Manual of Petroleum Measurement Standards
Chapter 17—Marine Measurement
Section 2—Measurement of Cargoes On Board Tank Vessels

THIRD EDITION, WG BALLOT DRAFT

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Measurement Coordination

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FOREWORD

This publication is intended to encourage the development of uniform practices for measurement of cargoes aboard marine tank vessels. It presents current methods of cargo measurement, but this is not intended to preclude the use of any new technology or the revision of the methods presented. To gain a better understanding of the methods described in this publication, the reader should review in detail the latest editions of the referenced publications.

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0 INTRODUCTION

Based on present technology, manual gauging, temperature measurement, and sampling are the most accurate overall methods for measuring quantities of cargo, free water, and on-board quantity (OBQ) and/or remaining on board (ROB) on marine tank vessels. Automatic gauging may be as accurate as manual gauging for measuring overall volumes if the manufacturer's instructions are followed and equipment is periodically calibrated and checked using manual gauging as a reference.

Safety and environmental regulations by all levels of government and other regulatory agencies worldwide, are limiting and/or prohibiting the release of hydrocarbon vapors to the atmosphere with regard to tank vessel operations. Consequently, numerous measurement methods and devices are now being used, along with the development of new equipment, that allow the necessary cargo measurements and samples to be taken without opening the vessel's gauge hatches.

The objective of this publication is to provide guidance to vessel and shore personnel on the generally accepted methods of determining cargo quantities on board marine tank vessels using open, closed, and restricted methods. This publication describes suggested techniques and procedures for measuring, calculating, reporting, and keeping records of quantities of crude oils and petroleum products transported in marine tank vessels.

1 SCOPE

The determination of the quantity and quality of cargo on board marine tank vessels is frequently complex. It is necessary to accurately gauge, ascertain the temperature, collect samples, and calculate the amount of all materials contained in the vessel's lines, cargo tanks, and slop tanks. Other spaces on the vessel may also contain cargo, such as ballast tanks, double bottoms, cofferdams, and numerous other non-cargo spaces, all of which shall be checked, and any volumes contained in them shall be calculated. Measurement accountability (quantity and quality) shall further take into account conditions such as, but not limited to, OBQ/ROB, line fullness, pre-loading tank inspection, closed measurement and sampling systems and special procedures for chemical and gas cargoes. Reconciliation of the foregoing may be required if gains or losses exceed expected tolerances.

The detailed requirements for performing all of these actions are contained in numerous *MPMS* standards. This publication identifies the methods for performing these procedures on crude oils, petroleum products, chemical cargoes, LPG and LNG, normally carried on board marine tank vessels; and guides the user to the appropriate standard / guidance document within the *MPMS* suite of standards.

2 NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API

MPMS Chapter 2 *Tank Calibration*

MPMS Chapter 3.1A *Standard Practice for Manual Gauging of Petroleum and Petroleum Products.*

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

MPMS Chapter 3.3 *Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Pressurized Storage Tanks by Automatic Tank Gauging*

MPMS Chapter 3.4 *Standard Practice for Level Measurement of Liquid Hydrocarbons on Marine Vessels by Automatic Tank Gauging*

MPMS Chapter 3.5 *Standard Practice for Level Measurement of Light Hydrocarbon Liquids Onboard Marine Vessels by Automatic Tank Gauging*

MPMS Chapter 7.1 *Liquid-in-Glass Thermometers*

MPMS Chapter 7.2 *Portable Electronic Thermometers*

MPMS Chapter 7.3 *Fixed Automatic Tank Temperature Systems*

MPMS Chapter 7.5 *Automatic Tank Temperature Measurement Onboard Marine Vessels Carrying Refrigerated Hydrocarbon and Chemical Gas Fluids (ANSI/API MPMS Ch. 7.5)*

MPMS Chapter 8.1 *Standard Practice for Manual Sampling of Petroleum and Petroleum Products* (ANSI[1]/ASTM[2]D 4057)

MPMS Chapter 8.2 *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products* (ANSI/ASTM D 4177)

MPMS Chapter 8.3 *Standard Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products (ASTM D5854)*

MPMS Chapter 11.1 *Standard Document and API 11.1 VCF Application Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils*

MPMS Chapter 11.2.4 *Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E, 60E*

MPMS Chapter 12.1.1 *Calculation of Static Petroleum Quantities, Part 1—Upright Cylindrical Tanks and Marine Vessels*

MPMS Chapter 14.1 *Collecting and Handling of Natural Gas Samples for Custody Transfer*

MPMS Chapter 14.8 *Liquefied Petroleum Gas Measurement*

MPMS Chapter 17.1 *Guidelines for Marine Cargo Inspection*

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

MPMS Chapter 17.5 *Guidelines for Voyage Analysis and Reconciliation of Cargo Quantities*

MPMS Chapter 17.6 *Guidelines for Determining Fullness of Pipelines Between Vessels and Shore Tanks*

MPMS Chapter 17.8 *Guidelines for Pre-Loading Inspection of Marine Vessel Cargo Tanks and Their Cargo-Handling Systems*

MPMS Chapter 17.10.1 *Measurement of Cargoes On Board Marine Gas Carriers, Part 1—Liquefied Natural Gas*

MPMS Chapter 17.10.2 *Measurement of Cargoes On Board Marine Gas Carriers, Part 2—Liquefied Petroleum and Chemical Gases*

MPMS Chapter 17.11 *Measurement and Sampling of Cargoes On Board Tank Vessels Using Closed and Restricted Equipment*

ASTMD1265 Standard Practice for Sampling Liquefied Petroleum (LP) Gases, Manual Method

D2421 Standard Practice for Interconversion of Analysis of C5 and Lighter Hydrocarbons to Gas-Volume, Liquid-Volume, or Mass Basis

D2598 Standard Practice for Calculation of Certain Physical Properties of Liquefied Petroleum (LP) Gases from Compositional Analysis

D3700 Standard Practice for Obtaining LPG Samples Using a Floating Piston Cylinder

OCIMF[3]

International Safety Guide for Oil Tankers and Terminals (ISGOTT)

IMO[4]

Inert Gas Systems

OSHA[5]

Occupational Safety and Health Standards (29 Code of Federal Regulations, Section 1910 and following)

ISO[6]

ISO 8943 – Sampling of Liquefied Natural Gas – Continuous and Intermittent Methods

ISO 4257 – Liquefied Petroleum Gases – Method of sampling

SIGTTO[7]

Liquefied Petroleum Gas Sampling Procedures

GPA[8]

STD 2145 Table of Physical Properties for Hydrocarbons and Other Compounds of Interest to the Natural Gas and Natural Gas Liquids Industries

STD 2174 Obtaining Liquid Hydrocarbons Samples For Analysis by Gas Chromatography

1 American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428.

3 Oil Companies International Marine Forum, Portland House, Stag Place, London SW1E SBH England.

4 International Maritime Organization, 4 Albert Embankment, London, SE1 7SR, United Kingdom

5 Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C. 20402.

6 International Standards Organization, ISO publications are available from the American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

7 Society of International Gas Tanker and Terminal Operators Ltd (SIGTTO), 42 New Broad Street, London EC2M 1JD

8 Gas Processors Association, 6526 East 60th Street, Tulsa, Oklahoma 74145

9 Energy Institute, 61 New Cavendish Street, London W1G 7AR, United Kingdom

3 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

For the purposes of this document, the following definitions apply. Terms of more general use may be found in the API *MPMS* Chapter 1 Online Terms and Definitions Database.

3.1.1 all levels sample

A sample obtained by submerging a stoppered beaker, bottle, or portable sampling unit (PSU) to a point just above the free water or other heavy material in the tank, then opening bottle or PSU and raising it at such a rate that the sampling device will be between 70-85% full when it emerges from the liquid.

3.1.2 automatic sampler

A device used to extract a representative sample from the liquid flowing in a pipe. The automatic sampler generally consists of a probe, a sample extractor, an associated controller, a flow-measuring device, and a sample receiver.

3.1.3 automatic tank gauge
ATG

(1) An instrument that automatically measures and displays liquid levels or ullages in one or more tanks either continuously, periodically, or on demand.

(2) The liquid level in a tank as measured using an automatic tank gauge system.

3.1.4 automatic tank temperature
ATT

A system that automatically measures and displays temperatures of liquids in one or more vessel tanks continuously, periodically, or on demand.

3.1.5 automatic vessel tank gauge system

A system that automatically measures and displays liquid levels or ullage in one or more vessel tanks continuously, periodically, or on demand.

3.1.6 ballast

The water taken on when a vessel is empty or partly loaded to increase draft in order to properly submerge the propeller, and to maintain stability and trim.

3.1.7 bottom sample

A spot sample collected from the material at the bottom of the tank, container, or line at its lowest point. In practice, the term bottom sample has a variety of meanings. As a result, it is recommended that the exact sampling location (for example, 15 centimeters (6 inches) from the bottom) should be specified when using this term.

3.1.8 bunker survey

The survey conducted to determine the quantity and quality of bunkers purchased by the vessel; or the process of accounting for bunker quantities on the vessel, before and after loading or discharging, to determine if any cargo was diverted into the vessel's bunker tanks during the cargo operations or voyage.

3.1.9 capacity tables (calibration tables, innage/ ullage tables)

Those tables developed by recognized industry methods that represent volumes in each tank according to the liquid (innage) or empty space (ullage) measurement in the tank. The tables are entered with linear measurements (i.e., feet, inches, meters, centimeters) to obtain calibrated volumes (i.e., barrels, cubic meters, cubic feet). (See Appendix B.4)

3.1.10 closed system

For the purpose of this document, a closed system exists when a marine tank vessel is so designed that no direct exposure and/or release of its cargo tank contents to the atmosphere occurs under normal operating conditions (see *restricted system*).

3.1.11 closed system measurement

Measurement of petroleum cargoes on a closed system marine tank vessel performed using closed measurement devices. [See *restricted system measurement*.]

3.1.12 closed system measurement devices

Those devices which penetrate the cargo tank, but which 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 *restricted measurement devices*.)

3.1.13 composite spot sample

Consists of equal portions of each upper, middle, and lower sample, or equal portions of spot samples taken at uniform intervals in a compartment. It is usually considered to be representative of the contents of the compartment being sampled.

3.1.14 crude oil washing
COW

See tank washing.

3.1.15 draft

The depth of a vessel below its water line as measured from the bottom of the vessel's keel to the surface of the water.

3.1.16 free water
FW

The volume of water present in a container that is not in suspension in the contained liquid (oil) (see text).

3.1.17 gross observed volume
GOV

The total volume of all petroleum liquids and sediment and water (S&W), excluding Free Water (FW), at observed temperature and pressure.

3.1.18 gross standard volume
GSV

The total volume of all petroleum liquids and sediment and water (S&W), excluding Free Water (FW), corrected by the appropriate volume correction factor (Ctl) for the observed temperature and API gravity, relative density, or density to a standard temperature such as 60°F or l5°C. If applicable, correct with pressure correction factor (Cpl) and meter factor.

3.1.19 letter of protest
LOP

A letter issued by any participant in a custody transfer citing any condition with which issue is taken. This serves as a written record that a particular action or finding was questioned at the time of occurrence.

3.1.20 liquefied natural gas
LNG

A mixture of hydrocarbon gases, composed primarily of Methane (CH_4) and Ethane (C_2H_6) that has been cooled to -259 degrees Fahrenheit (-161 degrees Celsius) and at which point it is condensed into a liquid which is colorless, odorless, non-corrosive and non-toxic. Characterized as a cryogenic liquid.

3.1.21 liquefied petroleum gas
LPG

A narrow boiling range mixture of hydrocarbons, typically maintained in the liquid state, consisting of propane, propylene, butanes, and butylenes, individually or in specified combinations, with limited amounts of other hydrocarbons and naturally occurring non-hydrocarbons.

3.1.22 list (heel)

The leaning or inclination of a vessel, expressed in degrees port or starboard.

3.1.23 list (heel) correction

The correction applied to the observed gauge or observed volume when a vessel is listing, provided that liquid is in contact with all bulkheads in the tank. Correction for list may be made by referencing the vessel's list correction tables for each tank, or by mathematical means.

3.1.24 lower sample

A spot sample from the mid-point of the lower one-third of the tank contents (a distance of five-sixths of the liquid depth below the top surface).

3.1.25 manifold sample

A spot sample taken from the ship's manifold to determine the quality of the cargo in the line at that time. A manifold sample is not a representative sample.

3.1.26 middle sample

A spot sample taken from the middle of a tank's contents (a distance of one half of the depth of liquid below the liquid's surface).

3.1.27 net standard volume
NSV

The total volume of all petroleum liquids, excluding sediment and water (S&W) and Free Water (FW), corrected by the appropriate volume correction factor (Ctl) for the observed temperature and API gravity, relative density, or density to a standard temperature such as 60°F or 15°C. If applicable, correct with pressure correction factor (Cpl) and meter factor.

3.1.28 on board quantity
OBQ

The material present in vessel's cargo tanks, void spaces, and pipelines before the vessel is loaded. On-board Quantity may include any combination of water, oil, slops, oil residue, oil/ water emulsions, and sediment.

3.1.29 open measurement

Occurs anytime the vessel's gauge hatches shall be opened to take the appropriate level gauges, samples and/or temperatures.

3.1.30 open measurement equipment

Those devices that are used to take open measurements.

3.1.31 portable manual sampling unit
PSU

Intrinsically-safe device used in conjunction with a vapor control valve to obtain required cargo samples under closed or restricted system conditions.

3.1.32 portable measurement unit
PMU

Intrinsically- safe device used in conjunction with a vapor control valve to obtain required liquid level and/or temperatures under closed or restricted system conditions.

3.1.33 remaining on board
ROB

The material remaining in a vessel's cargo tanks, void spaces, and pipelines after the cargo is discharged. Remaining On Board quantity may include any combination of water, oil, slops, oil residue, oil/ water emulsions, and sediment.

3.1.34 restricted measurement devices

Measurement devices, such as restricted PMUs and PSUs, that penetrate the cargo tank, but which form part of a restricted system that keeps to a minimum the cargo vapors from being released to the atmosphere. (See *closed system measurement devices*.)

3.1.35 restricted system

For the purpose of this document, a restricted system exists when a marine tank vessel is so designed to substantially reduce and minimize the direct exposure and/or release of its cargo tank vapors to the atmosphere under normal operating conditions. (See *closed system*.)

3.1.36 restricted system measurement

Measurement of petroleum cargoes on a restricted system marine tank vessel using restricted measurement devices. (See *closed system measurement*.)

3.1.37 running sample

A sample taken by lowering the unstoppered bottle or PSU through the liquid to the desired level just above the measured free water or other heavy material in the tank and then raising it at such a rate that the sampling devices will be between 70-85% full when it emerges from the liquid.

3.1.38 sludge

That element of the material in a ship's cargo tanks that is essentially not free-flowing. Sludge consists of hydrocarbon waxes and may contain water/oil emulsion and sediment. The use of this term for measurement purposes is not recommended.

3.1.39 spot sample

A sample taken with a bottle or PSU by lowering the stoppered sampling device to the desired level and then pulling the cork to open it and allow the device to fill at the designated level.

3.1.40 standpipe

A vertical pipe installed on the deck of a marine tank vessel to which the vapor control valve may be fitted.

3.1.41 tank washing

is divided into two types of activities:

a. *water washing:* The use of high-pressure water stream to dislodge clingage and sediment from the bulkheads, bottom, and internal tank structures of a vessel.

b. *crude oil washing (COW):* The use of high-pressure stream of the crude oil cargo to dislodge and dissolve clingage and sediment from the bulkheads, bottom, and internal tank structures of a vessel.

3.1.42 total calculated volume TCV

The total volume of all petroleum liquids and sediment and water, corrected by the appropriate volume correction factor (Ctl) for the observed temperature and API gravity, relative density, or density to a standard temperature such as 60 degrees F or 15 degrees C and also corrected by the applicable pressure correction factor (Cpl) and meter factor, plus all free water measured at observed temperature and pressure (gross standard volume plus free water).

3.1.43 total observed volume TOV

The total measured volume of all petroleum liquids, sediment and water (S&W), and Free Water (FW) at observed temperature and pressure.

3.1.44 trim

The condition of a vessel with reference to its longitudinal position in the water. Trim is the difference between the forward and aft drafts and is expressed by the head or by the stern.

3.1.45 trim correction

The correction applied to the observed gauge or volume in a vessel's tank when a vessel is not on an even keel, provided that liquid is in contact with all four bulkheads in the tank. Correction for trim may be made by referencing the vessel's trim tables for each tank or by mathematical calculations.

3.1.46 upper sample

A spot sample of liquid from the middle of the upper one-third of the tank's content (a distance of one-sixth of the depth liquid below the liquid's surface).

3.1.47 vapor control valve VCV

A valve fitted on a standpipe, expansion trunk, or the deck that permits use of the portable hand-held gauging instruments while restricting the release of vapors into the atmosphere.

3.2 SYMBOLS AND ABBREVIATIONS

ATG	Automatic tank gauge
ATT	Automatic tank temperature
COW	Crude oil washing
FW	Free water
GOV	Gross observed volume
GPA	Gas Processors Association
GSV	Gross standard volume
IMO	International Maritime Organization
ISGOTT	International Safety Guide for Oil Tankers and Terminals
IGS	Inert gas system
NSV	Net standard volume
OBQ	On-board quantity
OCIMF	Oil Companies International Marine Forum
PET	Portable electronic thermometer
PMU	Portable measurement unit
PSU	Portable sampling unit
ROB	Remaining on board
S&W	Sediment and water
SIGTTO	Society of International Gas Tanker and Terminal Operators Limited
SOLAS	Safety of Life at Sea Convention
TCV	Total calculated volume
TOV	Total observed volume
UTI	Ullage, temperature, interface (Also a portable measurement unit capable of measuring these three parameters.)
VEF	Vessel experience factor
VCV	Vapor control valve

4 SAFETY AND HEALTH CONSIDERATIONS

4.1 GENERAL

Personnel involved with the gauging and sampling of petroleum and petroleum-related substances should be familiar with their physical and chemical characteristics, including potential for fire, explosion, and reactivity, and with the appropriate emergency procedures as well as potential toxicity and health hazards. Personnel should comply with the individual company safe operating practices and with local, state, federal, and national regulations, including the use of proper protective clothing and equipment.

Personnel involved in the handling of liquefied natural gas should be familiar with its physical and chemical characteristics, including potential for fire, explosion, cryogenic burns (frostbite) and reactivity, as well as the appropriate emergency procedures. These procedures should comply with the individual company's safe operating practices, in addition to local, state and federal regulations, including those covering the use of proper protective clothing and equipment. Personnel should be alert in order to avoid potential sources of ignition.

Personnel involved in inspection, measurement, and/or sampling on board a vessel shall at all times be accompanied by a designated ship's representative.

4.2 STATIC ELECTRICITY HAZARDS

If the tank is in a noninert condition, specific precautions will be required with regard to safe measurement and sampling procedures when handling static accumulator oils. These are generally as follows: during loading, and for 30 minutes after the completion of loading, metallic equipment for dipping (gauging), ullaging, or sampling shall not be introduced into or remain in the tank. Examples of equipment include manual steel ullage tapes, portable gauging devices mounted on deck stand pipes, metal sampling apparatus, and metal sounding rods.

Nonconducting equipment with no metal parts may, in general, be used at any time. However, ropes or tapes used to lower equipment into tanks shall not be made from synthetic materials. After the 30-minute waiting period, metallic equipment may also be used for dipping (gauging), ullaging, and sampling, but it is essential that it is effectively bonded and properly grounded before it is introduced into the tank and that it remains grounded until after it has been removed. Operations carried out through stand pipes are permissible at any time because it is not possible for any significant charge to accumulate on the surface of the liquid within a correctly designed and installed stand pipe. A stand pipe should extend the full depth of the tank and be effectively bonded and earthed to the tank structure.

4.3 HEALTH HAZARDS

Petroleum vapor dilutes oxygen in the air and may also be toxic. Hydrogen sulfide (H2S) vapors are particularly hazardous. Petroleum vapors with relatively low concentrations of hydrogen sulfide may cause unconsciousness or death. During and after the opening of any tank or vapor control valve, personnel should position themselves to avoid any gas that may be released. Harmful vapors or oxygen deficiency cannot always be detected by smell, visual inspection, or judgment. Appropriate precautions should be used for the protection against toxic vapors or oxygen deficiency. It is recommended that users always wear gas monitors that, as a minimum, measure gas concentrations of H2S.

Procedures should be developed to provide for the following:

a) Exposure monitoring;

b) Need for personal protective equipment;

c) Emergency rescue precautions

When necessary, suitable fresh air breathing equipment should be worn prior to entering the gauge site and during the gauging and sampling procedure.

This discussion on safety issues is not exhaustive and the appropriate API or Energy Institute publications, together with ISGOTT, International Convention for the Safety of Life at Sea (SOLAS), Society of International Gas Tanker and Terminal Operators Limited (SIGTTO), and Oil Companies International Marine Forum (OCIMF) publications, should be consulted for applicable safety precautions.

5 DIFFERENCES BETWEEN LPG/LNG AND OTHER LIQUID PETROLEUM PRODUCTS

5.1 GENERAL

Liquefied gas cargo quantities delivered to or discharged from ships or barges are measured and calculated basically in a similar manner to that of other bulk liquid cargoes such as crude oils and petroleum products. That is to say by measuring cargo volume and obtaining cargo density and, after correcting both to the same temperature, multiplying these factors to obtain the cargo quantity.

However, unlike the generality of bulk liquids carried by sea, liquefied gases are carried as boiling liquids in equilibrium with their vapors in closed containment systems. This leads to more complicated measurements and calculation procedures than in the case of other bulk liquids.

(i) The inclusion of vapor.

Ullage spaces at all times, when cargo is in the tank, contain saturated vapor of the cargo liquid and very little, if any, of other gases. The vapor may evaporate from, or may condense back into, the liquid during the process of cargo handling and the containment and handling processes generally ensure that the vapor is not lost to atmosphere. The vapor is, therefore, an intrinsic and significant part of the cargo and shall be accounted for in the cargo quantification.

(ii) Net quantities of cargo transferred are the difference between “before” and “after” quantities.

It is common practice on discharge to retain on board a significant quantity of liquid (heel) and its associated vapor to keep tanks cool on the ballast voyage and to provide refrigerant for cooldown before loading the next cargo. At loading, the new cargo is added to the heel or, if the ship has arrived with uncooled tanks, to the product put on board for tank cooldown purpose. Thus, before and after transfer it is necessary to quantify the ship’s tanks’ contents in order to ascertain the cargo discharged or the cargo loaded.

(iii) Temperature and liquid level measurements.

Cargo being loaded may arrive in the ship’s tanks at temperatures which may vary over the loading period. This may be due to cargo being taken from different shore tanks at varying temperatures or to initial cooling of shore pipelines or to varying pump power input to flowing cargo. Liquefied gases have comparatively large coefficients of volume expansion with temperature. The result in variation in the density of the arriving cargo may therefore be sufficient to give rise to some stratification of a ship’s tank content after loading. A number of temperature sensors are usually provided at different tank levels and it is important that all these temperature readings are taken into account in order to assess more accurately the average temperatures of the liquid and of the vapor and from which the appropriate temperature corrections may be applied.

Also, by boil-off or by condensation, a tank’s liquid and vapor content will adjust themselves to saturated equilibrium; this equilibrium may not be achieved immediately after loading. It is desirable therefore to delay cargo measurement for as long a time as possible subject to the constraints of ship’s departure, etc.

5.2 LNG/LPG QUANTITY MEASUREMENTS

Quantity measurements can be obtained from calibrated vessel tank capacity tables, or from flow metering devices. Vapor outside of the transfer needs to be metered and properly accounted for during the loading or discharge operation (between the opening and closing gauges). Meters need to meet custody transfer standards. In order to determine LPG quantity, the following practices are followed:

- Pressure
- Gauging (API *MPMS* Chapters 3.3, 3.5, 17.10.2, and 14.8)
- Temperature (API *MPMS* Chapters 3.3, 3.5, 7, and 11.2.4)
- Composition (GPA 2145, ASTM D2163)
- Density (Direct or by Calculation (ASTM D1657, ASTM D2598))
- Sampling – (ASTM D1265, ASTM D3700, ISO 4257)

Additional guidance on marine measurement of LPG can be obtained from API *MPMS* Chapter 17.10.2.

In order to determine LNG quantity, multiple data points are needed to perform final calculations, such as:

- Pressure
- Gauging (API *MPMS* Chapters 3.3, 3.5, 17.10.1, and ISO 10976)
- Temperature (API *MPMS* Chapters 3.3, 3.5, 17.10.1, 11.2.4, and ISO 10976)
- Composition (GPA 2145, GPA 2261, ASTM D1945, ISO 6974)
- Density (Direct or by Calculation (ASTM D4784, ISO 6578)
- Sampling and Analysis – (GPA 2172, GPA 2174, GPA 2261, API *MPMS* 8.6, ISO 6974, ISO 8943)

Additional guidance on marine measurement of LNG can be obtained from API *MPMS* Chapter 17.10.1.

5.3 VOYAGE RECONCILIATION

When working with LNG/LPG cargo quantities, an unusual gain or loss of cargo volume may occur. The same principles described in API *MPMS* Chapter 17.5 for voyage reconciliations of Liquid cargoes can be applied to pressurized gasses and chemical cargos. Those principles are to collect measurement data, complete a Voyage Analysis Report (VAR) sufficient for LNG/LPG cargoes (Note: if required also complete a Voyage Summary and Reconciliation Report), investigate the reason(s) for the Loss/gain, and take action where appropriate. In all cases, reconciliations should be performed only to the accuracy of the uncertainty of the measurements and always should be performed with a consistent calculation methodology. It is also important to include any volumes that have been vented, flared, consumed or otherwise not included in both the ship and shore measurements.

6 OPEN MEASUREMENT EQUIPMENT AND PROCEDURES FOR LIQUID PRODUCTS

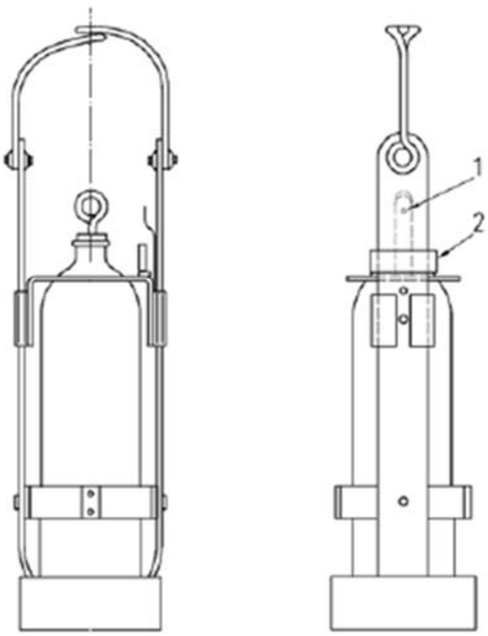
6.1 GENERAL

Open measurement occurs whenever a liquid product vessel's measurement hatch is opened to the atmosphere to perform the necessary measurement tasks. Due to the physical characteristics, composition, and safe handling of Liquefied Natural Gas and Liquefied Petroleum Gas, open measurement procedures for gauging and sampling of LNG/LPG are strictly prohibited.

6.2 OPEN MANUAL SAMPLING

A comprehensive guide and additional technical data on open manual sampling equipment and procedures can be found in API *MPMS* Chapter 8.1. The following are important aspects to consider when performing open sampling.

- Sampling equipment shall be in good condition, safe, and be made of such material that no interaction between the container and the cargo would affect the integrity of either.



Key

1 Swivel point

2 Locking piece

- Before use, all sampling equipment (including containers and cords or chains) shall be inspected to ensure that they are clean, dry, and free from all substances that might cause contamination to the sample and/or cargo.
- In order to maintain sample specifications, a wide assortment of sample containers are available to maintain quality. Please consult API *MPMS* Chapter 8.3 for additional guidance on what is the most appropriate sample container for how the sample will be used.
- In the event that it becomes necessary to sample Free Water and/or Sediment, additional specialized equipment should be utilized. Additional information on this equipment and its use can be found in API *MPMS* Chapter 8.1.

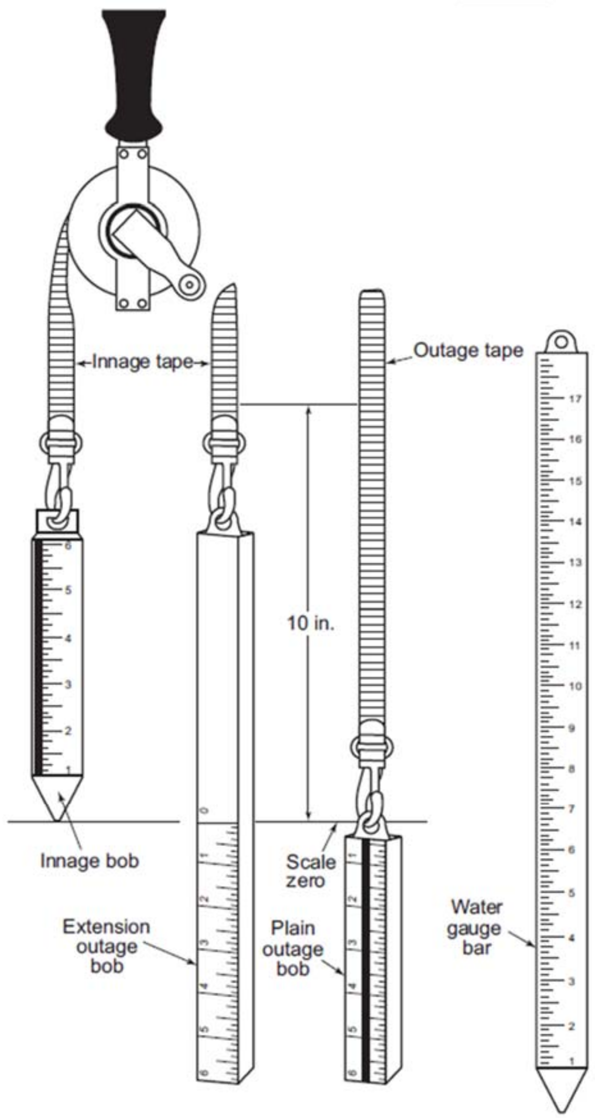
6.3 OPEN MANUAL GAUGING

Manual open gauging involves the use of tape and bob through an open tank gauge hatch to obtain the atmospheric level of liquid in the tank using the ullage or innage methods.

A comprehensive guide and additional technical data on open manual gauging equipment and procedures can be found in API *MPMS* Chapter 3.1A. The following are important aspects to consider when performing open gauging.

- All equipment used for manual gauging shall be safe for use with the material to be measured, shall be checked for accuracy, and shall be in good condition. Before a tape is used, it should be checked for breaks, kinks, and illegible markings. The tape hook should be inspected for wear and distortion. Ullage bobs and Innage bobs should be inspected for wear and damage of the tip and eye hole.

- Additional procedures are necessary when gauging involves determining the levels of Free Water in a tank. Guidance on these procedures can be found in API *MPMS* Chapter 3.1A.
- It should be noted that Tank Capacity tables on board vessels may have been created for only one type of gauging practice, i.e., Innage Tables, Ullage Tables, PMU, etc. The user may need to apply extra corrections to their observed readings in order to obtain accurate readings to account for using a different gauging procedure.
- API *MPMS* Chapter 17.4 contains further direction on determining On Board Quantities (OBQ) and/or Remaining On Board (ROB) volumes and calculation procedures.

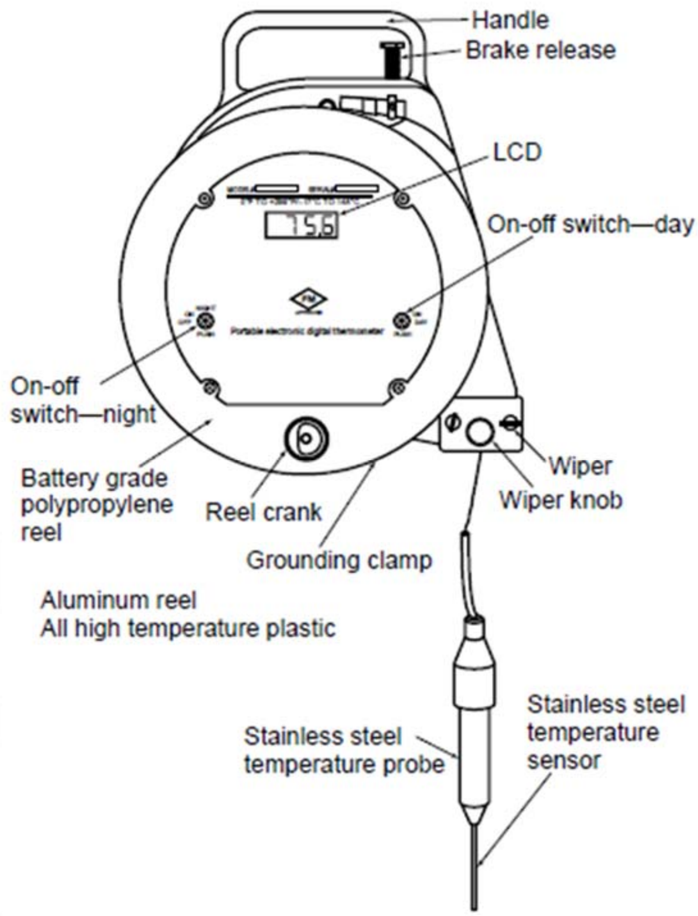


a) Typical Gauge Tapes and Bobs **b) Typical Water Gauge Bar**

6.4 OPEN TEMPERATURE DETERMINATION

Temperature has the most significant effect on the accurate determination of liquid quantities when correcting to standard atmospheric conditions. As a result, the most accurate means for temperature determination should be used for these applications.

API *MPMS* Chapter 7 contains a complete technical description and procedures for obtaining temperatures on open atmospheric measurements, as well as accuracy and calibration verification procedures for the various instruments that might be used to perform open temperature measurement.



7 CLOSED AND RESTRICTED MEASUREMENT

7.1 GENERAL

A closed measurement system is designed to allow cargo measurements to be taken with no vapors escaping to the atmosphere. A restricted measurement system is designed to allow measurements to be taken with minimal vapors being allowed into the atmosphere. The two basic categories of closed or restricted system measurement equipment used on marine tank vessels are a “portable measurement unit” (PMU) and “fixed automatic” (ATG). For more detailed information, please consult API *MPMS* Chapter 17.11.

If a closed or restricted measurement system is to be used for marine custody transfer measurements, the accuracy of the equipment used should fall within the tolerances set forth in all sections of API *MPMS* Chapters 2, 3, and 7. 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 shall be warranted by the manufacturer. 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 custody transfer volumes.

7.2 MANUAL CLOSED AND RESTRICTED SYSTEMS

This section describes the equipment to be used and the procedures to be followed when measuring cargoes on ships that have manual closed or restricted systems.

7.2.1 Manual Closed and Restricted Equipment

Manual equipment consists of a Portable Measurement Unit (PMU) which shall be carried from tank to tank to obtain the appropriate measurements through a Vapor Control Valve (VCV) located at each tank. Generally, PMUs and VCVs made by the same manufacturer are designed to be compatible. However, equipment made by different manufacturers may be used together with an appropriate adapter that either does not require measurement correction or has a known fixed correction.

7.2.1.1 Vapor Control Valve

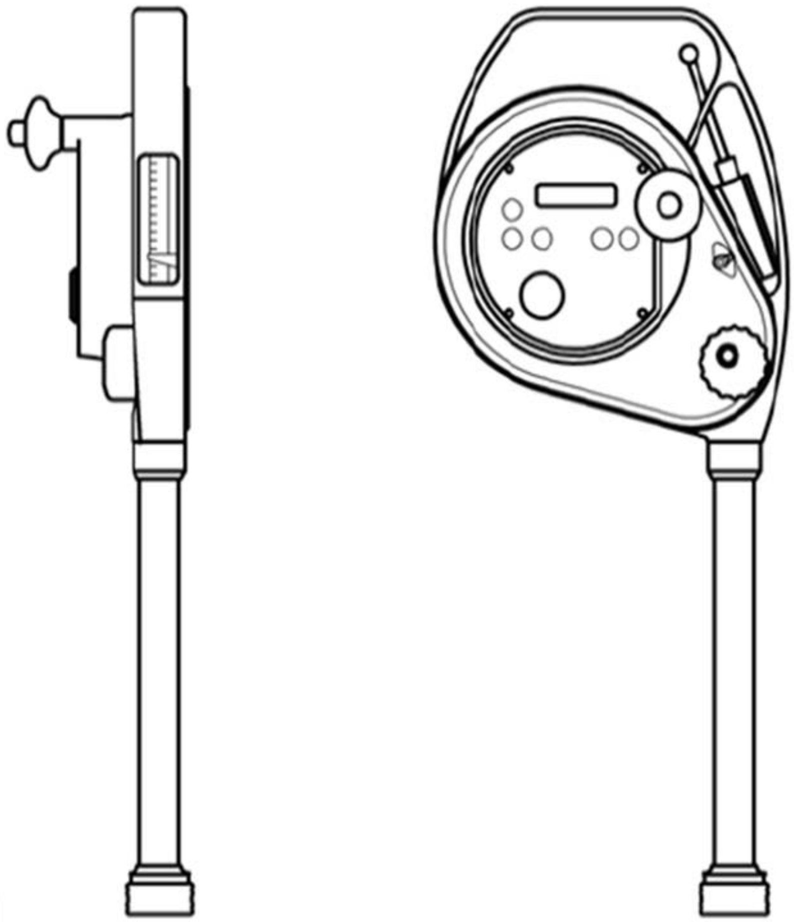
These valves are generally found on standpipes, flanges, existing ullage hatches, expansion trunks, or fitted flush to the vessel's deck (see Figures 9, 9a, and 9b).

They are designed to allow the attachment of the portable measurement or sampling device using a securing device or adaptor. By operating the VCV according to the manufacturer's instructions, the PMU probe, sampler tape, and/or sampler can be lowered into the tank through the VCV whether or not the vessel's inert gas system (IGS) is putting positive pressure into the tanks. VCV's can vary in size, diameter and location which are critical for the ability to measure tank contents and to take sufficient samples. Larger diameter VCV's are preferred (ideally 4 inch or 100mm in diameter), as smaller diameter VCV's increase the difficulty in obtaining a representative sample, and will also significantly reduce the amount of time required to obtain samples and thereby reduce personnel and environmental exposures. For more information, please refer to API *MPMS* Chapters 2.8B, 3.4 and 17.11.

NOTE Since many vessels have been fitted with vapor control valves 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 locations for PMU equipment. Also, the vapor control valve 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 actions may have to be taken to obtain correct measurements. Such corrective actions should take into consideration the use of adapters that allow the use of different manufacturers' portable measurement units with varying vapor control configurations.

7.2.1.2 Portable Measurement Unit (PMU)

The portable measurement unit (PMU) is designed to measure oil levels, water levels and/or temperatures of cargo in tanks. The unit may be designed to perform one, two, or all three of the foregoing functions. Multi-function units are sometimes referred to as UTIs (Ullage, Temperature, Interface). Most PMUs use an electronic sensing device integrated into on a measuring tape (see Figure 10) Each PMU shall 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. Also, before using a PMU, verify its design capabilities and refer to the manufacturer's instructions for proper use and warranted accuracies.



7.2.1.3 Maintenance/Verification

When measurement equipment is first put into service, it shall be carefully inspected and verified as suitable for its intended use. Individual components of all PMU's shall be maintained and verified in accordance with API *MPMS* Chapters 3.1A, 7.3 and 17.11.

7.2.2 Closed and Restricted Equipment Usage

When vessels are fitted with vapor control valves, portable electronic gauging equipment can be used to measure free water, petroleum liquid levels, and temperature. It may also be used for measuring liquid ROB/OBQ. Special PMUs and/or techniques may be used for taking samples and for measuring non-liquid ROB/OBQ. Use of this equipment requires observance of safety procedures outlined in the International Safety Guide for Oil Tankers and Terminals, (ISGOTT), the International Maritime Organization (IMO), Inert Gas Systems (IGS), and other applicable International Chamber of Shipping, the Oil Companies International Marine Forum (OCIMF) publications and manufacturer's instructions. For more detailed information refer to API *MPMS* Chapter 17.11.

7.2.2.1 Liquid Level/Free Water Gauging Using PMUs

Measurement of quantities on board marine tank vessels shall be performed in accordance with API *MPMS* Chapters 3.1A and 17.11.

7.2.2.2 Closed and Restricted Measuring of Small Quantities

Measurement of small quantities on board marine tank vessels, including OBQ and ROB volumes shall be performed in the same manner as that of gauging liquid levels described in API *MPMS* Chapter 17.4. 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 and/or list conditions, gauge points shall be located as close to the aft and forward bulkheads, as well as the centerline of the vessel, as possible. For more information on gauge point location, gauging and quantification see API *MPMS* Chapters 2.8B, 3.1A, 17.4, and 17.11.

7.2.2.3 Temperature Measurement Using PETs

PMUs that can take temperatures are a special type of portable electronic thermometer (PET) 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.

For more detail information refer to API *MPMS* Chapter 17.11

7.3 AUTOMATIC CLOSED SYSTEMS

Automatic closed measurement systems allow measurements of the ship’s cargo to be taken without opening the cargo hatches or using vapor control valves. Automatic measurement equipment consists of permanently installed, fixed devices in a vessel’s tanks to determine liquid levels, and temperature. Automatic sampling equipment used on tank vessels may be fixed or portable. This section describes the automatic equipment most widely used on ships and the procedures for properly using them to obtain accurate measurements.

7.3.1 AUTOMATIC TANK GAUGING EQUIPMENT

Automatic tank gauging equipment, also known as remote or fixed measurement equipment, is built into the vessel. Such measurement systems on tank vessels normally have automatic level measurement capability, with readouts located at the compartment or at a remote point, such as the cargo control room. More information on the types of ATG equipment available, installation, calibration, verification and reading reporting procedures can be found in API *MPMS* Chapter 3.4.

The operation and capabilities of these systems vary greatly by technology and manufacturer. Some systems may only measure liquid levels in the tank after the level reaches a certain height. Other systems may have the capability to measure multiple elements, such as free water, temperature, and ROB/OBQ. ROB/OBQ measurement necessitates that the liquid level is not below the minimal measurable range as indicated in the vessel’s capacity tables and where the level is not detectable by the automatic tank gauge sensor. Automatic Tank Gauge measurement can be used for custody transfer of liquid level quantities, as long as the overall system accuracy meets the requirements of API *MPMS* Chapter 3.1B.

7.3.2 AUTOMATIC TEMPERATURE EQUIPMENT

Temperatures can be taken automatically if a shipboard automatic tank temperature measuring system (ATT) is available. All of the requirements necessary for the installation, calibration, verification, and reporting procedures, as well as the custody transfer conditions needed, for a marine ATT system are fully described in API *MPMS* Chapter 7.3.

7.3.3 AUTOMATIC SAMPLING EQUIPMENT

Most automatic sampling equipment used for marine custody transfer measurement purposes is located ashore. While some vessels have automatic samplers permanently installed on or near the vessel’s manifold, most automatic samplers used on board vessels are of the portable type that are temporarily attached to the vessels manifold at the time of hose connection. Regardless of the type of installation, design, performance, and verification of all automatic sampling equipment shall be in accordance with API *MPMS* Chapter 8.2.

8 SAMPLING AND SAMPLE HANDLING

8.1 GENERAL

Manual sampling consists of obtaining a relatively small portion of material in a vessel’s tank(s) using the appropriate manual sampling equipment. Manual samples should be taken when sufficient quantities of petroleum liquid, free water, and/or sediment are present. Dynamic sampling is the obtaining of a representative sample of the material in the pipeline being loaded onto or off the vessel.

Samples should be taken in quantities that are mutually agreed upon by the parties involved. API *MPMS* Chapter 8.1 / ASTM D4057 contains detailed information on manual sampling.

Samples shall also be handled properly from the time they are obtained to the time they are ultimately used or stored. Accordingly, also refer to API *MPMS* Chapter 8.3.

8.2 MANUAL SAMPLING CONCEPTS AND OBJECTIVE

The objective of manual sampling varies. In some instances, the intention is to obtain a small portion of product that is representative of the tank or container contents. In other instances, samples are specifically intended to represent product only at that one particular point in the tank, such as a top, dead bottom, or suction level sample. When a tank is determined to be homogenous, a series of spot samples may be combined to create a composite sample. Precautions should be taken to maintain the integrity of the sample by preventing it from being contaminated by the sample point, the sample apparatus and equipment, the cleanliness of the container, the weather, and sample transfer operations.

If the liquid in the tank is determined to be non-homogeneous or stratified (see 8.1.7.1), the parties involved should be notified, and an appropriate sampling procedure is agreed upon.

When the liquid is known or suspected to be contaminated, the parties involved should mutually agree on an acceptable sampling procedure.

8.2.1 Upper, Middle, Lower, and Bottom Samples (Spot Samples)

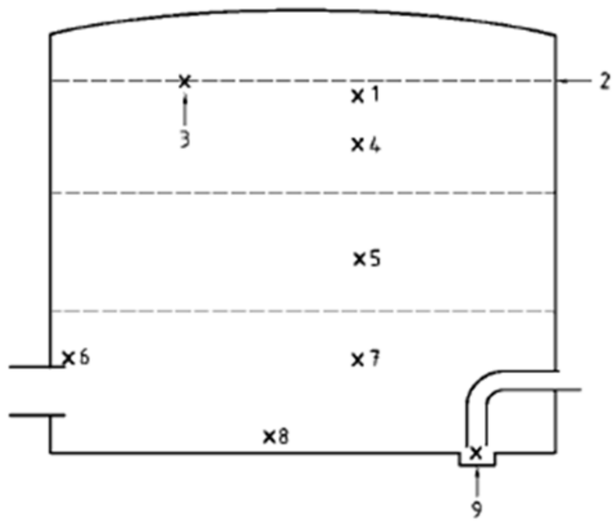
An upper sample is a spot sample taken at the midpoint of the upper third of the tank contents.

A middle sample is a spot sample taken at the middle of the tank contents.

A lower sample is a spot sample taken at the midpoint of the lower third of the tank contents.

A bottom sample is a spot sample collected from the material at the bottom of the tank, container, or line at its lowest point. In practice, the term bottom sample has a variety of meanings. As a result, it is recommended that the exact sampling location (for example, 15 centimeters (6 inches) from the bottom) should be specified when using this term.

A spot sample may be taken with either a weighted sampling bottle or sample can, or with a portable sampling unit (PSU). When using a PSU to take a spot sample, refer to API *MPMS* 8.1/ ASTM D4057 for guidance.



Key

1 Top sample
2 Surface of product
3 Skim sample
4 Upper sample
5 Middle sample
6 Suction level or outlet samples
7 Lower sample
8 Bottom sample
9 Sump sample

8.2.2 Composite Spot Samples

A composite spot sample is constituted of equal portions of each upper, middle, and lower sample, or equal portions of spot samples taken at uniform intervals in a compartment and is usually considered to be representative of the contents of the compartment being sampled.

NOTE When spot samples are used to make a composite sample that represents the contents of a tank, an increased number of spot samples taken at reduced, uniform intervals may be required to account for stratification.

Refer to API *MPMS* Chapter 8.1/ ASTM D4057 for guidance.

8.2.3 All-Levels Samples

An all-levels sample may be taken with either a weighted sampling bottle or with a portable sampling unit (PSU). When using a PSU to take an all-levels sample, follow the manufacturer's instructions for opening and closing the unit during the sampling process and determining the level of fill when it is withdrawn from the liquid.

Refer to API *MPMS* Chapter 8.1/ ASTM D4057 for guidance.

8.2.4 Running Samples

A running sample may be taken with either a weighted sampling bottle or with a portable sampling unit (PSU). When using a PSU to take a running sample, follow the manufacturer's instructions as to how to open and close the unit during the sampling process, and to determine the level of fill when it is withdrawn from the liquid.

Refer to API *MPMS* Chapter 8.1/ ASTM D4057 for guidance.

8.2.5 Free-Water Samples

Free water is normally found on the bottom of a vessel's tanks, although when the cargo is heavier than water, free water may be found on the cargo's surface.

The procedures to be used to sample any free water depend on the amount of water and where it is in relation to the cargo. If the water is of sufficient depth, spot samples may be taken as described in 8.1.1 of this standard.

Refer to API *MPMS* Chapter 8.1/ ASTM D4057 for guidance.

8.2.6 Small-Quantity OBQ and ROB Samples

The non-uniform nature and minimal depth of small quantities of OBQ and ROB material usually make it difficult to obtain a sample. However, whenever the nature of the material is in doubt, samples should be obtained from each tank containing OBQ or ROB when there is quantity to sample.

OBQ and ROB can usually be sampled using equipment such as a scoop sampler or tube sampler. The sampling report should indicate the method used.

Refer to API *MPMS* Chapter 8.1/ ASTM D4057 and API *MPMS* Chapter 17.4 for guidance.

8.2.7 Other Considerations for Sampling

Samples of other types of materials may also be required to verify product quality, and to identify recovered residue, oil and water emulsion layers, oil layers, sludge layers, and bunkers. Some additional considerations for samples are as follows:

8.2.7.1 Stratification

Stratification may exist in a tank due to cargo blending, differences in temperature, density, pour point, etc. If such conditions exist, additional sampling may be required within each layer. When individual spot samples for each layer detected are taken, each should be kept separate until the material sampled has been identified.

8.2.7.2 Sludge

If a sludge is present in the tank, its thickness should be measured; however, it is difficult to obtain a representative bottom sample of sludge, since other phases that exist above it will interfere. Under most circumstances, sludge sampling can be done in much the same way as sediment sampling (see API *MPMS* Chapter 17.1.6).

8.2.7.3 Bunkers (Ship's Fuel)

Bunker samples are taken as part of a bunker survey for the purposes of loss control, purchase, sale, or charter provisions. Such spot samples are to be taken as any other sample described in the foregoing sections.

8.2.7.4 First Foot Sample (Test Trial Portion)

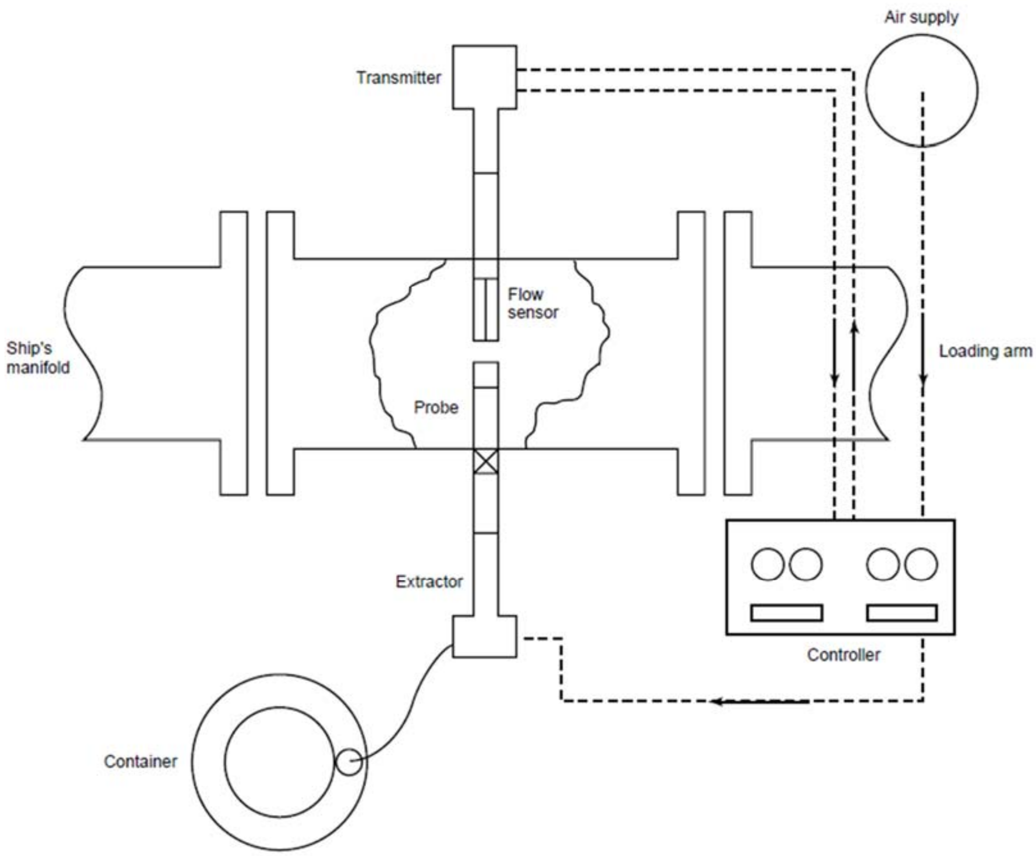
This is the process of loading a small amount of the cargo into the vessel's tanks, suspending the loading operation, and securing a sample to be tested for agreed specifications. The purpose of this procedure is to determine whether the loading lines and the vessel's cargo tanks have the ability to load "on-spec" product.

If a first-foot sample is required, it should be taken when approximately 0.3 m (1 ft) of cargo has been loaded into the tank. A sample is then drawn from the tank. The sample should be examined or tested to determine conformity with cargo specifications. If the sample indicates potential contamination, all parties should be notified and no additional cargo shall be loaded into the tank until the problem is resolved.

Additional guidance can be found in API *MPMS* Chapter 17.8.

8.3 DYNAMIC SAMPLING

If a shore or a vessel automatic in-line sampler is used for the custody transfer, follow 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.



8.4 MANIFOLD (SPOT LINE) SAMPLES

For quality control purposes, it may be necessary to obtain a line, pump, or manifold sample. This is especially true when clean products are being transferred and the specification of the product shall be determined at the beginning of the transfer and/or at any part of it. In those cases, it shall be understood that the "manifold sample" obtained is not to be used as a representative sample of the entire cargo. Refer to API *MPMS* Chapter 17.8 for guidance.

8.5 HANDLING OF SAMPLES

Taking samples from the tanks by whatever means is only part of the sampling process. Once a sample is obtained, it shall be protected from contamination or alteration, such as the loss of light ends and water. Additional guidance can be found in API *MPMS* Chapter 8.3.

8.6 LABELING OF SAMPLES

Sample containers should be labeled immediately after a sample is obtained. Refer to API *MPMS* Chapter 8.3 for guidance.

9 DATA COLLECTION, TABLES, BASIC CALCULATIONS, RECORDS, AND REPORTS

9.1 GENERAL

Vital components of good measurement of cargo on vessels is the accurate recording of observations obtained either through physical measurement or automatic systems, then applying the appropriate tables for the correct calculation of volumes. This section will present a framework for vessel data collection to determine vessel volumes.

9.2 DATA COLLECTION

Measurement data should be gathered and recorded in a systematic manner and permanently maintained in an appropriate Field record book. A checklist of measurement tasks to be performed is given in API *MPMS* Chapter 17.1.

9.3 OBSERVATIONS, MEASUREMENTS, AND CALCULATIONS

Vessel measurement data collection includes several steps:

- recording the draft, trim, and list on both the port and starboard sides of the vessel,
- observed cargo level, water cuts, and temperatures on all cargo compartments at the reference point indicated on the vessel's capacity tables,
- Inspect for the presence of cargo in non-designated cargo spaces, ballast tanks, cofferdams, and void spaces,

The preferred condition of the vessel is to be on an even keel (i.e. with zero trim and list), which eliminates the need for any trim or list corrections to be applied to the gauge readings. Otherwise trim and list corrections listed in the vessel capacity tables will be necessary. When vessels have no list or trim correction tables, refer to API *MPMS* Chapter 12.1.1. Vessel capacity tables should be certified by the shipbuilder, classification society, independent inspection company, or other approved competent third party for accuracy of use on board the specific vessel for which they are issued. For more detailed information, please refer to API *MPMS* Chapter 17.1.

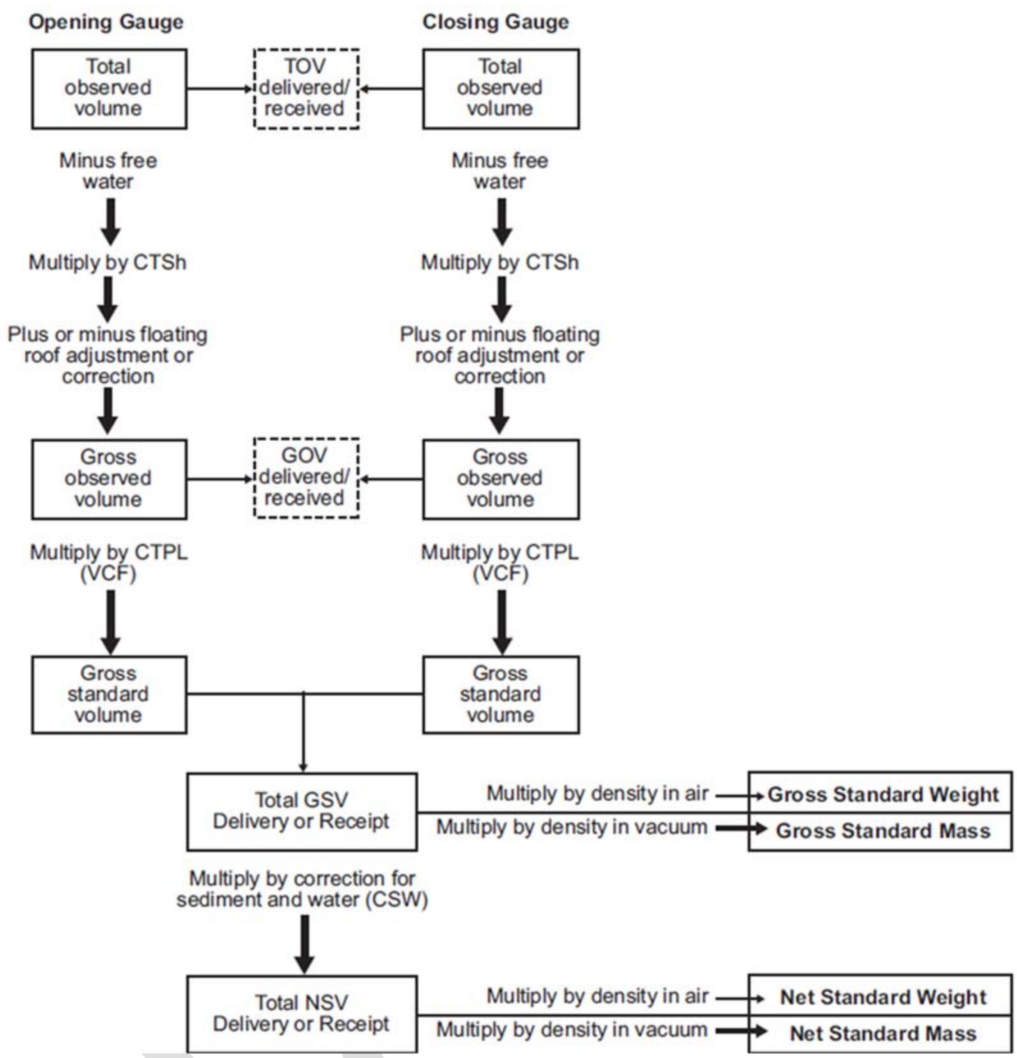
Knowledge of the pipeline volume condition during data gathering, and/or line fullness verification, is important to determine volume accuracy. For more detailed information, please refer to API *MPMS* Chapter 17.6.

9.4 VOLUME CORRECTION TABLES AND CALCULATIONS

After all vessel measurement data has been collected, observed and standard volume calculations can now be made. The flow chart shown below is from Annex A of API *MPMS* Chapter 12.1.1 and illustrates the proper step sequence to performing volume calculations. For additional information not covered in the flow chart, please refer to API *MPMS* Chapter 12.1.1.

In order to obtain standard volumes, a volume correction factor, (or Correction for Temperature and Pressure of Liquid – CTPL) is needed to complete the calculation. Its purpose is to take observed volumes at observed temperatures, and convert the volumes to a standard base temperature, such as 60 °F or 15 °C. For additional information on using the appropriate volume correction factor, please consult the relevant section of API *MPMS* Chapter 11.1, or as otherwise agreed with commercial parties.

Examples of Shore Tank and Marine Vessel Tank Calculations [3]



10 SPECIAL CONSIDERATIONS

10.1 GENERAL

Because of the wide variation in physical properties of all world crudes, special consideration shall be given to the properties of the particular crude in question when an attempt is made to gauge quantities on board marine tank vessels. Heavy fuel oils - and even some clean products - may also have characteristics that require special consideration when performing measurement activities. In addition, conditions existing at the time of measurement sometimes require special attention for the task at hand to be properly performed. Some of those considerations are addressed in this section.

10.2 HIGH-VISCOSITY AND HIGH-POUR-POINT CARGOES

High-viscosity and high-pour-point cargoes can present specific problems with respect to the gauging of free water. In this case, when the presence of free water is suspected, the vessel's tanks should be sampled for free water. If examination of the sample clearly indicates the existence of free water, further steps should include the following:

a. Advise principals.

b. Advise vessel.

c. Take additional samples for testing and retention.

d. Document steps taken and findings.

When a high-viscosity or high-pour-point crude can be cut with water-indicating paste, time should be allowed for the paste to react with the oil/water emulsion.

10.3 HEATED CARGOES

Heating of cargoes may cause unusual temperature stratification. In such cases, additional temperatures may be required to get a good average temperature of the cargo.

Heated cargoes sometimes present problems with respect to the type of water-indicating paste being used. Some pastes do not withstand higher temperatures and are either dissolved or washed off before readings can be taken.

10.4 MEASUREMENT ON BOARD ROLLING MARINE TANK VESSELS

Occasionally, a vessel will encounter operational scenarios where the cargo compartment levels will fluctuate, due to the kinetic water conditions affecting the vessel's hull. These operations include but are not limited to: Ship to Ship (STS) lightering in an open seaway, floating offshore facilities (i.e., FPSO, FSO), a berth that can be affected by meteorological and/or oceanographic, or other physical occurrences while the vessel is alongside. When cargo levels are in motion, please follow the procedures indicated in API *MPMS* Chapter 3.1A.

In the event that three gauges cannot be taken within a range of 3 mm (or 1/8 in.) because the cargo is moving, at least five readings shall be obtained in minimal time, recorded, and then averaged. The ullage/outage gauges are to be taken as quickly as is practical and the immersion time of the bob/tape should be as brief as possible. Adverse conditions such as these shall be recorded.

10.5 SPIKED CRUDES

Some crudes are injected with light hydrocarbons such as butanes, liquefied petroleum gas, or condensate. Special care should be taken with these crudes because of potential vapor buildup, especially after long voyages. In addition, in-transit vapor loss may be higher than usual.

10.6 HIGH VAPOR PRESSURE CARGOES

High Vapor Pressure cargoes such as gasoline and other light products, some very light crude oils, and condensates all have potential problems as those indicated in the previous section. As such, special care should be used when taking open hatch measurements, especially on hot days.

10.7 SOLIDIFIED OBQ/ROB

If the OBQ/ROB quantities are solidified (non-liquid), a trim and/or list correction may still be applied if the material is in contact with all four bulkheads and the angle of solidification can be determined. If the solidified material is not in contact with all bulkheads, a wedge calculation may be done. However, wedge calculations and/or wedge tables can only be used to calculate the volume of the solid OBQ/ROB if it can be determined that the solid has taken, and is in, the shape of a wedge. It shall be noted that such determinations usually involve taking measurements at more than one place in the tank and that it may not always be possible to do so because of physical restrictions presented by the tank or because of operating conditions. In all circumstances, the cargo documents should include the vessel's trim and list and should note that material was solidified. Solids and small quantities of liquid for which temperatures cannot be obtained may be assumed to be at standard temperature. For calculations of small quantities see API *MPMS* Chapter 17.4.

10.8 OUT-OF-TRIM VESSELS

When a marine tank vessel is out of trim, oil and free water may not be measurable at the usual gauge points. Although the oil or water should be found in the general direction of the trim or list, it may be trapped in segregated areas of the tank. In these circumstances, more extensive methods of liquid determination may be employed if safety and operational conditions permit. In such circumstances, the cargo documents should include the vessel's trim and list, as well as any other pertinent facts.

10.9 STATIC ACCUMULATOR CARGOES

Some cargoes have a tendency to accumulate a static charge during the loading or discharge process and need a relaxation time for the charge to dissipate before measurement equipment can be safely introduced into the tank. Most clean products are static accumulators while most black oils are not. In addition, static inhibitors may be added to some cargoes to reduce the risk of static charge. To determine which cargoes are accumulators and for special considerations to be taken during the measurement and sampling of them, refer to ISGOTT for full details.

ANNEX A
(Informative)
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 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 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.

ANNEX B
(Informative)
ADDITIONAL INSTRUCTIONS AND CAUTIONARY NOTES

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

B.1 Different Types of Ships and Barges

There are various types of ships and barges used to carry petroleum products. Each presents its own challenges to the performance of accurate measurement. This section discusses most of the basic types and the potential problems each may cause in obtaining proper cargo measurements. When going on board a ship for the First time, the ship's general arrangement plans should be reviewed to see where all the tanks are and whether the ship is single- or double-hulled. Barges usually do not carry such plans and the bargeman should provide the required information.

B.1.2 DOUBLE HULL VESSELS

Double hull vessels are more common due to increased environmental and industry regulations. These differ from the single hull vessels in that the cargo tanks are surrounded by another hull or series of tanks (see Figure B-1). Because of the "clean" tank design of the vessels cargo tanks, there usually are no obstructions in the cargo tanks to hinder the taking of good innages. However, because the main cargo tanks are located above a series of other tanks, it may be difficult to measure any material, cargo, water, bunkers, etc. in those tanks. Double hull vessels also usually have fewer tanks to gauge than does a conventional, single hull vessel. Some of the problems with double hulls are similar to those of OBOs/OROs (also see B.1.4).

B.1.3 MID-DECK TANKERS

One of the detriments to the double hull design is that ships can lose as much as 33% of their potential cargo-carrying capacity to the empty spaces comprising the double hull. In order to help remedy this problem, alternate hull designs have been proposed by shipowners. The mid-deck tanker is one of several designs that provide protection of the cargo in case of a hull rupture without significantly reducing the vessel's carrying capacity (see Figure B-2). The existence of a two-deck cargo tank system, however, can cause various potential measurement problems, many of which may not be fully realized until ships of this type come into full service. Some of the problems would be similar to those noted in OBOs or OROs (see B.1.4).

B.1.4 COMBINATION CARRIERS—OBOs and OROs

Combination carriers, such as ore/bulk-oil carriers (known as OBOs) and ore-or-oil carriers (known as OROs), are specialty vessels designed to carry either dry or liquid bulk cargoes. The basic procedures described in this publication apply to combination carriers. In addition, because of the unique design of combination carriers, extra care should be taken when liquid cargoes are measured on board these vessels.

The following points should be noted:

a. Combination vessels usually have double bottoms and side and wing tanks in addition to normal cargo tanks.

b. Bottom lines on combination vessels may not be calibrated and often run beneath the cargo tanks.

c. Because of the large width of each ore/bulk-oil tank, trim and list corrections are critical, and errors can be magnified if the corrections are not correctly applied.

d. Some combination vessels have cargo ducts instead of piping systems.

e. Because the bottoms of combination vessels' tanks may sustain random deformities resulting from dry bulk handling procedures, OBQ/ROB determinations may be affected, especially in regard to the establishment of the liquid plane.

f. Such deformities may affect the validity, development, and application of the vessel's VEF.

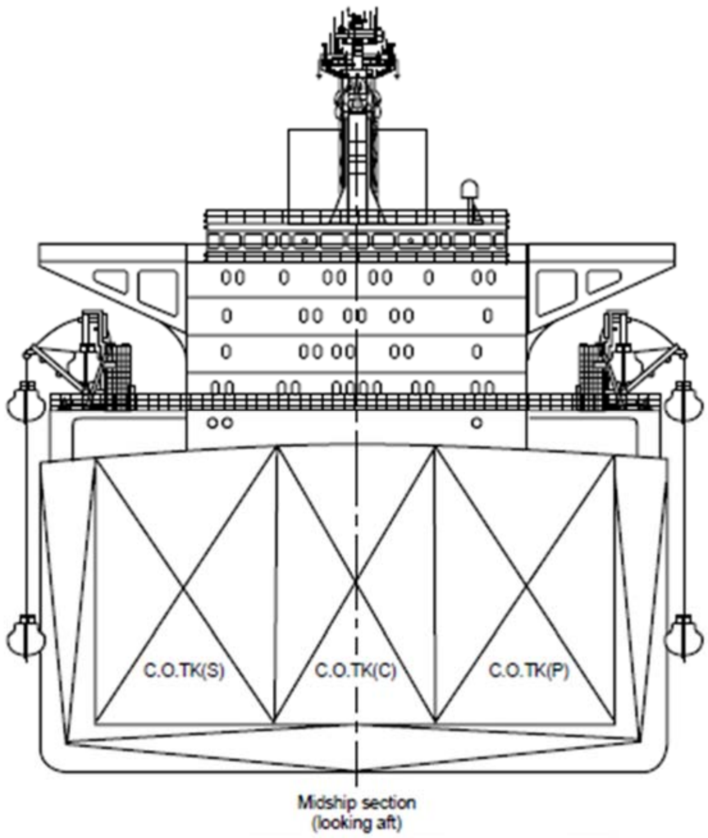


Figure B-1—Typical Double Hull Cross Section

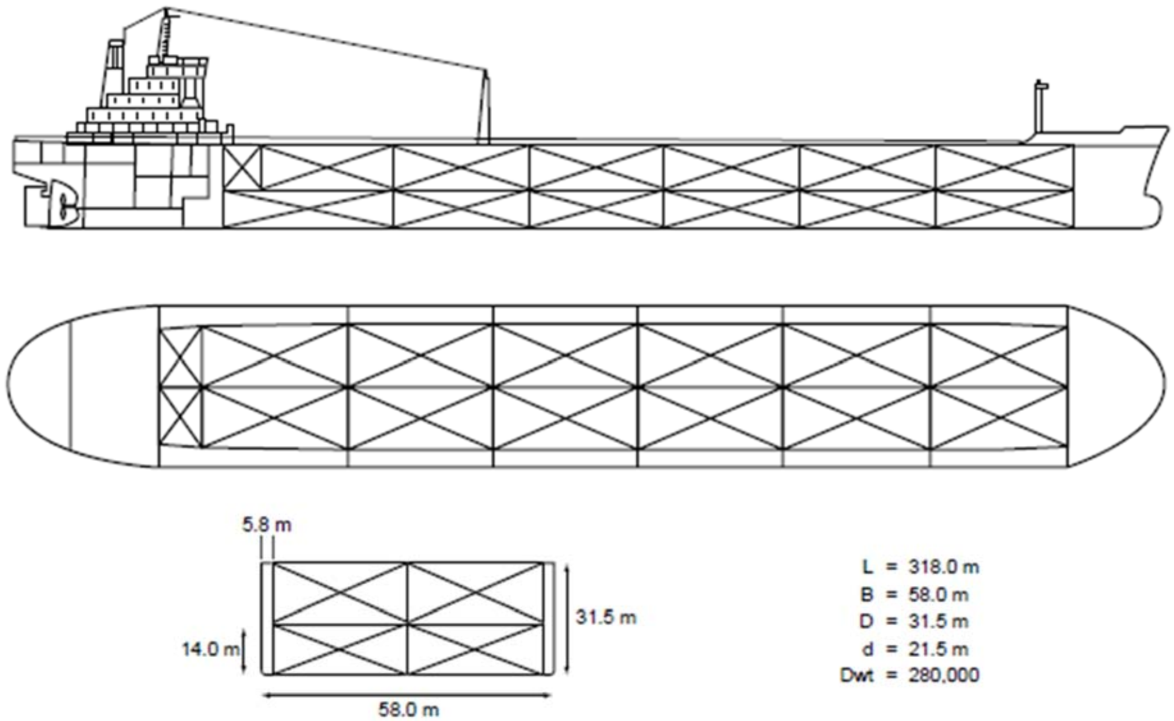


Figure B-2—Typical Mid-Deck VLCC Design

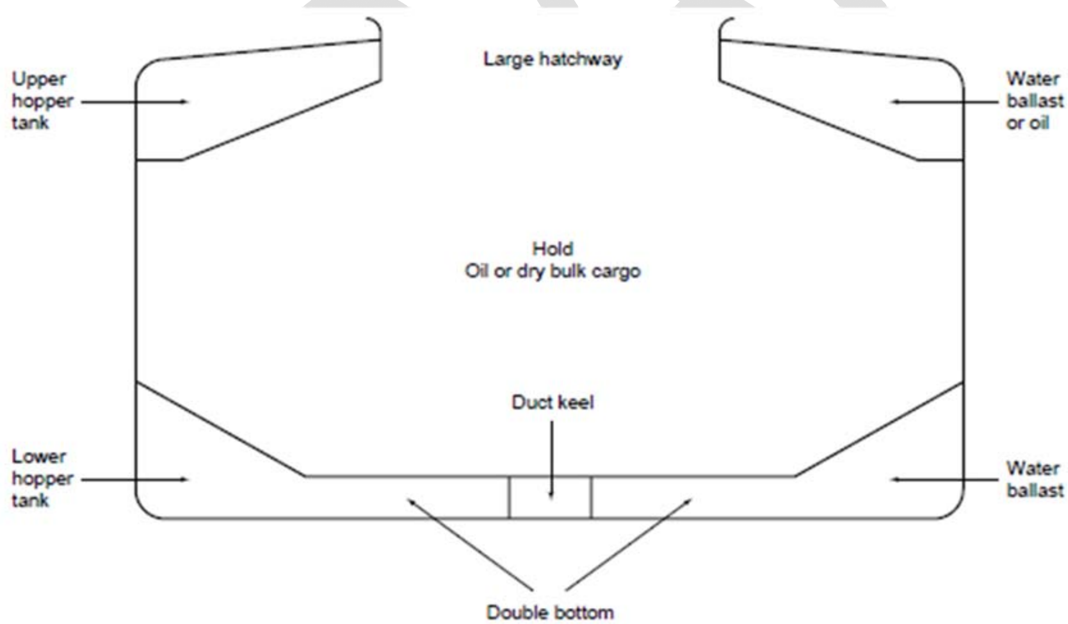


Figure B-3—Typical OBO Cross Section

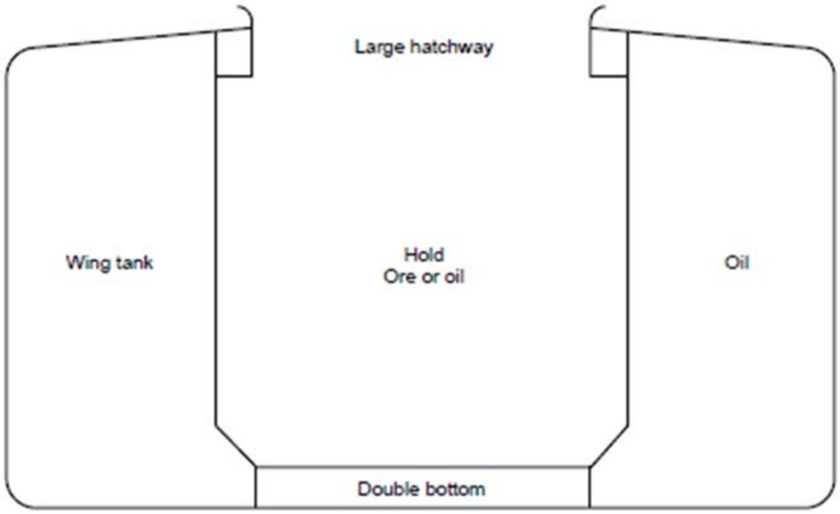


Figure B-4—Typical ORO Cross Section

B.2 Training

B.2.1 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.

B.2.2 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 measurement and sampling of cargoes on marine tank vessels.

B.2.3 Although this publication describes 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 Gauge Height

B.3.1 The reference gauge height is the distance from the tank bottom or datum plate to the established reference point. The reference point is the position on the gauge hatch or tank where all measurements should be taken. To establish good practices and reliable measurements, the reference point should be clearly marked and the reference height clearly inscribed near the reference point.

B.3.2 Observed and official gauge heights should be recorded and compared for each tank, with any differences and reasons for them noted on the inspection report. If a reference height is not specified in the capacity tables, a note should be included in the cargo documents indicating how the reference height was obtained.

B.3.3 Some reasons that may cause differences in observed gauge heights and potentially affect the accuracy of measurement are: gauge hatches situated on improperly-secured manways; sediment build-up in tanks; obstacles or deadwood in tanks; and changes in tank configuration.

B.3.4 In the event that differences are found, the gauger shall determine whether to use the innage or the ullage method to measure the levels in the tank. This decision will depend on the cause of the discrepancy. 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 caused by an increase in reference height as a result of improper setting of the tank top, the innage method should be used. If it is established that the tank configuration has changed, a protest should be filed, and the official capacity tables amended (see B.4).

B.4 Certification of Capacity and Wedge Tables

Some vessel owners or operators may use a set of capacity tables prepared for a class of vessel based on one sister vessel. Capacity 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 they 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 why there is no shipbuilder certification, as well as the name of the shipbuilder (see B.3).

B.5 Missing Capacity Tables

All parties involved, including the vessel's owners, should be notified immediately and a letter of protest issued when the vessel's capacity tables cannot be located. Copies of the tables should be obtained at the earliest possible opportunity. In such situations, measurement data shall 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 shall 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 shall not be used. All equipment, whether automatic or manual, shall conform to the latest edition of the *API Manual of Petroleum Measurement Standards* (*MPMS*), 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 DRAFT READINGS

B.7.1.1 Draft marks are displayed in US Customary (feet and inches) or SI (metric) units. The numbers for US Customary units are 6 inches high and are spaced 6 inches apart. Readings are made from the bottom of each number and are estimated to the nearest inch (see Figure B-5). The numbers 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 numbers and estimated to the centimeter (see Figure B-6).

B.7.1.2 Draft readings shall be taken before and after loading and discharging. They are usually 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.

B.7.1.3 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 draft survey. To accomplish this, the salinity of the water in which the vessel is floating shall be determined and the vessel's port and starboard, fore, aft, and midships drafts taken, averaged, and recorded. The vessel's deadweight/displacement scale is then entered using the average draft and the salinity. This gives the total weight on board the vessel at the time of observation. Subtract the vessel's fuel, water, stores, and constant from the total weight on board to determine the weight of the cargo on board. Additional guidance can be found in API *MPMS* Chapter 17.14.1 and API *MPMS* Chapter 17.14.2

B.7.2 DETERMINATION OF TRIM AND LIST

B.7.2.1 A vessel's trim is the difference between the vessel's forward draft and after draft. A vessel with a deeper stern draft than bow draft is said to be trimmed by the stern or down by the stern. A vessel with a deeper bow draft than stern draft is said to be trimmed by the head (bow) or down by the head (bow). A vessel in normal operations is usually trimmed by the stern.

B.7.2.2 A vessel's list can be accurately determined in two ways, namely:

a. By reading the appropriate clinometer on the vessel's centerline or,

b. By reading the difference between the vessel's port and starboard drafts and calculating the list (see Figure B-7).

B.7.3 TRIM AND LIST CORRECTIONS

B.7.3.1 When a vessel is not on even keel at the time of gauging, the vessel's trim or list shall be taken into account to accurately determine the liquid volumes on board. To do so, the instructions found in the vessel's trim/list tables shall be followed to make the required adjustments for any trim or list noted. If the vessel does not have such trim or list tables, a note to that effect should be made on the ullage report.

B.7.3.2 When the trim and list tables are not available, a calculated adjustment to the observed ship tank measurements should be made if the relative vessel and tank dimensions are known (see Figures B-8 and B-9).

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. Additional reference for measurements when vessels are offshore can be found in Section 10.4 of this standard. For the purposes of VEF calculations, loadings from and discharges to SBMs, SPMs, sea-docks, etc. are to be considered shore operations even though they are conducted offshore. Lighterings are considered ship-to-ship transfers. 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 and swells will present problems in gauging accuracy if they cause the vessel to roll or pitch. These can be offset by appropriate attention being paid to gauging the petroleum products in motion in the tanks. Additional reference for measurements when vessels are rolling can be found in Section 10.4 of this standard.

b. Any type of precipitation encountered during the measurement/sampling process shall 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 so 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, high air or water temperatures can lead to vaporization of cargoes whereas cold water or air temperatures could lead to solidification and higher ROBs of high-pour-point cargoes.

Figure B-5—Draft Readings: US Customary Unit

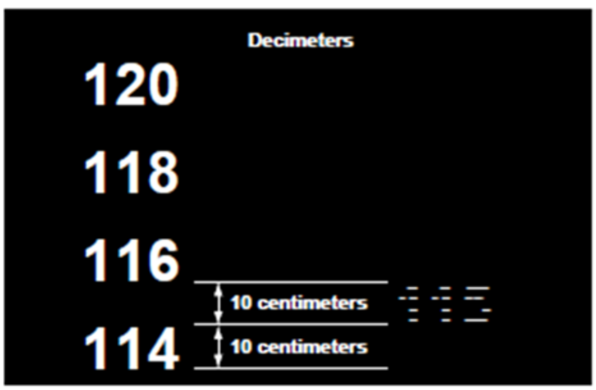
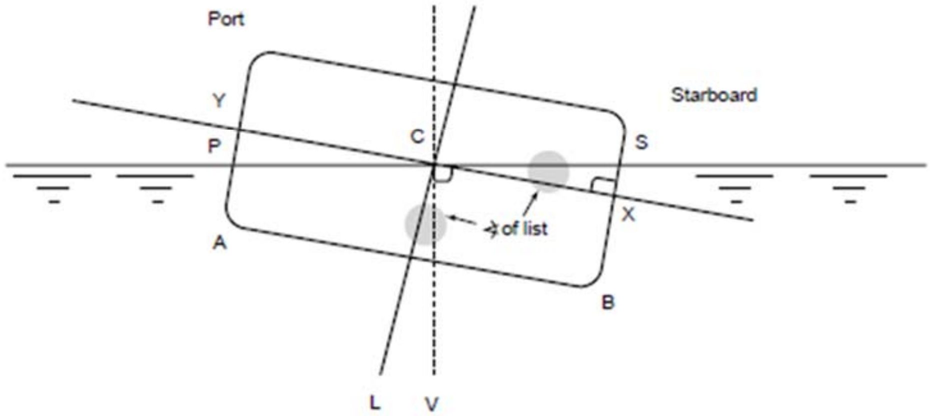


Figure B-6—Draft Readings: Metric Unit



Legend:

PA = Port Draft = 10.0 m
SB = Starboard Draft = 12.0 m
XY = Vessel Beam = 30.0 m

Theory:

Angle LCV = Angle SCX = Angle of List = Θ

$$\text{Tangent } \Theta = \frac{SX}{CX} = \frac{(\text{Starboard Draft} - \text{Port Draft})/2}{(\text{Vessel's Beam})/2}$$

This reduces to

$$\text{Tangent } \Theta = \frac{\text{Starboard Draft} - \text{Port Draft}}{\text{Vessel's Beam}}$$

Calculation:

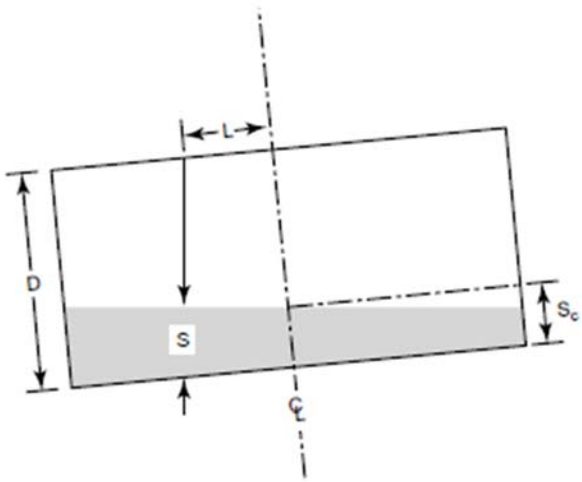
$$\text{Tangent } \Theta = \frac{(12.0 - 10.0)}{30.0} = 0.0667$$

From the attached chart of "Natural Functions of Angles" a tangent value of 0.0667 represents an angle of 4°, rounded to the nearest 0.5°.

Result: Vessel is listed 4° to Starboard

Source: API MPMS Chapter 12.1.

Figure B-7—Method To Calculate Vessel's List Using Midships Draft Readings



The trim correction is given by the following equation:

$$S_c = S \pm \left[\left(\frac{L \times T}{LBP} \right) - \left(\frac{[D - S] \times T^2}{LBP^2} \right) \right]$$

where

- D = tank height, from the reference point,
- S = observed gauge,
- L = distance of the gauge hatch from the center of tank,
- S_C = trim corrected gauge
- LBP = length of ship between perpendiculars,
- T = trim of the ship.

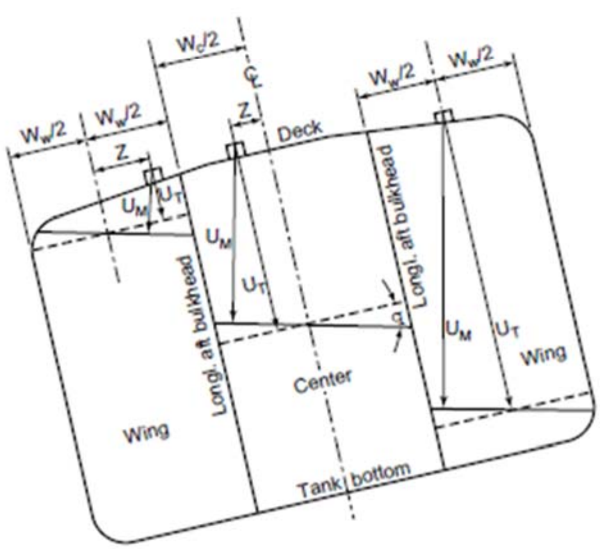
All of the above must be expressed in the same units of length.

Note that the bracketed quantity is added when the observed gauge is forward and subtracted when aft of the center of the tank.

When the liquid level in the tank is such that it no longer reaches the forward end, a wedge is formed and the application of the trim correction will no longer give the true gauge.

Source: API MPMS Chapter 12.1.

Figure B-8—Calculating a Trim Correction



When no list correction tables are available, the observed ullage (U_m) should be corrected for list as illustrated in Figure B-9.

The correction for list may be expressed as follows:

$$U_T = \frac{U_M}{\cos\theta} \pm Z \tan\theta$$

The sign for the second portion of the expression is positive when the list is toward the side on which the ullage point is located and negative when the list is toward the side opposite from the ullage point. (Refer to Figure B-9.)

Source: API MPMS Chapter 2.8A.

Figure B-9—Method to Calculate List Correction

B.10 Alternate Procedures for Measurement of Small Quantities

B.10.1 ALTERNATE FREE WATER MEASUREMENT

B.10.1.1 Alternate methods of water determination may be used; such as the dip rod/water gauge bar, which, when used in conjunction with water-finding paste, can be used for determination of free water. Refer to API *MPMS* Chapter 3.1A/EI HM 4. Additional guidance can be found in API *MPMS* Chapter 17.11.

B.10.2 BRASS BOB PMU—ROB/OBQ MEASUREMENT

Alternate methods of ROB/OBQ determination may be used; such as the dip rod/water gauge bar. Additional guidance can be found in API *MPMS* Chapter 17.11.

Examples of Typical Special Weighted Bar and Bob Units

B.11 Size and Location of Vapor Control Valves

The size and location of the vapor control valves used for closed or 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 improperly located and of insufficient size. Larger diameter VCV's are preferred (ideally 4 inch or 100mm in diameter), as smaller diameter VCV's increase the difficulty in obtaining a representative sample and will also significantly reduce the amount of time required to obtain samples and thereby reduce personnel and environmental exposures. For the best way to measure OBQ/ROB and free water under most operating conditions, the VCV shall 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 at stern conditions. When the VCV is located in the middle of a tank, it usually will 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 shall 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 necessary to know the correct operating limits of the equipment used so that the designed measurement parameters 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 custody transfer purposes.

ANNEX C
(Informative)
CONVERSION FACTORS
Interrelation of Units of Measurement

The following table has been extracted from Appendix C of NIST Handbook 44. A more complete table is presented in API *MPMS* Ch. 15, *Guideline for the Use of the International System of Units (SI) in the Petroleum and Allied Industries*.

LENGTH

To Convert	Multiply by
Metres:	
To Yards	1.093613
To Feet	3.280840
To Inches	39.37008
Yards:	
To Metres	0.9144 [Ψ]
Feet:	
To Metres	0.3048 [Ψ]
Inches	
To Centimetres	2.54 [Ψ]

WEIGHT

To Convert	Multiply by
Long Tons:	
To Pounds (Avdp) **	2240 [Ψ]
To Short Tons	1.12 [Ψ]
To Metric Tons	1.0160469088 [Ψ]
Short Tons:	
To Pounds (Avdp)	2000 [Ψ]
To Long Tons	0.8928571
To Metric Tons	0.90718474 [Ψ]
Metric Tons:	
To Long Tons	0.9842065
To Short Tons	1.102311
Pounds (Avdp):	
To Kilograms	0.45359237 [Ψ]
Kilograms	
To Pounds (Avdp)	2.204623

VOLUME AND CAPACITY *

To Convert	Multiply by
U.S. Gallons:	
To Cubic Inches	231 [Ψ]
To Cubic Feet	0.1336806
To U.S. Barrels	0.02380952
To Litres	3.785412
U.S. Barrels:	
To U.S. Gallons	42 [Ψ]
To Cubic Inches	9702 [Ψ]
To Cubic Feet	5.6145852
To Litres	158.987304
Cubic Feet:	
To U.S. Gallons	7.480519
To U.S. Barrels	0.1781076
To Litres	28.31685
To Cubic Metres	0.02831685
Cubic Inches:	
To U.S. Gallons	0.004329004
To Litres	0.016387064
Litres:	
To Cubic Inches	61.02374
To Cubic Feet	0.03531467
To U.S. Gallons	0.2641721
To U.S. Barrels	0.006289812
Cubic Metres:	
To U.S. Gallons	264.1721
To U.S. Barrels	6.289812
To Cubic Feet	35.31467

* These factors are solely for conversion at the same temperature.
** Pounds (Avdp) = Avoirdupois pound
Ψ This relationship is exact by definition. All other values are derived and rounded to the displayed precision.

Table C-1 Conversion of Lengths, Weights, and Volumes

$$°F = 1.8\ °C + 32$$

and

$$°C = (°F - 32)/1.8$$

Table C-2—Conversion of Temperatures