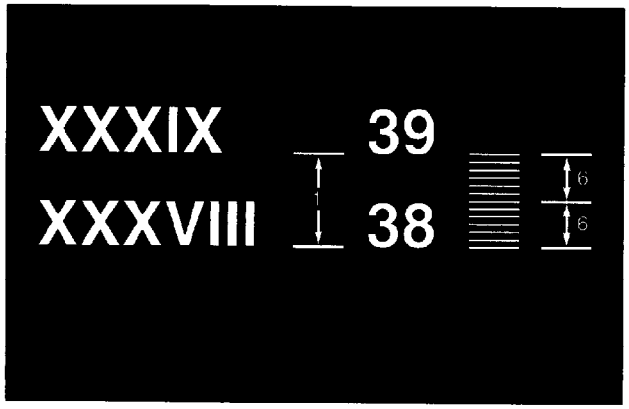


Figure B-1—Draft Readings: Customary Unit

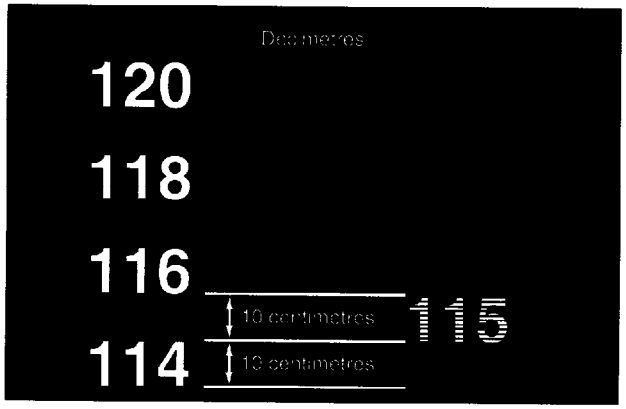


Figure B-2—Draft Readings: Metric Unit

a. By reading the differences between starboard and port drafts and calculating the list.
b. By reading the appropriate clinometer on the vessel's centerline.

A vessel's trim and list must be taken into account when the on-board cargo and free-water volumes are calculated. The ullages or innages that are taken or the volumes that are determined to be in the tanks must be adjusted according to the instructions in the calibration tables. If no adjustments are available, a note to that effect should be made on the ullage report. Measurements may be mathematically adjusted if tank and vessel measurements are known.

B.8 Lightering, Single-Buoy Mooring (SBM), and Other Offshore Activities

Offshore measurements should generally be performed in the same manner as measurements at the dock, but because a transfer is being made while the vessel is on the open sea or in the roadstead, some inherent problems may be involved in lightering operations.

In many instances, lightering will take place between a large tank vessel and one or more smaller vessels. To ensure that all of the material is accounted for, measurements are required on all vessels before and after each transfer.

B.9 Adverse Weather Conditions

Adverse weather will affect personnel safety, marine measurements, and gauging accuracy when the following conditions arise:

a. High winds and heavy seas will present a problem in gauging accuracy if they cause the vessel to roll or pitch. This can be offset by appropriate attention being paid to gauging the oil in motion in the tanks.
b. Any type of precipitation encountered during the measurement/sampling process must be dealt with very carefully. Water-indicating paste should be protected from activation by rain, atmospheric humidity, or moisture on the gauge bob or bar or the tape. Sample containers should be kept clean and dry, and care should be taken that no rain or other external moisture is introduced to the containers.
c. Extremes in atmospheric temperature require special consideration during measurement because of possible reaction of the cargo involved (for example, vaporization or solidification).

B.10 Alternate Procedures for Measurement of Small Quantities

B.10.1 ALTERNATE FREE WATER MEASUREMENT

When using an interface detecting PMU, water finding paste may be placed onto the outside of the probe before

lowering it to the tank bottom. When a clean strike of the tank bottom is felt, allow the probe to remain in the tank a sufficient amount of time for any water present to react with the paste. Normally 30-60 seconds will be required but more time might be necessary for heavier oils. After the required reaction time, retrieve the probe without hesitation and measure the cut on the probe using a calibrated tape. This is the innage of the water in the tank being measured.

The free water ullage obtained by using the PMU can then be converted to a calculated innage by subtracting the ullage from the published reference height. Compare the innage obtained by using water paste to the calculated innage and record both readings if they are different.

B.10.2 BRASS BOB PMU—WATER MEASUREMENT

The traditional brass bob and water finding paste method can be used through a VCV by using a specially designed PMU. This equipment allows the bob to be attached to the end of it. It then may be lowered into the tank like the usual PMU equipment. When this method is used, water levels are determined in API MPMS Chapter 17.2.4.2.1.4.2. (See Figure 8.)

B.10.3 BRASS BOB PMU—OBQ/ROB MEASUREMENT

The traditional brass bob gauging method can be used through a VCV by using a specially designed PMU. This equipment allows the bob to be attached to the end of it. It then may be lowered into the tank like the usual PMU equipment. When this method is used, ROB/OBQ levels are determined as described in API MPMS Chapter 17.2. (See Figure 9.)

B.11 Size and Location of VCVs

The size and location of the VCVs used for closed and restricted system measurement are critical to the process. A VCV of the proper size, located correctly, will allow more accurate measurements to be taken than one that is improperly located and of insufficient size. To be of the best use to allow the measurement of OBQ/ROB and free water under most operating conditions, the VCV must allow access to the tank as far aft as possible and still allow the gauge tape to be lowered to the bottom of the vessel's tank without touching the aft bulkhead during extreme trim by the stern conditions. When the VCV is located in the middle of the tank, it will usually be impossible to measure any free water or OBQ/ROB under normal operating conditions.

Note: To take sufficient samples and accurate measurements of small quantities and free water when the vessel is not on an even keel, a VCV must be located as close as possible to the aft bulkhead or to the bulkhead toward the direction of the vessel's normal operating trim and list.

B.12 Operating Temperature Ranges of PMUs

Each PMU has a designed operating range of temperatures above or below which the units may not function accurately. It is therefore necessary to know the correct operating limits of the equipment used so that the measurement parameters for which they were designed are not exceeded in the field. Only a PMU with a designed operating range suited for the temperature and gravity of the cargo being measured should be used for MCTM purposes.

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