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ERRATA

Please replace page 48, Table C-2—Conversion of Temperature, with the following table.

Table C-2—Conversion of Temperatures

Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit	Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit	Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit
-45.6	-50	-58.0	-17.8	0	32.0	10.0	50	122.0
-45.0	-49	-56.2	-17.2	1	33.8	10.6	51	123.8
-44.4	-48	-54.4	-16.7	2	35.6	11.1	52	125.6
-43.9	-47	-52.6	-16.1	3	37.4	11.7	53	127.4
-43.3	-46	-50.8	-15.6	4	39.2	12.2	54	129.2
-42.8	-45	-49.0	-15.0	5	41.0	12.8	55	131.0
-42.2	-44	-47.2	-14.4	6	42.8	13.3	56	132.8
-41.7	-43	-45.4	-13.9	7	44.6	13.9	57	134.6
-41.1	-42	-43.6	-13.3	8	46.4	14.4	58	136.4
-40.6	-41	-41.8	-12.8	9	48.2	15.0	59	138.2
-40.0	-40	-40.0	-12.2	10	50.0	15.6	60	140.0
-39.4	-39	-38.2	-11.7	11	51.8	16.1	61	141.8
-38.9	-38	-36.4	-11.1	12	53.6	16.7	62	143.6
-38.3	-37	-34.6	-10.6	13	55.4	17.2	63	145.4
-37.8	-36	-32.8	-10.0	14	57.2	17.8	64	147.2
-37.2	-35	-31.0	-9.4	15	59.0	18.3	65	149.0
-36.7	-34	-29.2	-8.9	16	60.8	18.9	66	150.8
-36.1	-33	-27.4	-8.3	17	62.6	19.4	67	152.6
-35.6	-32	-25.6	-7.8	18	64.4	20.0	68	154.4
-35.0	-31	-23.8	-7.2	19	66.2	20.6	69	156.2
-34.4	-30	-22.0	-6.7	20	68.0	21.1	70	158.0
-33.9	-29	-20.2	-6.1	21	69.8	21.7	71	159.8
-33.3	-28	-18.4	-5.6	22	71.6	22.2	72	161.6
-32.8	-27	-16.6	-5.0	23	73.4	22.8	73	163.4
-32.2	-26	-14.8	-4.4	24	75.2	23.3	74	165.2
-31.7	-25	-13.0	-3.9	25	77.0	23.9	75	167.0
-31.1	-24	-11.2	-3.3	26	78.8	24.4	76	168.8
-30.6	-23	-9.4	-2.8	27	80.6	25.0	77	170.6
-30.0	-22	-7.6	-2.2	28	82.4	25.6	78	172.4
-29.4	-21	-5.8	-1.7	29	84.2	26.1	79	174.2
-28.9	-20	-4.0	-1.1	30	86.0	26.7	80	176.0
-28.3	-19	-2.2	-0.6	31	87.8	27.2	81	177.8
-27.8	-18	-0.4	0.0	32	89.6	27.8	82	179.6
-27.2	-17	1.4	0.6	33	91.4	28.3	83	181.4
-26.7	-16	3.2	1.1	34	93.2	28.9	84	183.2
-26.1	-15	5.0	1.7	35	95.0	29.4	85	185.0
-25.6	-14	6.8	2.2	36	96.8	30.0	86	186.8
-25.0	-13	8.6	2.8	37	98.6	30.6	87	188.6
-24.4	-12	10.4	3.3	38	100.4	31.1	88	190.4
-23.9	-11	12.2	3.9	39	102.2	31.7	89	192.2
-23.3	-10	14.0	4.4	40	104.0	32.2	90	194.0
-22.8	-9	15.8	5.0	41	105.8	32.8	91	195.8
-22.2	-8	17.6	5.6	42	107.6	33.3	92	197.6
-21.7	-7	19.4	6.1	43	109.4	33.9	93	199.4
-21.1	-6	21.2	6.7	44	111.2	34.4	94	201.2
-20.6	-5	23.0	7.2	45	113.0	35.0	95	203.0
-20.0	-4	24.8	7.8	46	114.8	35.6	96	204.8
-19.4	-3	26.6	8.3	47	116.6	36.1	97	206.6
-18.9	-2	28.4	8.9	48	118.4	36.7	98	208.4
-18.3	-1	30.2	9.4	49	120.2	37.2	99	210.2
−17.8	0	32.0	10.0	50	122.0	37.8	100	212.0

Note: This table provides conversion values for temperatures in degrees Fahrenheit and degrees Celsius for each whole degree from −50° to +250°. The temperature to be converted is found in the center "temperature to be converted" column. If the temperature to be converted is in degrees Fahrenheit, its equivalent in degrees Celsius is found in the "degrees Celsius" column to the left. If the temperature to be converted is in degrees Celsius, its equivalent in degrees Fahrenheit is found in the "degrees Fahrenheit" column to the right.

Manual of Petroleum Measurement Standards Chapter 17—Marine Measurement

Section 2—Measurement of Cargoes On Board Tank Vessels

SECOND EDITION, MAY 1999

American Petroleum Institute

Helping You Get The Job Done Right.℠

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Upstream Segment

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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.

Metric units are listed in this document in a manner that reflects current marine practice.

Nothing contained in this publication is intended to supersede any operating practices recommended by organizations such as the Oil Companies International Marine Forum or individual operating companies, nor is the publication intended to conflict with any safety or environmental considerations, local conditions, or the specific provisions of any contract.

All procedures described in this publication should be performed by or in the presence of the ship's master, the barge captain, or their representatives. For reasons of safety, only non-sparking equipment shall be used for measurements on board marine tank vessels.

This standard requires the purchaser to specify certain details and features. Although it is recognized that the purchaser may desire to modify, delete, or amplify sections of this standard, it is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard, rather than by rewriting or incorporating sections thereof into another complete standard.

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0 Introduction

Based on present technology, careful 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 hydrocarbons to the atmosphere with regard to tank vessel operations. This has resulted in the restriction and, in some cases, the prohibition of traditional methods of obtaining cargo measurements through open gauge hatches. Consequently, numerous measurement methods and devices are now being used and additional ones developed 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

To determine the quantity and quality of cargo on board marine tank vessels, it is necessary to accurately gauge, ascertain the temperature, collect a representative sample, and calculate the amount of all materials contained in the vessel's lines, cargo tanks, and slop tanks. Any void spaces that may contain cargo, such as permanent ballast tanks, double bottoms, and cofferdams, must also be checked, and any volumes contained in these spaces must be calculated. This publication describes the appropriate methods of performing these procedures for crude oils and petroleum products normally carried on board marine tank vessels.

This standard covers the use of manual and automatic measurement systems commonly used on marine tank vessels. It establishes the procedures for obtaining the level measurements of cargo, free water, and OBQ/ROB as well as taking the temperatures and samples required for the marine custody transfer of most bulk liquid petroleum cargoes. 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 liquid petroleum gas (LPG) and liquid natural gas (LNG).

2 Normative References

The following standards contain provisions which, 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

MPMS Chapter 1	*Vocabulary*
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 3.4	*Standard Practice for Level Measurement of Liquid Hydrocarbons on Marine Vessels by Automatic Tank Gauging*
MPMS Chapter 7.1	*Static Temperature Determination Using Mercury Thermometer*
MPMS Chapter 7.3	*Static Temperature Determination Using Portable Electronic Thermometers (PETs)*
MPMS Chapter 7.4	*Fixed Automatic Tank Thermometers*
MPMS Chapter 8.1	*Manual Sampling of Petroleum and Petroleum Products* (ANSI[1]/ ASTM[2] D 4057)
MPMS Chapter 8.2	*Automatic Sampling of Petroleum and Petroleum Products* (ANSI[1]/ ASTM[2] D 4177)
MPMS Chapter 9.1	*Hydrometer Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products* (ANSI[1]/ASTM[2] D 1928)

[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.

MPMS Chapter 10.1	*Determination of Sediment in Crude Oils and Fuel Oils by the Extraction Method* (ANSI[1]/ASTM[2] D 473, IP[3] 53)
MPMS Chapter 10.2	*Determination of Water in Crude Oil by Distillation* (ANSI[1]/ASTM[2] D 4006)
MPMS Chapter 10.3	*Determination of Water and Sediment in Crude Oil by the Centrifuge Method* (ANSI[1]/ASTM[2] D 4007)
MPMS Chapter 10.4	*Methods of Test for Water and Sediment in Crude Oils* (ANSI[1]/ASTM[2] D 96)
MPMS Chapter 11.1	*Volume Correction Factors* (ANSI1/ ASTM[2] D 1250, IP[3] 200, ISO[4] R914)
MPMS Chapter 12	*Calculation of Petroleum Quantities*
MPMS Chapter 17.1	*Guidelines for Marine Cargo Inspection*
MPMS Chapter 17.4	*Method for Quantification of Small Volumes on Marine Vessels (OBQ/ROB)*

ASTM[2]

D 287	*Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)*

ICS[5]/OCIMF[6]/IAPH[7]

International Safety Guide for Oil Tankers and Terminals (ISGOTT)

IMO[8]

Inert Gas Systems

OSHA[9]

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

[3]Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR, England.

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

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

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

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

[8]International Maritime Organization, London, England.

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

3 Definitions and Abbreviations

3.1 DEFINITIONS

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

3.1.1 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.

3.1.2 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.

3.1.3 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.

3.1.4 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.

3.1.5 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.

3.1.6 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.

3.1.7 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)

3.1.8 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*).

3.1.9 closed system measurement (CSM): Measurement of petroleum cargoes on a closed system marine tank vessel performed using closed measurement devices. [See *restricted system measurement* (RSM).]

3.1.10 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.*)

3.1.11 crude oil washing: See *tank washing.*

3.1.12 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.

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

3.1.14 letter of protest: 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.

3.1.15 list (heel): The leaning or inclination of a vessel, expressed in degrees port or starboard.

3.1.16 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.

3.1.17 load-on-top: Defined as both a procedure and a practice:

a. *load-on-top procedure:* The shipboard procedure of collecting and settling water and oil mixtures resulting from ballasting and tank cleaning operations (usually in a special slop tank or tanks) and subsequently loading cargo on top of mixtures and pumping the mixture ashore at the discharge port.
b. *load-on-top practice:* The act of commingling on-board quantity with cargo being loaded.

3.1.18 open measurement: Occurs anytime the vessel's gauge hatches must be opened to take the appropriate level gauges, samples and/or temperatures.

3.1.19 open measurement equipment: Those devices that are used to take open measurements.

3.1.20 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.

3.1.21 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.

3.1.22 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.*)

3.1.23 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.*)

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

3.1.25 sampling: Taking a portion of the contents of the cargo/material being measured. Manual sampling consists of obtaining a portion of material in the vessel's tank(s) including the petroleum liquid, free water, and/or any sediments, using the appropriate manual sampling equipment. *Dynamic sampling* is the method used to obtain a representative sample of the material in the pipe while it is being loaded onto or off of the vessel (see *automatic sampler*).

Samples may be taken using the following methods:

a. *All-Levels Sample* is one 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.

b. *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.

c. *Manifold Sample* is 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.

d. *Running Sample* is one 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 device will be between 70–85% full when it emerges from the liquid.

e. *Spot Sample* is a sample taken with a bottle or a 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.

f. *Upper, Middle, and Lower Samples (Spot Samples):*

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

2. A *middle sample* is a spot sample taken at the middle of the tank contents (a point halfway between upper and lower sample points).
3. A *lower sample* is a spot sample taken at the midpoint of the lower third of the tank contents.

3.1.26 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.

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

3.1.28 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.

3.1.29 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.

3.1.30 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.

3.1.31 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.

3.1.32 volumes are defined as follows:

a. *gross observed volume (GOV):* The total volume of all petroleum liquids and sediment and water—excluding free water—at observed temperature and pressure.
b. *gross standard volume (GSV):* The total volume of all petroleum liquids, sediment, and water—excluding free water—corrected by the appropriate volume correction factor (*Ctl*) for the observed temperature and API gravity, relative density, or standard temperature such as 60°F or 15°C. Also corrected by the applicable pressure correction factor (*Cpl*) and meter factor.
c. *indicated volume:* The change in meter reading that occurs during a receipt or delivery.
d. *net standard volume (NSV):* The total volume of all petroleum liquids—excluding sediment and water and free 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°F or 15°C. If applicable, correct with pressure correction factor (*Cpl*) and meter factor.
e. *on-board quantity (OBQ):* The material remaining in vessel tanks, void spaces, and/or pipelines prior to loading. Onboard quantity includes water, oil, slops, oil residue, oil/water emulsions, sludge, and sediment.
f. *remaining on board (ROB):* The material remaining in vessel tanks, void spaces, and/or pipelines after discharge. Remaining on-board quantity includes water, oil, slop, oil residue, oil/water emulsions, sludge, and sediment.
g. *total calculated volume (TCV):* The total volume of all petroleum liquids and sediments and water, corrected by the appropriate volume corrected 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, and free water measured at observed temperature and pressure (gross standard volume plus free water.)
h. *total observed volume (TOV):* The total measured volume of all petroleum liquids, sediment and water, and free water at observed temperature and pressure.

Note: For further information on volumes, see 8.4.

3.2 SYMBOLS AND ABBREVIATIONS

ATG	Automatic tank gauge
ATT	Automatic temperature system
COW	Crude oil washing
CSM	Closed system measurement
FTG	Float-operated automatic tank gauge
FW	Free water
GOV	Gross observed volume
GSV	Gross standard volume
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
NIST	National Institute of Standards and Technology
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
P/V	Pressure vacuum (valve)
ROB	Remaining on board

RSM	Restricted system measurement
RTG	Radar tank gauge
S&W	Sediment and water
SOLAS	Safety of Life at Sea Convention
STG	Servo-operated automatic tank gauge
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 General Safety Precautions

This section applies to all types of 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.

Note: Nothing contained in this publication is intended to supersede any operating practices recommended by organizations such as the Oil Companies International Marine Forum or individual operating companies, nor is the publication intended to conflict with any safety or environmental considerations, local conditions, or the specific provisions of any contract.

Accordingly, the appropriate additional API publications, the *International Safety Guide for Oil Tankers and Terminals* (ISGOTT), and OCIMF publications should be consulted for applicable safety precautions.

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.

4.1 ELECTRICAL AND OPERATING SAFETY

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

4.2 MAINTENANCE

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

4.3 SEALING

All ATGs and vapor control valves shall be sealed to withstand the vapor pressure of liquid in the tank. ATGs and vapor control valves 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.

4.4 VAPOR CONTROL VALVE INSTALLATION

The vapor control valve shall be installed as per specifications of design and appropriate governing body, i.e., U.S. Coast Guard, Classification Society, etc.

5 Open Measurement Equipment and Procedures

Open measurement occurs whenever a vessel's measurement hatch is opened to the atmosphere to perform the necessary measurement tasks. The equipment needed and procedures to be used to perform open measurements on ships and barges are described in this section.

5.1 OPEN MANUAL SAMPLING

This section describes the equipment to be used to take a manual sample. For details about sampling procedures and handling of samples see Section 7 of this document.

5.1.1 Open Sampling Equipment—General

Sampling equipment must 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. Additional consideration should be given as to how the sample will be used. Each device should be used in the manner prescribed by its manufacturer. For additional technical data on open manual sampling equipment, see API MPMS Chapter 8.1.

5.1.1.1 Liquid Petroleum—Open Sampling Equipment

5.1.1.1.1 There are several containers (receivers) which are used to sample cargo. The most common types currently in use are the weighted glass bottle, beaker thief, and zone sampler. When the weighted glass bottle method is used, each sample can be stored in the bottle it was taken in. This minimizes the risk of loss of light ends and accidental introduction of water. See Figures 1 through 3 for examples of typical container assemblies for bottle sampling, and zone and bottom samplers.

5.1.1.1.2 The use of a beaker or thief to obtain a tank sample may run the risk of loss of quality of the sample through contamination, loss of light ends, introduction of water, etc. This potential risk results from the need to transfer the sample from the beaker to another container for transportation to the lab. During the transfer from the beaker, light ends will be lost and outside moisture may be introduced. In addition, the use of the same beaker to sample more than one tank may cause a contaminant to be introduced to an otherwise uncontaminated sample.

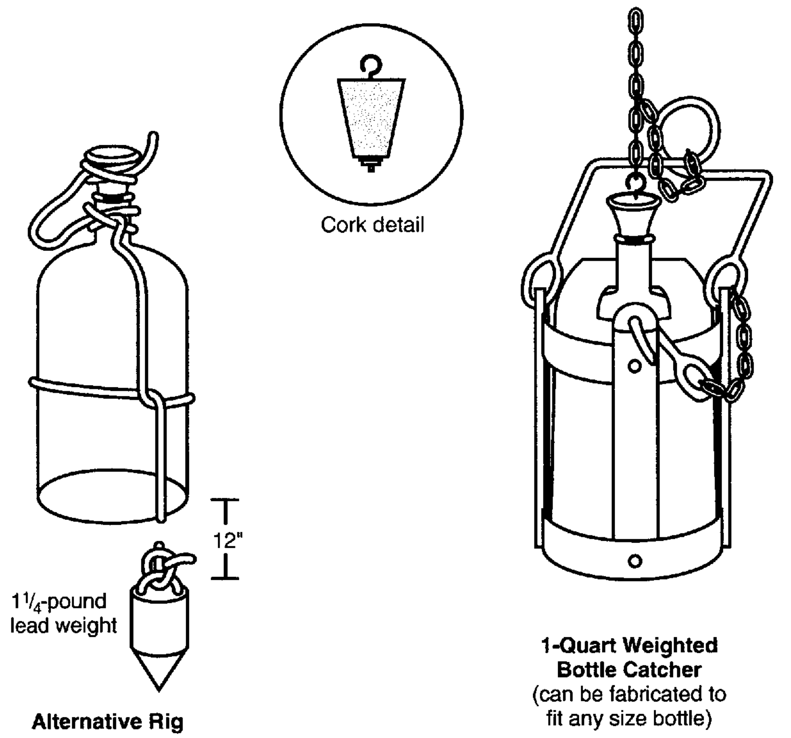


Figure 1—Typical Container Assemblies for Bottle Sampling

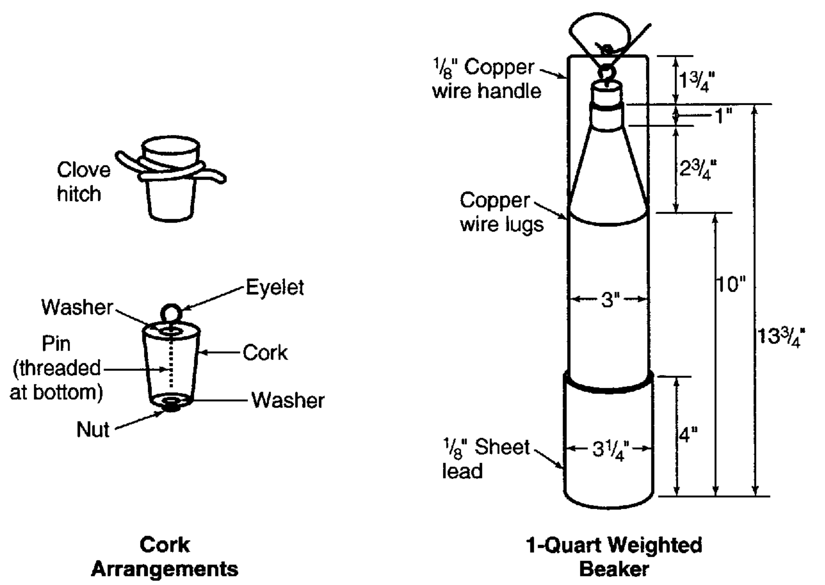


Figure 1a—Typical Container Assemblies for Beaker Sampling

5.1.1.2 Free Water—Open Sampling Equipment

5.1.1.2.1 As with cargo sampling, there are several containers that can be used to sample free water at the bottom of vessel tanks with the most common being a bottom sampler (tube container), glass bottle, or thief.

5.1.1.2.2 If the free water level is higher than 1 foot, a weighted bottle can be used. Otherwise, a bottom sampler or thief must be used. Bottom or thief samplers (Figures 2 and 3) are usually used to sample free water under a cargo. A typical bottom sampler has a projecting stem on a valve rod that opens two valves automatically as the stem strikes the bottom of the tank. The sample enters the container through the bottom valve, and air is simultaneously released through the top valve. The valves snap shut when the sampler is lifted (see Figures 2 and 3).

5.1.1.3 Sediment—Open Sampling Equipment

A scoop sampler is used to sample sediment on the bottom of vessel tanks that is not covered by a liquid (see Figure 4).

5.1.1.4 Sample Containers

5.1.1.4.1 Containers used for samples taken from vessel tanks are usually clear or brown glass bottles, plastic bottles, or metal cans. The only cans that may be used are those with seams soldered on the can's exterior surface with a flux of rosin cleaned in a suitable solvent.

5.1.1.4.2 If the cargo sample is sensitive to light, brown bottles should be used. To minimize the loss of light ends, appropriate high-quality, clean, cork or glass stoppers, bungs, or screw caps should be used to seal sample container. Rubber stoppers should never be used.

Note: The manufacturer should be consulted if there is any question about the acceptability of the construction or type of material of a container or cap.

5.1.1.5 Inspection of Sampling Equipment

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 contaminate the sample. The use of dirty sample cords or tapes should be avoided because of the possibility of a sample being contaminated. In addition, certain cargoes may require special precautions to be taken when preparing sampling equipment (i.e., nitrogen purging of sample containers to assure dryness). The principals involved should be consulted if there are any questions as any special requirements necessary. Also see note in 5.1.1.4.

5.1.2 Open Manual Sampling Procedures

For specific sampling procedures refer to Section 7 of this document.

5.2 OPEN MANUAL GAUGING

Manual open gauging involves the use of tape and bob through the open tank gauge hatch to obtain the levels of liquid in the tanks using the ullage or innage methods. This section describes the equipment and procedures to be used to perform this task.

5.2.1 Manual Open Gauging Equipment

All equipment used for manual gauging must be safe for use with the material to be measured, must be checked for accuracy, and must be in good condition. Levels of dark liquids are normally easily read on the tapes whereas the levels of light colored liquids may require the use of indicating pastes. API MPMS Chapter 3.1A contains a complete technical description of manual gauging equipment and accuracy verification procedures.

5.2.1.1 Open Innage/Ullage Equipment

An innage tape shall only be used with an appropriate innage bob. An ullage tape shall only be used with an ullage bob. The measurement units on the innage/ullage equipment used should be consistent with the measurement units in the vessel's capacity tables; that is, the equipment should be graduated in 1-mm, $^1/_8$-in., or 0.01-ft increments (see Figure 5).

5.2.1.2 Water Gauge Bars

A water gauge bar may be used to assist in determining the height of free water in a tank. Typically a water gauge bar is a 12-in. (30-cm) or 18-in. (45-cm) round bar. The longer length of these bars can reduce the incidence of water cuts occurring on clasps and areas not scaled between the tape and bob. A square bob is not recommended because the corners on the bar may cause dips and slants to occur on the paste, resulting in false readings. See Figure 5.

5.2.1.3 Indicating (Product/Water) Paste

Indicating pastes can be used to determine the levels of water in a tank or assist in the reading of product levels. The pastes should be applied and used according to the manufacture's specifications and the shelf life should be noted before each use. See 5.2.2.3.

5.2.1.4 Inspection of Innage/Ullage Equipment

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. Innage bobs should be inspected for wear and damage of the tip and eye hole. The bob/tape interface should be measured to determine accuracy. If these inspections indicate any inaccuracies, the equipment should not be used. (See API MPMS Chapter 3.1A for tape and bob accuracy requirements.)

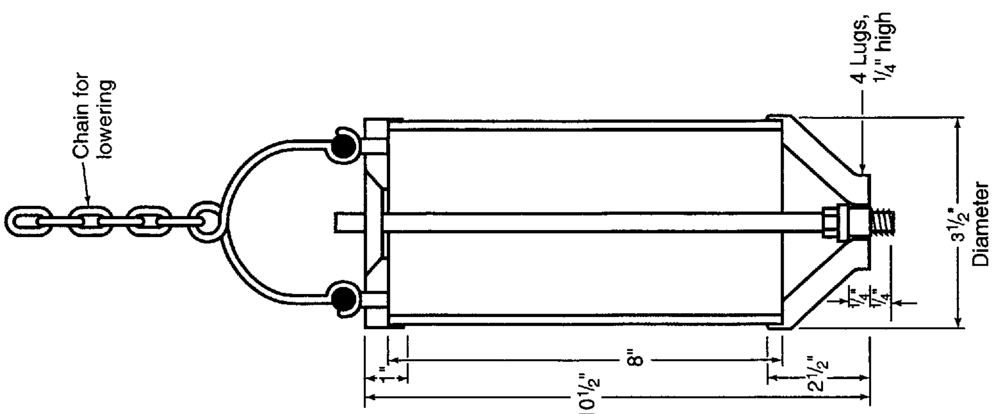


Figure 2—Typical Bottom Sampler

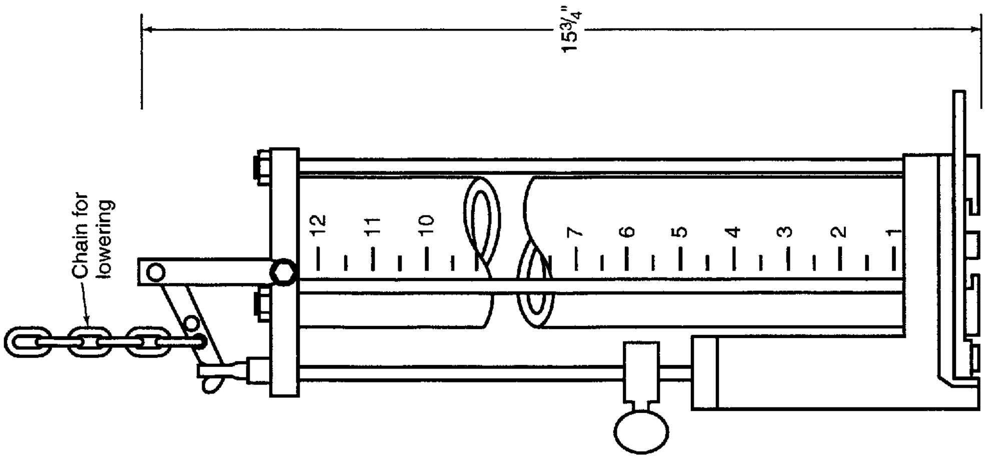


Figure 3a—Typical Thief Type Sampler

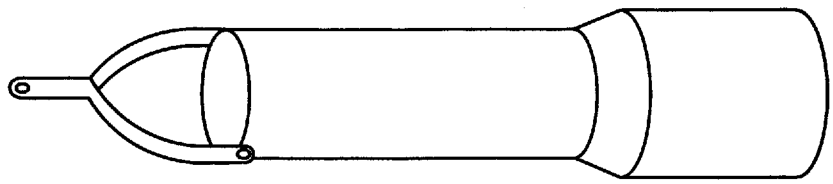


Figure 3b—Typical Core/Zone Type Sampler

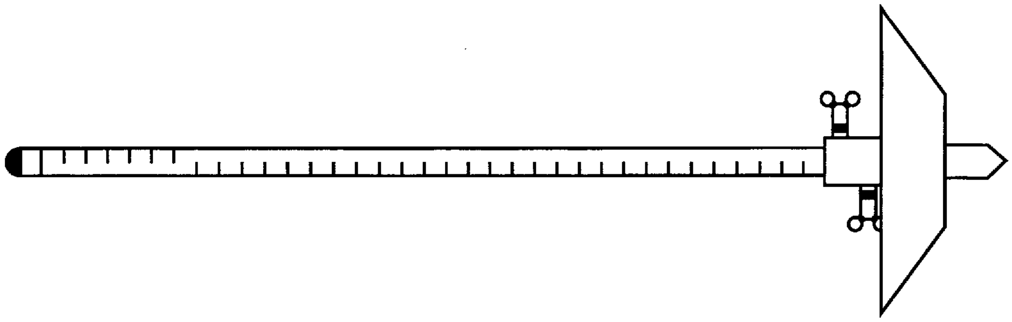
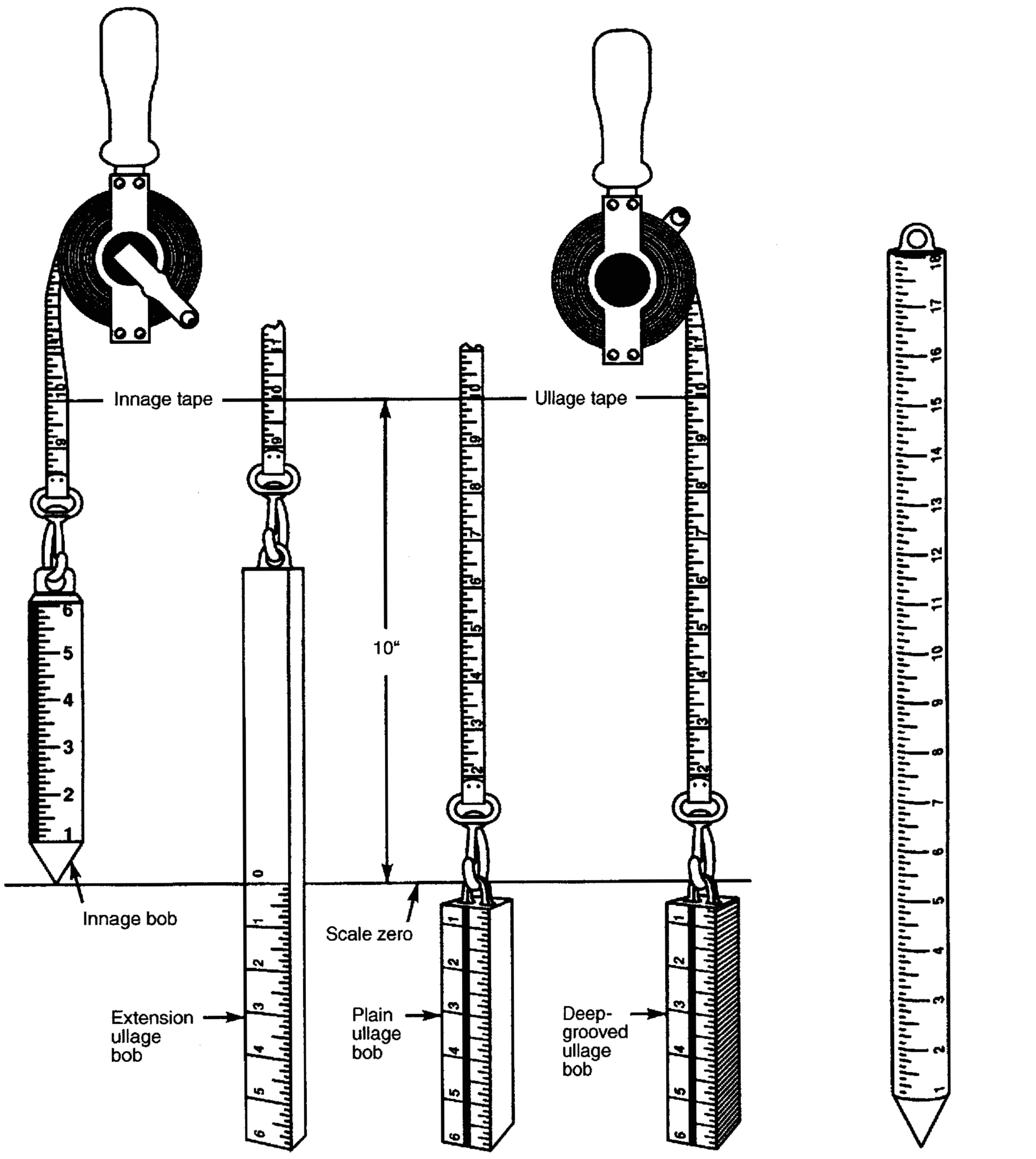


Figure 4—Typical Scoop Sampler



Typical Gauging Tapes and Bobs

Typical Water Gauge Bar

Figure 5—Typical Innage/Ullage Equipment

5.2.1.5 Tank Capacity Tables

5.2.1.5.1 Tank capacity tables show the volume corresponding to each measured innage or ullage. Measurements should be taken in the same units used in the capacity tables. If measurements must be taken in other units, the conversion factors in Appendix C should be used.

5.2.1.5.2 When tank capacity tables are not calculated to the minimum prescribed graduations ($^1/_8$ in., 1 mm, or 0.01 ft), and when gauge readings fall between the values in the tables, interpolation will be necessary.

5.2.1.5.3 The observed reference height should be compared with the reference height given in the tables and recorded. (See Appendix B.3.)

5.2.2 Procedures for Open Manual Gauging

Manual gauging consists of either innage or ullage gauging of the liquid level with appropriate gauging equipment. Considerations in determining whether innages or ullages are to be taken are whether the capacity tables are presented in innage or ullage format, the amount of liquid in the tanks and the nature of the material. (See Appendix B.3.) Measurements should be taken in the units in which the tank capacity tables are presented.

When taking custody transfer measurements, all cargo tanks, ballast tanks, bunker tanks, void spaces and cofferdams should be inspected and/or gauged as appropriate. (See API MPMS Chapter 17.1.8.3.) Measurements should always be taken at the reference points noted in the capacity tables. The reference height should be stenciled or otherwise permanently marked near the gauge point. The observed reference height should equal the reference height of the tank. If it does not, the procedures described in Appendix B.3, should be followed. An accurate permanent record of the gauge measurements should be made when the readings are taken.

Note: Some tanks and void spaces on the vessel may not have reference heights. Also, in some instances, it may be necessary to take gauges of water, ROB, OBQ, etc. at points other than those designated as official gauge points. In those cases, full details of such gauging must be noted in the gauger's log and on the appropriate cargo measurement documents.

If foam is present on the surface of the liquid, no gauge should be taken until the foam has subsided or been cleared from the surface of the liquid beneath the gauging hatch. Before a tank is gauged, time should be allowed to permit the oil to free itself of entrained air, gas, and water.

When the surface of the oil is at rest, at least two identical readings should be obtained before a measurement is recorded. Best accuracy is usually obtained when oil is motionless in the tanks. Measurement procedures to be followed when the liquid in the tank is in motion, as occurs when a vessel is pitching and rolling, are described in 9.3. Measurement procedures to be followed when the vessel is out of trim are described in 9.7. In all cases, trim and list should be recorded to determine the necessary corrections to be applied (see Appendix B.7).

5.2.2.1 Open Ullage Procedure

Ullage measurement is the determination of the distance from the gauge point to the surface of the material being measured. This may be accomplished by using ullage or innage tape and bob combination.

5.2.2.1.1 Using an Ullage Tape and Bob

Ullage measurement using ullage equipment should be conducted as follows:

a. Obtain approximate tank ullage using vessel ATG or other method.

b. After safely grounding the tape and opening the gauge hatch, slowly lower the tape and bob into the tank until the bob just touches the surface of the liquid (see Figure 6).

c. After the bob has stopped swinging, lower the tape slowly until a small portion of the bob is in the liquid and an even inch, centimeter, or hundredth of a foot graduation on the tape is at the reference gauge point.

d. Record the tape reading at the reference point.

e. Withdraw the tape from the tank and read the ullage bob scale at the liquid cut and record the reading. Care should be exercised during the withdrawal procedure to ensure that the tape and bob are not allowed to re-enter the liquid and thereby give a false reading.

f. The sum of the tape readings at the reference gauge point and the ullage bob reading at the cut is the ullage gauge (see Table 1).

5.2.2.1.2 Using an Innage Tape and Bob

When innage equipment is used to take an ullage, the procedure in the previous section should be followed except the bob reading must be *subtracted* from the tape reading. See the example in Table 1.

5.2.2.1.3 Alternative Ullage Procedure

An innage gauge may be converted to an ullage gauge by subtracting the innage from the reference height shown on the capacity table. See the example in Table 2 and Figure 6.

5.2.2.2 Open Innage Procedure

Innage measurement is the determination of the height of the liquid in the tank. This may be accomplished by using ullage or innage tape and bob combination and may be a direct reading or calculated value.

5.2.2.2.1 Using an Innage Tape and Bob

a. After safely grounding, the innage tape and bob should be lowered into the tank until the bob is a short distance from the bottom, as determined by the tape reading at the reference point (see Figure 6).
b. The tape should then be unwound slowly until the tip of the bob just touches the bottom or datum plate. If the tape is lowered too far, the bob will tilt and an incorrect gauge will be obtained.
c. The tape reading at the reference point should be recorded, as well as any variance from the reference height.
d. The liquid cut on the tape should be read and recorded as the innage. (A suitable oil-indicating paste or grease or a light lubricating oil may be used to facilitate reading the cut. The use of chalk or talcum powder is not recommended, since oil or product has a tendency to creep on a chalked tape.)

5.2.2.2.2 Alternative Innage Procedure

An ullage gauge may be converted to an innage gauge by subtracting the ullage from the reference height shown on the capacity tables. See the example in Table 3 and Figure 7.

5.2.2.3 Open Free-Water Measurement

The use of water-indicating paste in conjunction with innage or ullage procedures provides a measurement of the free water in a vessel's tanks. The recommended procedure for free-water gauging is by the innage method. If the level of the water being measured is high enough to show a cut on or above the tape clip, a larger gauge bar should be used. However, if measurement conditions dictate, it may be necessary to utilize the ullage method or other methods as agreed upon by all the parties. For measurement under adverse conditions, see Appendix B.9.

Vessel tanks should be gauged for free water using water-indicating paste or other equipment agreed upon by the parties involved. Measurements should be taken independently of any other innage or ullage measurements and should be properly recorded. Free water should be measured at both the loading and the discharging port.

5.2.2.3.1 Using an Innage Tape and Bob To Measure Free Water

a. Apply the water-finding paste on the bob or bar sufficiently high to measure the anticipated level of water (see note 2).
b. After grounding, the innage tape and bob should be lowered into the tank until the bob is a short distance from the bottom, as determined by the tape reading at the reference point (see Figure 6).
c. The tape should then be unwound slowly until the tip of the bob just touches the bottom or datum plate. If the tape is lowered too far, the bob will tilt and an incorrect gauge will be obtained.
d. Once the bob touches bottom, keep it there long enough for the paste to react to the water (see note 3).
e. Withdraw the tape and read and record the highest, clearly defined water cut (see notes 4 and 6).
f. Repeat steps a through e until two identical readings are obtained.
g. Record the cut as "clearly defined," "speckled," or "slightly discolored."

Measurement of free water on vessels that are out of trim is addressed in section 9.7.

Note 1: There are many brands of water-indicating pastes available that change color on contact with free water. It should be noted, however, that all brands may not react the same in the presence of water. Accordingly, the following qualities should be known before selecting a water paste:

a. Clarity of color change.
b. Ability to "shed" oil.
c. Shelf life.
d. Ease of application to the bar and ability to "grip" the bar.
e. Dense enough not to wash off when passing through the oil.

Note 2: It is recommended that two different pastes be applied on the bar for each free water innage gauge at the beginning of gauging. After it has been established which paste yields the highest, continuous clear water cut, the other can be discontinued. When applying the two pastes to the bar, cover a little less than one-half of the entire surface of the round bar with each paste. Make sure that the measurement scale remains free of paste. The coating of paste on the bar should be thin but opaque.

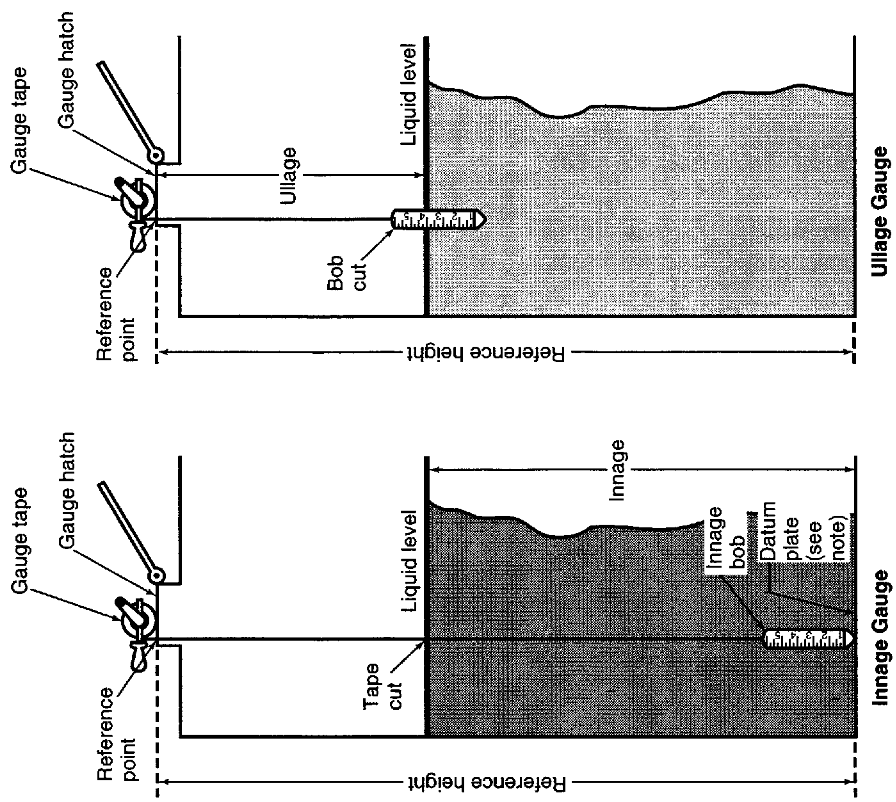
Note 3: Allow the paste-coated bar to remain in the gauging position for a minimum of ten seconds for gasoline, kerosene, and similar light products, and one-to-five minutes for heavy, viscous products (or as otherwise specified by the manufacturer). This amount of time is required to shed the petroleum that adheres to the paste. In heavy viscous petroleum, apply an even film of light lubricating oil over the paste to facilitate the shedding of the petroleum from the paste (see 9.1).

Note 4: When the bob or bar is removed to read the water cut, do not blow or wipe the petroleum off the paste as this may distort the clarity of the water cut. If the water cut is obscured by the petroleum (black oils), wash the surface of the paste with a suitable solvent. The solvent should be poured or lightly sprayed on the paste-covered bar well above the anticipated cut and allowed to rinse down over the cut area. Pouring directly on the paste may distort the clarity of the water cut.

Note 5: Wipe the bar clean after gauging each tank and re-apply paste before gauging subsequent tanks.

Note 6: If the paste on one side is spotted or lower than the other, record the highest level reading as the official measurement of free water level. Oil adhesion may cause low readings, but will not cause high readings. Spotting may indicate a layer of emulsified oil and water or that the product did not completely shed off the paste.

If water cuts indicate that an emulsion layer may be present, read and record both the clear cut and the height of the spotting measurement.



Note: The datum plate may actually be the ship's bottom, a striking plate, or another point from which the reference height is measured.

Figure 6—Manual Tank Gauging

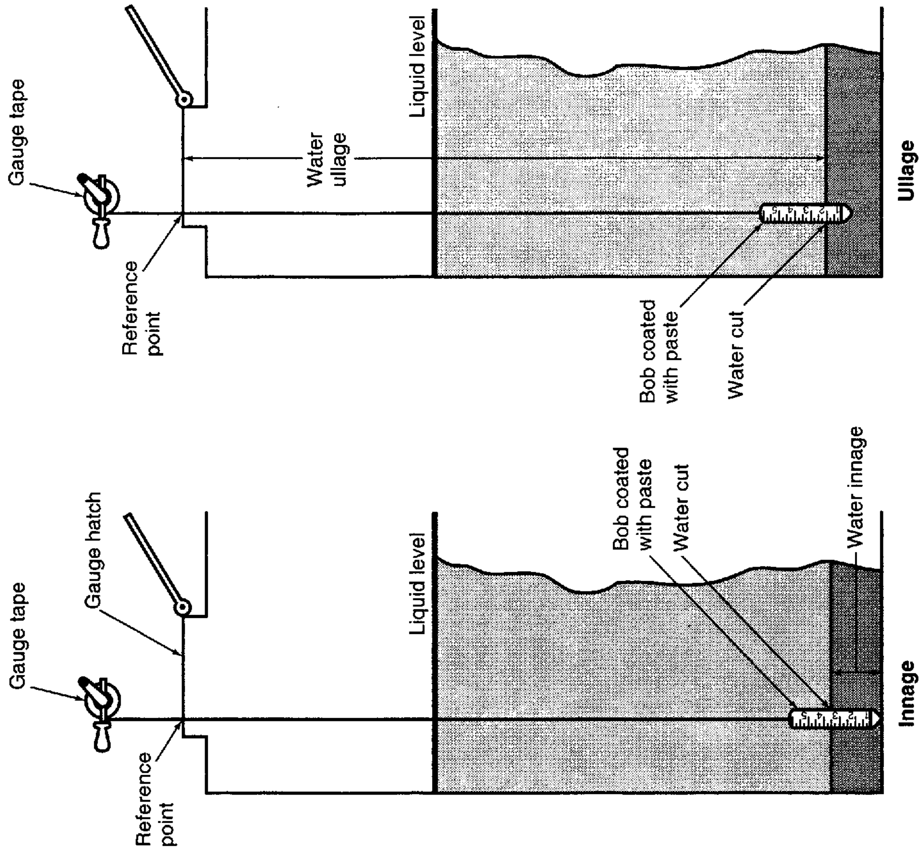


Figure 7—Measurement of Free Water

Table 1—Sample Calculations of Ullage Gauge

Reading	Customary Units Feet	Customary Units Inches	Metric Units (Meters)
Using an Ullage Tape and Bob			
Tape at reference point	19	8	5.994
Bob	0	$2^1/_4$	0.070
Sum (ullage gauge)	19	$10^1/_4$	6.064
Using an Innage Tape and Bob			
Tape at reference point	20	2	6.147
Bob	0	$3^1/_4$	0.083
Difference (ullage gauge)	19	$10^1/_4$	6.064
Using an Innage Tape and an Extension Ullage Bob			
Tape at reference point	19	8	5.994
Bob	0	$2^1/_4$	0.070
Difference (ullage gauge)	19	$10^1/_4$	6.064

Table 2—Sample Calculation of Ullage Gauge Using the Alternative Ullage Procedure

Reading	Customary Units Feet	Customary Units Inches	Metric Units (Meters)
Reference height	55	10	17.127
Innage at reference point	0	10	0.256
Difference (ullage gauge)	55	0	16.871

Table 3—Sample Calculation of Innage Gauge Using the Alternative Innage Procedure

Reading	Customary Units Feet	Customary Units Inches	Metric Units (Meters)
Reference height	43	$5^1/_4$	13.256
Ullage at reference point	32	$5^1/_4$	9.903
Difference (innage gauge)	11	0	3.353

5.2.2.4 Open OBQ/ROB Measurement

5.2.2.4.1 OBQ and ROB volumes may be determined by either the innage or the ullage method. Liquid material is usually innaged. Solid material must be ullaged. ROB should be measured after lines (hoses) have been drained into the vessel. By draining lines (hoses) to a single small tank, ROB may be measured more accurately.

5.2.2.4.2 When a vessel is out of trim, some OBQ and ROB quantities may not be measurable at the proper gauge points. In these circumstances, more extensive methods of volume determination may be necessary, and additional measurements will usually be required. Safety and operational considerations must always be factors in determining what actions can be taken, but in all situations, existing conditions and the specific actions taken to measure ROB and OBQ must be noted in the report.

5.2.2.4.3 Liquid cargo should only be trim and/or list corrected if the liquid is in contact with all bulkheads. When the liquid is not in contact with all bulkheads, a wedge correction should be applied. In all circumstances, the cargo documents should include the vessel's list and trim. The nature of the material in the tank should be described in detail, and the conditions of measurement and other pertinent information should be noted. For calculation of small quantities, refer to API MPMS Chapter 17.4.

Note: Wedge, trim, and list corrections do not normally apply to sediment and sludge but may apply to solidified (non-liquid) cargo (see 9.6). In addition, when the wedge formula or wedge tables are used, extreme care must be exercised to ensure that wedge does exist, that the measured material is not just a puddle under the gauge hatch, and that the formula used is applicable to the actual shape of the tank (that is, it accounts for the curve of the bilge). Measures to be taken in such a case should include—but are not necessarily limited to—taking ROB measurements at more than one point in the tank. This would verify the existence of a wedge and the extent of cargo solidification.

5.3 OPEN TEMPERATURE DETERMINATION

The temperature of the cargo being measured is one of the most important elements needed to accurately determine its volume. This section fully describes the equipment and procedures that should be used to manually obtain the cargo's temperature.

5.3.1 Open Temperature Measurement Equipment

All temperature equipment must be safe for use with the material whose temperature is to be obtained. The preferred method of obtaining temperatures of the liquid in a vessel's tanks is to use a portable electronic thermometer (PET). Alternately, a mercury-in-glass thermometer with etched glass face may be used.

Thermometers used for custody transfer should be properly calibrated and their accuracy verifiable and traceable to a NIST standard thermometer and meet the requirements specified in API MPMS Chapter 7 (see Figure 8).

5.3.1.1 Thermometers

Thermometers are precision instruments and should be handled with care. For a technical description of the specifications of each type, see Figure 8 and refer to API MPMS Chapter 7.

5.3.1.2 Field Verification of Temperature Equipment

All thermometers used for custody transfer measurements should be verified for accuracy before initial use, and at least once a year thereafter. In addition, before each use or once per day (whichever is less frequent) the thermometer should be spot-checked. For full details of thermometer verification, please refer to API MPMS Chapter 7.1.

5.3.1.2.1 Mercury-in-Glass Thermometers

Glass stem thermometers should be verified for accuracy before initial use and at least once a year thereafter. In addition before each use or once a day (whichever is less frequent) the thermometer should be field checked by visually checking the glass capillary for breakage and separation of the mercury column. Glass stem thermometers with abnormally worn etched faces or broken mercury column should not be used. If the column is rejoined, it may be used provided that it successfully passes a bench inspection. For additional technical details see API MPMS Chapter 7.1.

5.3.1.2.2 Portable Electronic Thermometers (PETs)

Before initial use, and at least once a year thereafter, all electronic thermometers shall be restandardized in a laboratory or other qualified facility. For full details see API MPMS Chapter 7.3. In addition before each use, or once a day (whichever is less frequent), PETs should be spot-checked by comparing the ambient reading against an ASTM glass stem thermometer in liquid. If the readings differ by more than 1°F or 0.5°C, the PET should be restandardized before it is used for custody transfer. For details on verification of the PET see API MPMS Chapter 7.3.

5.3.2 Open Temperature Measurement Procedures

Manual temperature measurement is the determination of the temperature of a liquid in a vessel's tank, using the appro-

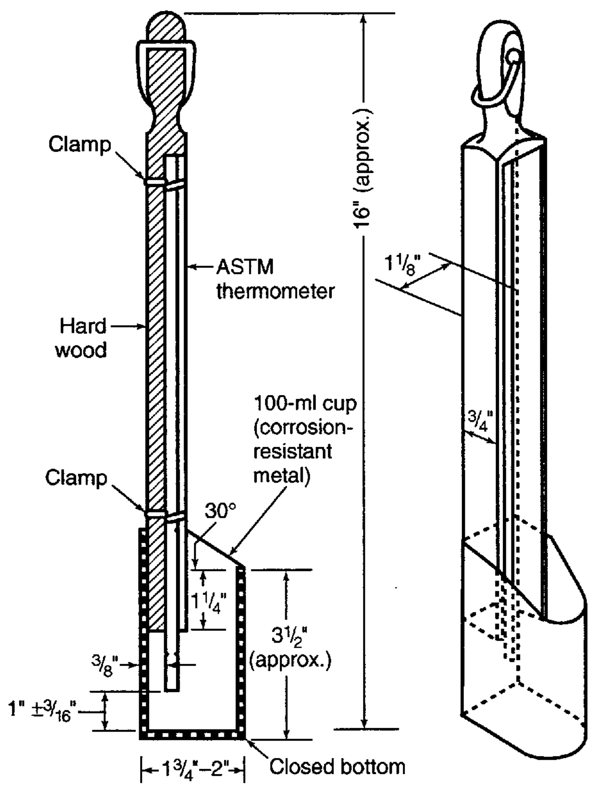


Figure 8a—Typical Mercury-in-Glass Thermometer Assemblies

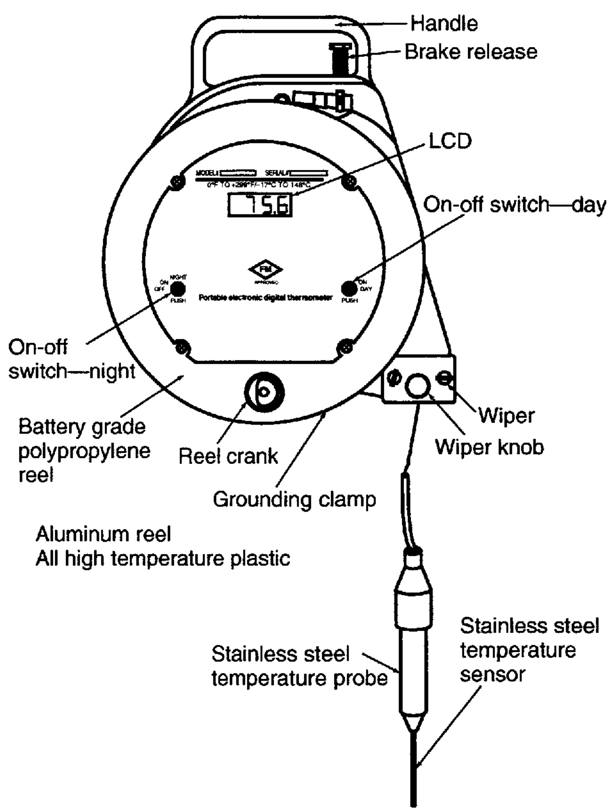


Figure 8b—A Type of PET

priate devices. The primary considerations of accurately determining temperature are (a) the size and location of cargo tanks, (b) whether or not heat has been applied to the cargo, (c) the atmospheric and seawater temperatures, and (d) the degree of temperature stratification within the cargo. Temperatures should be taken and should be clearly designated as degrees Fahrenheit or Celsius, as appropriate.

Temperatures should be determined at the same time gauging is performed. Temperatures should be taken in all tanks, and upper, middle, and lower temperatures should be taken in each tank whenever the liquid level is greater than 10 feet (3 meters). For vessel tanks with less than 5000 barrels (795 cubic meters), a single temperature measurement at the middle of the liquid will suffice (see Table 4). The total vessel volume should be corrected to the standard temperature on a tank-by-tank basis, using the average temperature determined for each tank. By agreement of all parties involved, more or less than three temperatures may be taken to calculate an average tank temperature.

Note: When temperature differentials greater than 5°F (3°C) are found, additional temperatures should be taken. The number of additional temperatures will vary with the temperature differential. However, they must always be equally spaced and averaged accordingly.

The immersion time required for the thermometer reading to reach equilibrium will vary depending on the type of liquid and equipment. For more specific guidelines on immersion times, see Tables 5a and 5b and refer to API MPMS Chapters 7.1 and 7.3.

5.3.2.1 Portable Electronic Thermometers (PETs)

In addition to the steps described in 5.3.2, the following procedure is recommended for measuring temperatures with a portable electronic thermometer (PET):

a. Attach an electrical ground between the thermometer and the tank before the hatch is opened. Check the ground to ensure that it is securely attached to the thermometer.
b. Set the temperature range selector as appropriate.
c. Lower the sensing probe to the predetermined level.
d. Raise and lower the probe 1 foot (0.3 meter) above and below the predetermined level to allow rapid stabilization.
e. After stabilization, read and record individual temperatures to the nearest 0.1°F or 0.1°C.
f. Determine the average tank temperature to a tenth of a degree.
g. Round off and report the average tank temperature in accordance with the most recent edition of API MPMS Chapter 7.3 (at the time of this document's publication—round off and report average tank temperature to 1°F or 0.5°C [round 0.5°F up]). Temperatures may be reported in units less than whole degrees by mutual agreement.

If the probe is allowed to remain stationary, contact with a convection current of colder oil will cause low readings. With

Table 4—Liquid Temperature Measurement Location Requirements for 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 barrels		X	
Tank capacity greater than 5,000 barrels			
Level <10 feet		X	
10 feet ≤ level	X	X	X

Table 5a—Recommended Immersion Times for Woodback Cup-Case Assembly

API Gravity at 60°F	Recommended Immersion Times (minutes)[a]	
	In-Motion	Stationary
>50	5	10
40 to 49	5	15
30 to 39	12	25
20 to 29	20	45
<20	45	80

[a]These immersion times were established based on the test procedure outlined in MPMS Chapter 17.1, Appendix A. Failure to use these recommended times may result in incorrect temperature readings.

Notes:
1. The woodback cup-case assembly can be used in either an in-motion or a stationary mode. In-motion is defined as raising and lowering the assembly 1 foot (0.3 meter) above and below the desired depth.
2. Cup-case assemblies made of other materials will have different immersion times. Immersion times should be established by testing, and all parties involved should agree on the immersion times (see MPMS Chapter 17.1, Appendix A).
3. If additional mass, such as a weight to cause the woodback cup-case assembly to sink, is placed in the liquid near the thermometer, the immersion time of the assembly will be longer than those listed in this table. Immersion times should be established by testing, and all parties involved should agree on the times (see MPMS Chapter 17.1, Appendix A).
4. If the temperature differential between the woodback cup-case assembly and the liquid is less than 5°F (3°C), the immersion times listed in Table 5b can be used.

Table 5b—Recommended Immersion Times for Woodback Cup-Case Assembly When Temperature Differential is Less Than 5°F (see note 4 above)

API Gravity at 60°F	Recommended Immersion Times (minutes)[a]	
	In-Motion	Stationary
>50	5	10
40 to 49	5	15
30 to 39	12	20
20 to 29	20	35
<20	35	60

[a]These immersion times were established based on the test procedure outlined in MPMS Chapter 17.1, Appendix A. Failure to use these recommended times may result in incorrect temperature readings.

a moving probe, however, the thermometer may be considered stabilized if the readout varies by no more than 0.2°F (0.1°C) for 30 seconds.

5.3.2.2 Mercury Thermometers

In addition to the steps described in 5.3.2, the following procedure is recommended for measuring temperatures with a mercury thermometer.

a. Lower the thermometer assembly through the gauge hatch to the required level.
b. Repeatedly raise and lower the thermometer 1 foot (0.3 meter) above and below the required level so that the equilibrium temperature will be reached more rapidly.
c. Withdraw the thermometer after the required immersion time.
d. Round off and report the average tank temperature in accordance with the most recent edition of API MPMS Chapter 7.1 (round off and report average tank temperature to 1°F or 0.5°C [round 0.5°F up]). Temperatures may be reported in units less than whole degrees by mutual agreement.
e. Report the temperature to the nearest 1°F or 0.5°C.
f. Repeat items a through e for every tank to be temperatured.

6 Closed and Restricted Measurement

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 minimum vapors being allowed into the atmosphere. The two basic categories of closed or 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 and 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 that 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 (i.e., for determination of proper trim and stability and cargo loading/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, 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.

6.1 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.

6.1.1 Manual Closed and Restricted Equipment

Manual equipment consists of a Portable Measurement Unit (PMU) which must 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 used together. However, equipment made by different manufacturers may be used together with an appropriate adapter.

6.1.1.1 Vapor Control Valve

6.1.1.1.1 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).

Note: Figure 9b is an illustration of a vessel that 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 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 the vessel's inert gas system (IGS) is putting positive pressure into the tanks or not.

6.1.1.1.2 Vapor control valves come in varying diameters from 1 in. (25.4 mm) to 4 in. (101.6 mm). 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).

6.1.1.1.3 The location and size of the VCV is critical to the ability to be able to measure tank contents and to take sufficient samples. In order to be able 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 assure 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 Chapter 2.8B, and API MPMS Chapter 3.4.

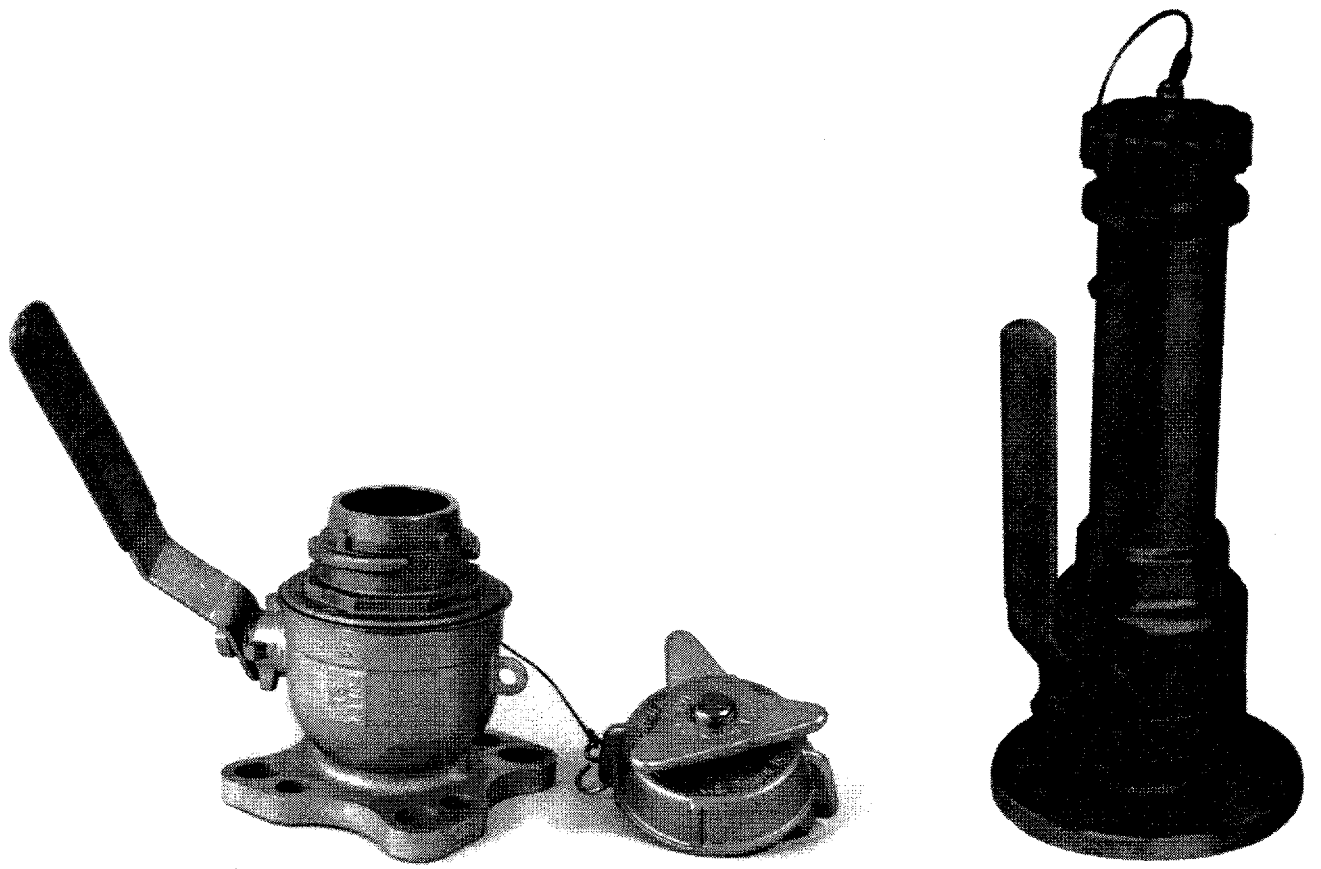


Figure 9—Typical Vapor Control Valves (VCVs)

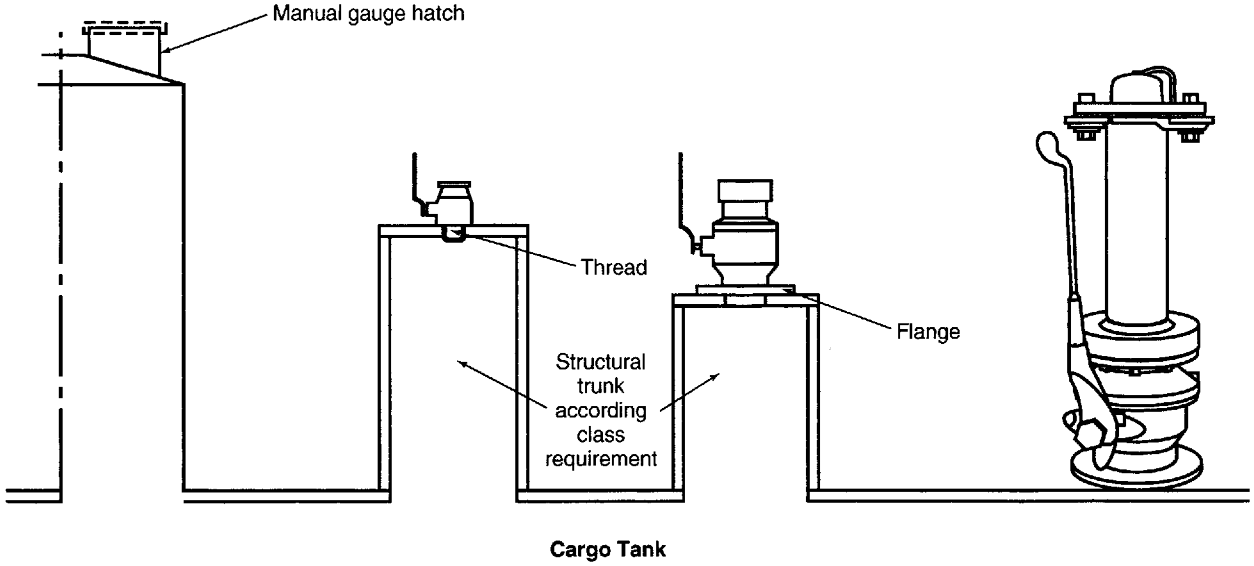
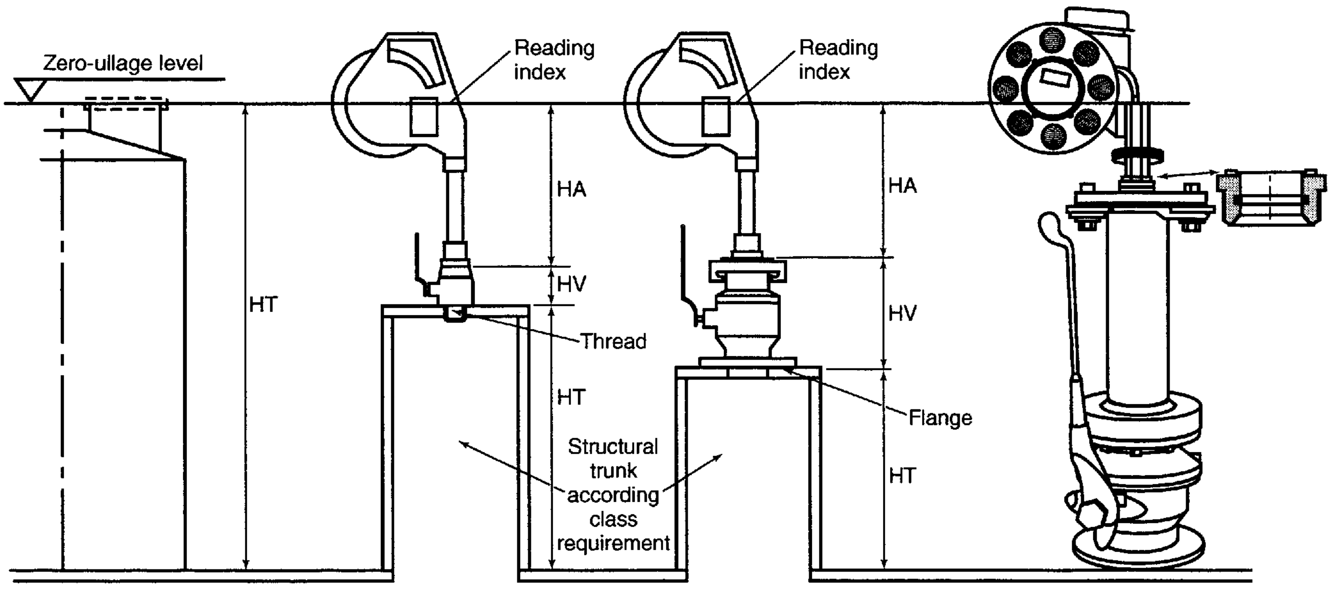


Figure 9a—Typical Deck Mountings of Vapor Control Valves
PMUs Not Attached



HT = Height of trunk.
HA = Height of adaptor.
HV = Height of vapor control valve (VCV).

Figure 9b—Typical Deck Mountings of Vapor Control Valves
PMUs Attached

Note: Since many vessels have been retrofitted 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 location for PMU equipment. Also, the vapor control valve locations should be placed in accordance 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 in consideration the use of adapters that allow the use of different manufacturers' portable measurement units with varying vapor control configurations.

6.1.1.2 Portable Measurement Unit (PMU)

6.1.1.2.1 The portable measurement unit (PMU) is designed to measure oil levels, water levels and/or temperatures of cargo in a tank. 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).

6.1.1.2.2 Each PMU must be fitted with a means to provide a tight seal on the VCV. For 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.

6.1.1.3 Portable Manual Sampling Unit (PSU)

The portable manual sampling unit (PSU) is designed to obtain samples under closed or restricted system conditions and to be compatible with vapor control valves 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 12).

6.1.1.4 Maintenance/Verification

6.1.1.4.1 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.

6.1.1.4.2 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 must be followed and a log kept of all maintenance and verifications performed. UTIs and single function 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.

Note: From time to time it may become necessary to use a vessel's PMU that does not have adequate documentation of its verification and calibration. In those instances, it is acceptable to use such unit provided it is field verified as follows:

a. The tape function is visually verified against a manual steel gauge tape that has been calibrated to API MPMS Chapter 3.1A.
b. The thermometer function is verified as per section 5.3.1.2 of this standard.

6.1.2 Procedures for Measurement—Closed and Restricted

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.

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

In addition, before gauging, verify that:

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 which 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 (replace 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 affect on measurements and/or volumes.

6.1.2.1 Closed and Restricted Manual Sampling

Since closed or restricted sampling is performed through VCVs, refer to 6.11. If samples are to be taken using the same VCV as the one being used to obtain the other tank measurements, sampling should be done first. To obtain the best cargo

Figure 11—Typical Recessed Sensor

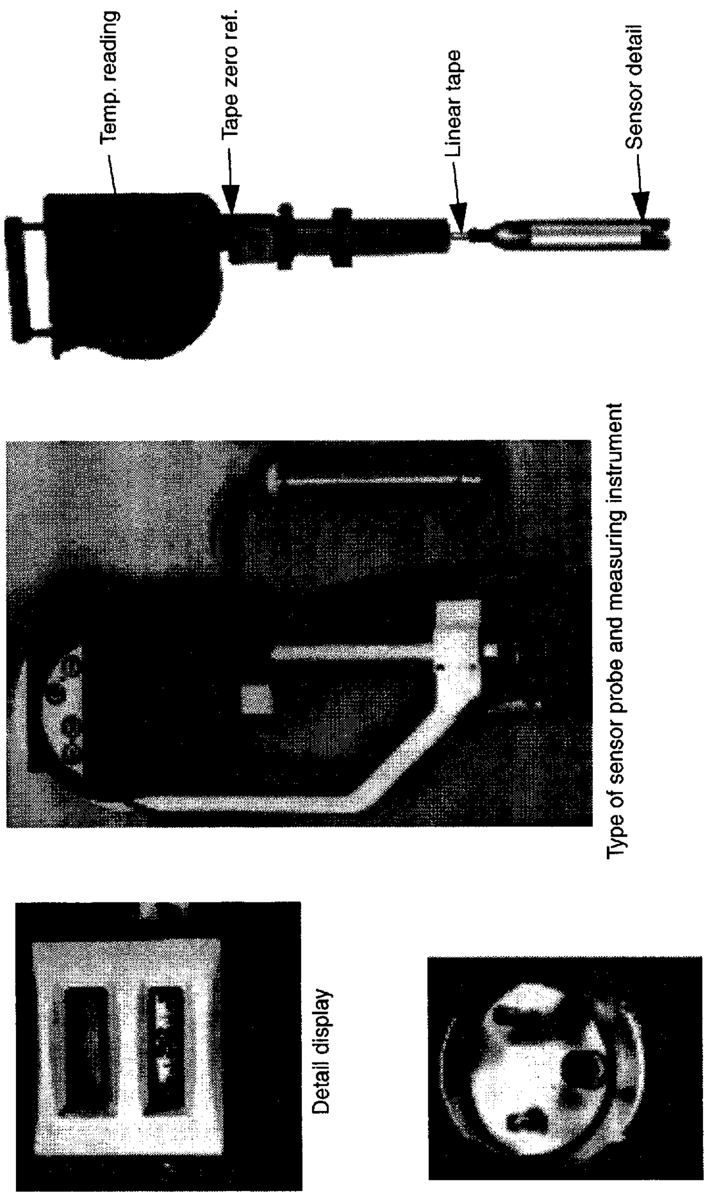


Figure 10—Two Types of Portable Measurement Units (PMUs)

samples from each tank, they must be taken in accordance with API MPMS Chapter 8.

For specific sampling procedures see Section 7 of this standard.

6.1.2.2 Liquid Level/Free Water Gauging Using PMUs

a. Examine tank capacity 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 3.1A.)

b. Record the reference gauge height indicated for each vessel's tank on the vessel's capacity tables. Note any corrections for individual standpipes and/or 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 vessel's officer that no cargo is being transferred and request an estimate of the cargo level in each tank.

e. Verify that the vapor control valve is closed.

f. Place the gauging tape assembly onto the vapor control valve and screw it down tightly (or lock firmly, if quick-release type).

g. To measure oil, open the vapor control valve 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 ($^1/_8$-in., 1-mm, 0.01-ft). See API MPMS Chapters 3.1A.

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 $^1/_8$-in. (3-mm) span. Record liquid level.

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.

i. When cargo level measurement is complete, determine the free-water ullage by lowering the sensor to approximately 1 ft (300 mm) above the bottom of the tank. Determine the oil/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: Due to varying gauge locations and trim conditions, the detection of cargo and free water at the specific gauge locations on a vessel is not always possible. For more information on gauge point location, See MPMS Chapters 2.8B and 3.1A.

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 11). 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 feel, necessitating the use of a specially designed weighted bob. (See Figure 13.) Also, 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 water ullage reading to the nearest tape graduation ($^1/_8$-in., 1-mm, 0.01-ft) 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 vapor control valve and disconnect the gauging equipment from the valve.

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

6.1.2.3 Closed and Restricted Measuring of Small Quantities

6.1.2.3.1 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 6.1.2.2. 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 the gauge points, care must be given to assure 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.

6.1.2.3.2 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

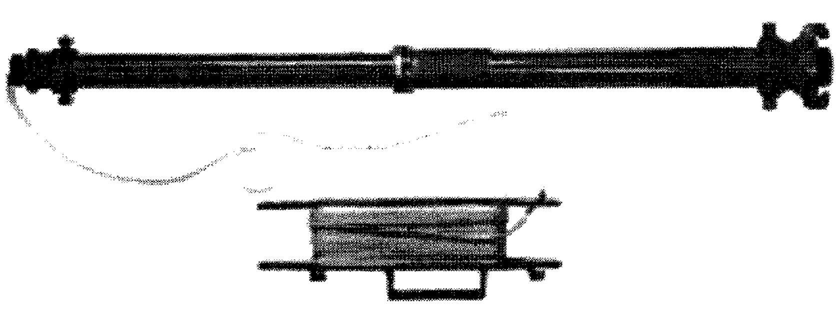


Figure 12—Type of Portable Sampling Unit (PSU)

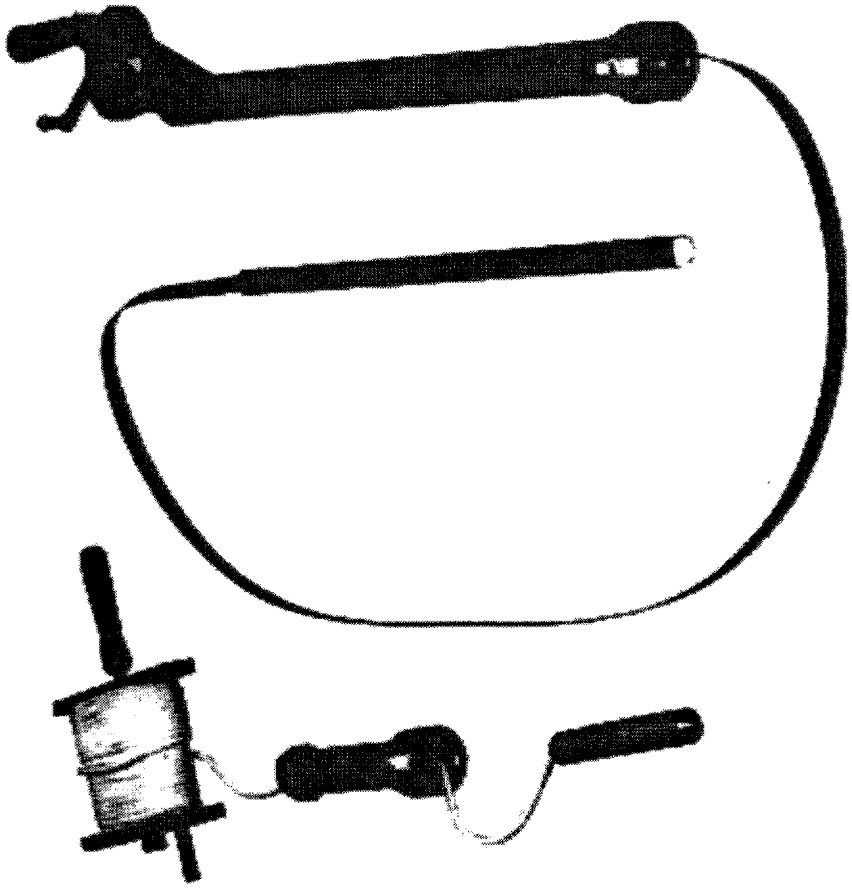


Figure 13—Typical Special Weighted Bar and Bob Units

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 marine custody transfer measurements.

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 11). Therefore, in that situation an adjustment to the gauge must be made.

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

6.1.2.4 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 (see 5.3.2.1).

6.2 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. This section describes the automatic equipment most widely used on ships and the procedures for properly using them to obtain accurate measurements.

6.2.1 Automatic Equipment

Automatic measurement equipment consists of permanently installed, fixed devices in a vessel's tanks to determine liquid levels, and temperature (see Figure 14). Automatic sampling equipment used on tank vessels may be fixed or portable.

6.2.1.1 Automatic Sampling Equipment

Most automatic sampling equipment used for marine custody transfer measurement (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 vessels manifold at the time of hose connection (see Figure 15). In either case, design and performance of all automatic sampling equipment shall be in accordance with API MPMS Chapter 8.2. See definition of *automatic sampler.*

6.2.1.2 Automatic Measurement Equipment

6.2.1.2.1 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/or temperature measurement capability, with readouts located at the compartment or at a remote point, such as the cargo control room. It includes Automatic Tank Gauging (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).

6.2.1.2.2 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.

6.2.1.2.3 In all cases the tank capacity tables should be specifically developed or issued for the automatic gauging system used. For more information, see API MPMS Chapters 2.8B and 3.4.

6.2.1.2.4 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 ROB/OBQ. Fixed automatic measurement equipment does not generally measure free water, and the level of ROB/OBQ, 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 marine custody transfer measurement.

6.2.1.2.5 However, if the overall accuracy of the ATG system and temperature taking system, described in API MPMS Chapters 3.4 and 7.4 are met, they can be used to determine cargo level and temperature for marine custody transfers.

6.2.1.2.6 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 manufacturer's 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 6.

6.2.1.3 Automatic Temperature Equipment

6.2.1.3.1 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

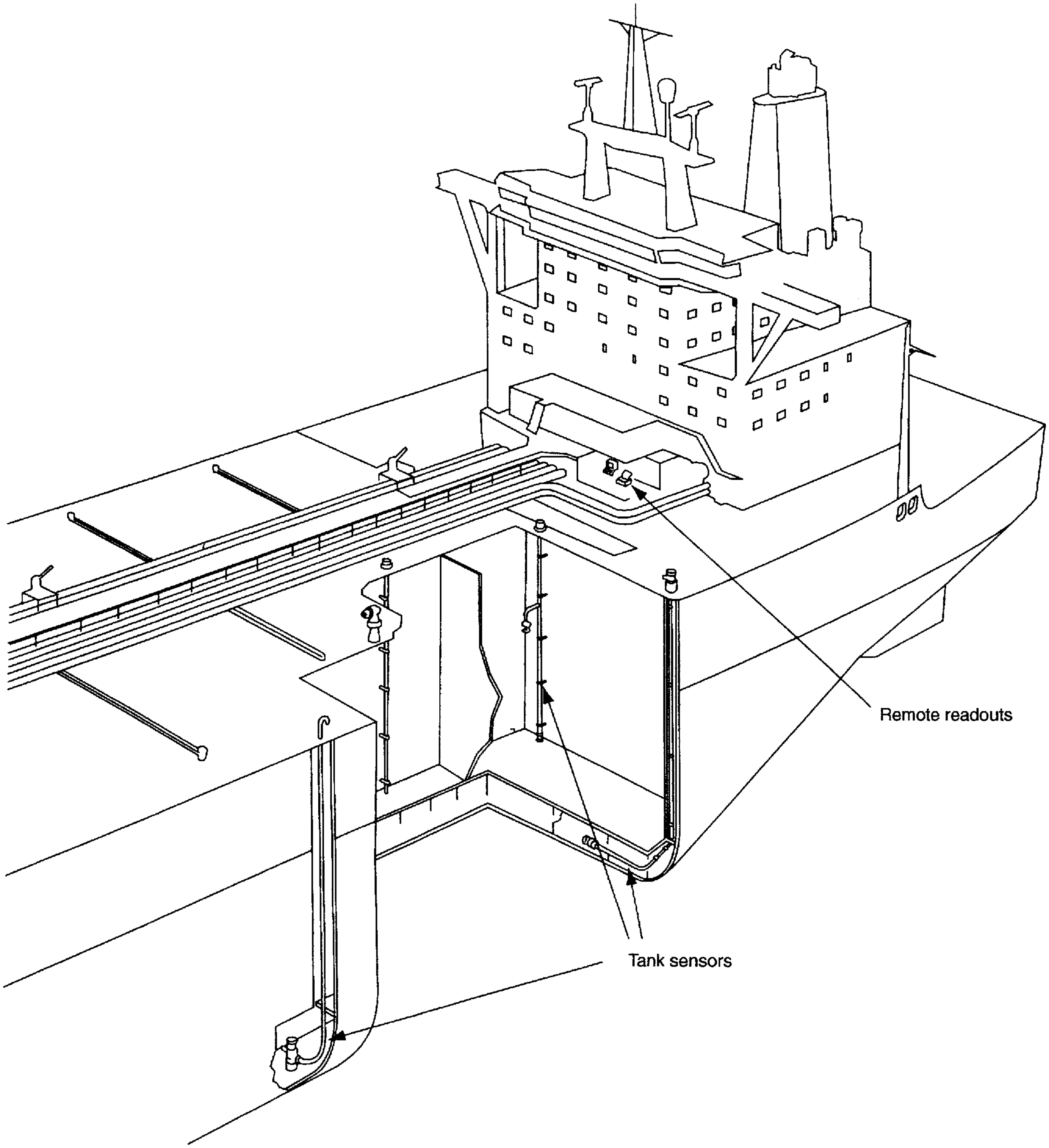


Figure 14—A Type of Automatic Fixed Measurement System Permanently Installed on a Vessel

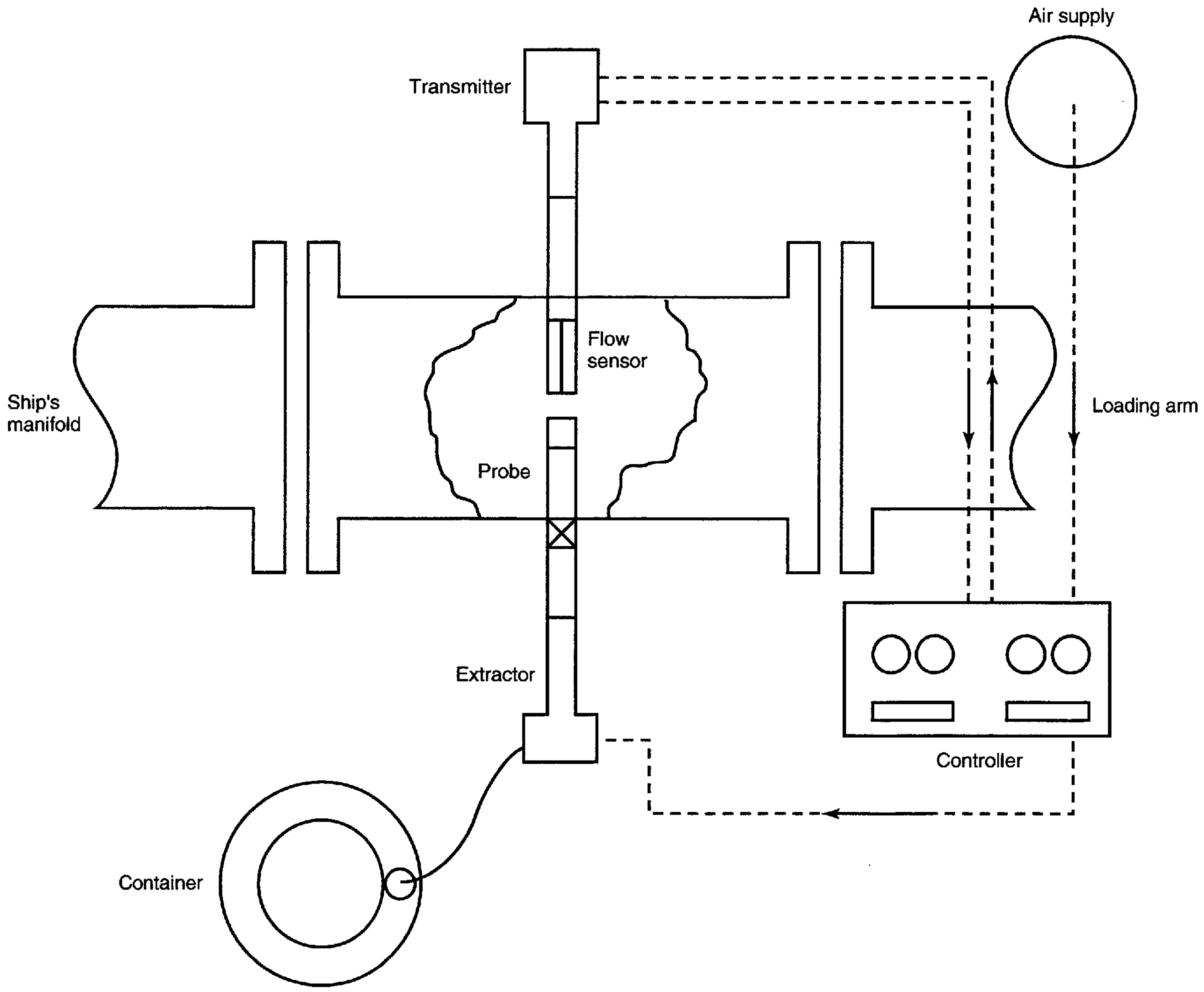


Figure 15—Type of Automatic Sampler Designed for Shipboard Use

cargo temperature in accordance with API MPMS Chapter 7.4. Manufacturer's operating specifications and installation literature must indicate location of sensors and if automatic averaging of temperature is provided by immersed sensors.

6.2.1.3.2 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 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, manufacturer's description of each system and its capabilities must be fully reviewed and understood before use.

6.2.1.4 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.

6.2.2 Procedures For Automatic Closed System Measurement

When vessels are fitted with automatic measurement equipment, it may be used to measure petroleum liquid levels and, in some cases, temperature. 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, and other applicable International Chamber of Shipping and the Oil Companies International Marine Forum (OCIMF) publications as well as manufacturer's instructions.

Before taking automatic measurements, verify that:

a. All cargo operations have been stopped and that 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 affect on measurements and/or volumes.

6.2.2.1 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. Determine whether the system calculates volumes automatically, or requires the input of measurement data to generate calculated volumes.

b. Verify that measurements are being taken from the reference point 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 ($^1/_8$-in., 1-mm, 0.01-ft). 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.

6.2.2.2 Measuring of Small Quantities/Free Water

Most automatic tank gauging systems do not have the ability to accurately measure free water under oil or small amounts of ROB/OBQ, especially if the surface of the ROB/OBQ cannot be detected due to the trim or list. With those systems which 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 which 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 seen on the vessel. For more information on gauge point location, see API MPMS Chapters 2.8B, 3.1B, and 3.4.

6.2.2.3 Automatic Temperature Measurement Procedures

Review temperature system verification log and record last calibration date. Read and record the temperature at each 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 0.5°F or 0.5°C. If not, temperatures at each tank level should be recorded to the nearest 0.1°F or 0.1°C and then the level temperatures of each tank manually-averaged to 0.5 degrees, and so reported (see Table 4).

7 SAMPLING AND SAMPLE HANDLING

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 contains detailed information on manual sampling.

Taking of samples is only part of the sampling process. Samples must also be handled properly from the time they are obtained to the time they are ultimately used or stored. Accordingly, also refer to 7.4, Handling of Samples.

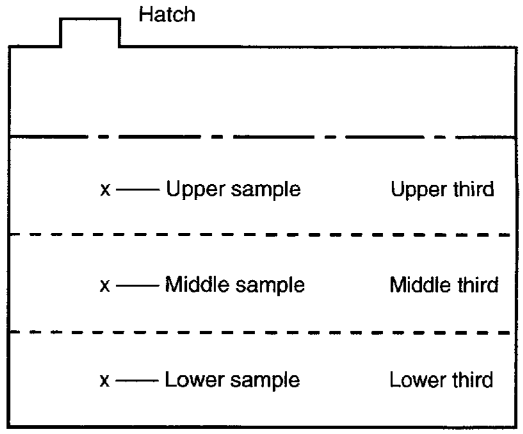


Figure 16—Sampling Depths in Ship or Barge Tank

7.1 MANUAL SAMPLING OF PETROLEUM LIQUIDS

If the liquid in the tank is homogeneous, a manual sample should be representative of the entire tank contents. If the liquid in the tank is non-homogeneous or stratified (see note in 7.1.1), a manual sample is acceptable under the following conditions:

a. Sufficient time must have elapsed for any non-cargo phases (such as free water or sludge) to separate from the cargo.
b. The level of any separate non-cargo phases is measurable so that no portion of them will be included in manual samples.
c. An appropriate sampling procedure is used to obtain the best representation of each component at the available sampling location(s).

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

7.1.1 Upper, Middle, and Lower Samples (Spot Samples)

7.1.1.1 An upper sample is a spot sample taken at the midpoint of the upper third of the tank contents (see Figure 16).

7.1.1.2 A middle sample is a spot sample taken at the middle of the tank contents (a point halfway between upper and lower sample points, see Figure 16).

7.1.1.3 A lower sample is a spot sample taken at the midpoint of the lower third of the tank contents (see Figure 16).

7.1.1.4 A proportionate mixture of one-third of each upper, middle, and lower sample is usually considered to constitute a representative composite of the contents of the compartment being sampled (see 7.4.1).

7.1.1.5 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, follow the manufacturer's instructions for opening and closing the unit during the sampling process.

a. Inspect the sampling bottle, can, or PSU and the sample container for cleanliness and use only clean, dry equipment.
b. Measure the liquid level in the tank by gauging or reading automatic gauges and determine the ullage levels at which the spot sample(s) should be taken.
c. Insert the cork in the sample bottle or close the PSU.
d. Attach the weight to the bottle or place the bottle in a sampling cage.
e. Lower the open bottle, can, or PSU to the desired level.
f. At the required level, pull out the stopper with a sharp jerk of the sampling line and allow sufficient time for the sampling device to completely fill at the specific location.
g. Withdraw the sampling assembly and verify that the sampling device is completely full. If it is not full, empty the device and repeat steps d and e above.
h. If samples will remain in the bottle used for sampling, pour off 20% of the contents of the bottle to allow an adequate vapor space.
i. When a PSU or other intermediate device is used to draw spot samples, pour each spot sample into a clean, dry container, filling the container to between 70–85% of capacity. Discard the remaining portion from the spot sampling device.
j. Cap, wipe, and label the bottle per labeling section.

Note: When a spot sample or an all-levels sample is taken, ensure that the stopper is not accidentally withdrawn from the sample container before it reaches the intended level. 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/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 one foot above any measured level of free water. Review manufacturer's description of equipment to determine the design capabilities and limitations of the units.

7.1.2 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.

7.1.3 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.

a. Inspect the sampling bottle, can, or PSU and the sample container for cleanliness—only clean, dry equipment should be used.
b. Attach the weight to the sample bottle or place the bottle in a sampling cage.
c. Lower the stoppered bottle assembly or the closed PSU to the desired level [approximately 1 foot (0.3 meters) above measured free water].
d. Open the stoppered bottle or PSU and raise it at such a rate that it will make the sampling device between 70–85% full when it emerges from the liquid.
e. If the sampling device is more than 85% full, discard the sample and repeat steps b through d above.
f. Cap, wipe, and label bottle per labeling section.
g. Pour sample obtained using PSU into appropriate container, close, and label.

7.1.4 Running Sample Procedure

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.

a. Inspect the sampling bottle or PSU and the sample container for cleanliness and use only clean, dry equipment.
b. Attach the weight to the bottle or place the bottle in a sampling cage.
c. Lower the open bottle, can, or PSU to a level approximately 1 foot (0.3 meters) above the measured free-water level and raise it at a rate that the sampling device will be between 70–85% full when it emerges from the liquid.
d. If the sampling device is more than 85% full, discard the sample and repeat steps b and c above.
e. A notched cork or restricted opening in the sample bottle or can, or a PSU with an adjustable opening, may be required to obtain running samples less than 85% full in very light liquids or very deep cargo compartments.
f. Cap, wipe, and label bottle per labeling section.
g. Pour sample obtained using PSU into appropriate container, close, and label.

Note: A running sample or an all-levels sample is not necessarily a representative sample because the tank volume may not be proportional to the depth and because the operator may not be able to raise the sampler at the rate required for proportional filling. The rate of filling is proportional to the square root of the depth of immersion.

7.1.5 Free-Water Samples

7.1.5.1 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. Liquids that are only slightly heavier than water may contain layers of free water.

7.1.5.2 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, a spot or spot samples may be taken as described in 7.1.1. If there is not enough water to take the spot sample, other methods and equipment must be used and their manufacturers' instructions followed.

7.1.6 Small-Quantity OBQ and ROB Samples

7.1.6.1 The usual nonuniform 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 sufficient quantity to do so.

7.1.6.2 When the other methods cannot be used, OBQ and ROB can usually be sampled using equipment such as a scoop sampler or tube sampler or from scrapings from a gauge bob. The sampling report should indicate the method used.

7.1.7 Other Types of Samples

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 of the types of samples routinely required are as follows:

7.1.7.1 Stratification Layers

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 samples for each layer detected are taken, each should be kept separate until the material sampled has been identified.

7.1.7.2 Sludge

If a sludge is present in the tank, its thickness should be measured; however, it is difficult to obtain a representative 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 17.1.6).

7.1.7.3 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 samples are to be taken as any other sample described in the foregoing sections.

7.1.7.4 First Foot Sample (Test Trial Portion)

7.1.7.4.1 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.

7.1.7.4.2 If contaminants are found, all parties should be notified that the compartment or compartments may have to be off-loaded or transferred to a slop tank and another parcel loaded and retested on "first-foot." Also see 9.8 for safety considerations when taking this type of sample.

7.2 DYNAMIC SAMPLING

7.2.1 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.

7.2.2 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 (piping elbows, etc.) provide better upstream mixing at the higher velocities. Therefore, it is recommended that the initial start-up of a marine vessel discharge be conducted from a tank that is relatively free of water as determined by the pre-transfer 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 that are being discharged.

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

a. Inspect 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 pitot probe) should be cleaned after every use to prevent plugging.

Sediment buildup in the sampler head can cause problems with o-ring seals and the proper operation of internal check valves, thereby compromising the sampling grab size. If more than one line is to be sampled into one receiver, be sure that the sampling grab size is essentially the same for each. This ensures that the lines are sampled in a volume-proportional manner.

b. Check that the power source is activated.

c. Prepare the sample system for the transfer, including the following steps:

1. Drain and clean container(s).
2. Verify that valves are in proper position.
3. Verify that the sample lines are drained (which should have been performed at the end of the last sampling exercises).
4. Ensure that container is securely closed.
5. Hook up container(s) if necessary.

d. Seal container(s) and record seal numbers if receiver is left unattended.

e. Set up controller. Since flow rates can vary a great deal during marine vessel loading/discharges, time-proportional sampling is normally not appropriate; and a pacing device should be used to ensure flow-proportional sampling.

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

1. Expected Parcel Volume (TOV) to be transferred, *PVe*.
2. Expected extractor grab size (ml), *b*.
3. Expected sample volume (normally 80% of receiver capacity), *SVe*.
4. Expected number of sample grabs, *n*.
5. 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.

g. 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 mid-point of the transfer and at the end.

h. 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.

7.3 MANIFOLD (SPOT LINE) SAMPLES

In addition to those samples noted in the previous sections, it may be necessary to obtain a line, pump, 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 and/or at any part of it. In those cases, it must be understood that the "manifold 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.

7.4 HANDLING OF SAMPLES

Taking samples from the tanks by whatever means is only part of the sampling process. Once a sample is obtained, it must be protected from contamination or alteration, such as the loss of light ends and water. This can be achieved by closing the sample container immediately after the sample is drawn. Additional guidelines for compositing of samples are as follows:

7.4.1 Compositing is the blending of spot samples or another appropriate group of samples (usually on a volumetrically-proportional basis) for testing. When individual samples are taken (see 7.1.1), each sample should be brought to the laboratory in its separate container. To maintain the integrity of the sample, compositing and distribution to interested parties should be done under laboratory conditions. When compositing must be done on board a vessel, the procedures described in 7.1.2 shall be followed.

7.4.2 When the upper, middle, and lower sampling method is used, an individual composite should be made up for each tank from the upper, middle, and lower samples taken from that tank. These individual tank composites should then be blended in proportion to the volume of material in each compartment for each grade on board.

7.5 LABELING OF SAMPLES

Sample containers should be labeled immediately after a sample is obtained. The following information should be included on the label:

a. The date, time, and location.

b. The name of the person who took the sample and his employer.

c. Identification of the vessel.

d. The name or grade of the sampled material.

e. Identification of the tank sampled.

f. The type of sample (for example, upper, middle, lower, all-levels, composite).

g. How the sample was taken (type of equipment used).

8 Data Collection, Tables, Basic Calculations, Records, and Reports

Vital components of good measurement of cargo on ships is the use of the proper tables, the accurate recording of the basic data obtained through physical measurement, and the correct calculation of the necessary volumes. This section is a discussion of these items that are essential to accurate determination of cargo volumes.

8.1 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.

8.2 CAPACITY TABLES

8.2.1 Capacity tables show the volume corresponding to each measured innage or ullage. Measurements should be taken in the same units used in the tables. If measurements must be taken in other units, the conversion factors given in Appendix C should be used. When capacity tables are not calculated to the prescribed graduations ($^1/_8$-in., 1-mm, or 0.01-ft), and when gauge readings fall between the values in the tables, interpolation will be necessary.

8.2.2 The observed reference height should be compared with the reference height given in the tables and recorded (see Appendix B.3). Trim corrections must be carefully applied when the vessel is not on even keel. Additional corrections are required when the vessel is listing. Trim and list corrections must be carefully applied as indicated in the appropriate vessel tables (see Appendix B.4, B.5, and B.7).

8.2.3 The trim and list corrections given in the tables shall be applied only when the liquid is in contact with all bulkheads in the tank but is not in contact with the top of the compartment. When the free water of cargo surface does not touch all bulkheads of the tank, wedge tables or a wedge formula may be used to determine the volumes present in the tank.

8.3 VOLUME CORRECTION TABLES

The volume correction tables are necessary to convert the observed cargo volumes being measured to standard volumes at standard temperatures such as 60°F or 15°C. When making these conversions, always be sure to use the correct tables according to the sales contract or as otherwise agreed. Generally, Tables 6A, 24A, and 54A are to be used for crude oils, 6B, 24B, and 54B are to be used for products, and 6D, 24D, and 54D are to be used for lubricating oils. It must be noted however, that not all crude oils and products fall into the common categories and other tables such as Tables 6C, 24C, and 54C may provide a better "fit" for calculation purposes. If you are not familiar with the specific cargo being measured, confirm with principals which table should be applied.

8.4 OBSERVATIONS, MEASUREMENTS, AND CALCULATIONS

After all observations and measurements shown on the checklist (see API MPMS Chapter 17.1) have been made, quantity calculations must be performed. Volumes should be determined according to the steps as follows:

Total Observed Volume (TOV)

– *Free Water (FW)*

= Gross Observed Volume (GOV)

x *Volume Correction Factor (VCF or Ctl)*

= Gross Standard Volume (GSV)

– *Sediment and Water (S&W)*

= Net Standard Volume (NSV)

Note: The parties involved should agree whether to calculate the ship volumes to a GSV or NSV end volume and which values should be used for the required calculations (i.e., ship or shore S&W, FW, API, etc. values).

Note: If the cargo being measured does not have an S&W content (as is the case with most clean products), the GSV would then equal the NSV of the cargo.

Total Calculated Volume (TCV) = GSV + FW of the cargo being measured

a. Total Observed Volume (TOV).

Determine the total observed volume by entering the appropriate capacity table for each vessel's tank with the measured innage/ullage readings, with trim and list corrections (if any) applied according to the instructions in the tables. As an alternative, the trim and list corrections may be applied as adjustments made to the volumes, based on observed gauges. The capacity tables will indicate the correct method of applying trim and list corrections.

b. Free Water (FW).

Determine the free water volumes by entering the capacity tables, as described in step a, using the obtained water-cut measurements.

c. Gross Observed Volume (GOV).

Subtract the free water volume from total observed volume determined in steps a and b to calculate gross observed volume.

d. Gross Standard Volume (GSV).

Calculate the gross standard volume by multiplying the gross observed volume by the volume correction factor. The volume correction factor is obtained as appropriate from API MPMS Chapter 11.1.

e. Net Standard Volume (NSV).

When required, calculate the cargo's NSV volume by subtracting its S&W content from the calculated GSV volume. Therefore, if the cargo has no S&W, the vessel's NSV would be equal to its GSV.

f. Total Calculated Volume (TCV).

Add any free water (FW) determined to be on board to the calculated gross standard volume (GSV) to calculate the total calculated volume (TCV).

8.5 VOLUME OF SHIP'S PIPELINES

Each ship should have a diagram on which the location of loading and discharging piping is clearly indicated. The diagram should show the diameter of each line and the volume of each line when full or provide sufficient information to allow the calculation of these volumes. Knowledge of the lines used during the cargo-handling operation should make it possible to determine which pipes could contain oil at any point in the cargo operation. It must be understood, however, that the actual pipeline volumes usually cannot be quantified at all times.

9 Special Considerations

Because of the wide variation in physical properties of all world crudes, special consideration must 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.

9.1 HIGH-VISCOSITY AND HIGH-POUR-POINT CARGOES

9.1.1 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, using a bottom or thief sampler. 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.

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

9.2 HEATED CARGOES

9.2.1 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.

9.2.2 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.

9.3 MEASUREMENT ON BOARD ROLLING MARINE TANK VESSELS

During offshore operations or lightering, or when the vessel is at an exposed berth, cargo may be in motion within the vessel's tanks. In such situations, at least five successive gauge readings should be taken, the highest and lowest readings dropped and the remaining three averaged and recorded. The successive gauges should be taken as quickly as is practical and a description and extent of the adverse measurement conditions recorded.

9.4 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.

9.5 HIGH RVP CARGOES

High RVP cargoes such as gasoline and other light products, some very light crude oils, and condensates all have potential problems as those indicated in 9.4. As such, special care should be used when taking open hatch measurements, especially on hot days.

9.6 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 must 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.

9.7 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.

9.8 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.

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 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.

APPENDIX B—ADDITIONAL INSTRUCTIONS AND CAUTIONARY NOTES

This appendix 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 oil. 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.1.1 SINGLE HULL VESSELS

The most common type of ship and barge currently is the single hull or single skin vessel (see Figure B-1). These generally cause the least problems for measurement because their single skin design usually allows easy access to all compartments. Even on these, however, obstructions may prevent gauge tapes from getting all the way to the bottom of the tank. In addition, it is not uncommon to have some leakage of cargo between tanks due to small cracks in internal bulkheads. Therefore, it is important that all tanks be gauged and the reference heights of each tank carefully noted and recorded.

B.1.2 DOUBLE HULL SHIPS

Double hull ships are becoming more and more common due to increased environmental and industry regulations. These ships differ from the single hull vessels in that the cargo tanks are surrounded by another hull or series of tanks (see Figure B-2). Because of the "clean" tank design of the ships 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 ships also usually have fewer tanks to gauge than does a conventional, single hull ship. 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-3). 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.

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

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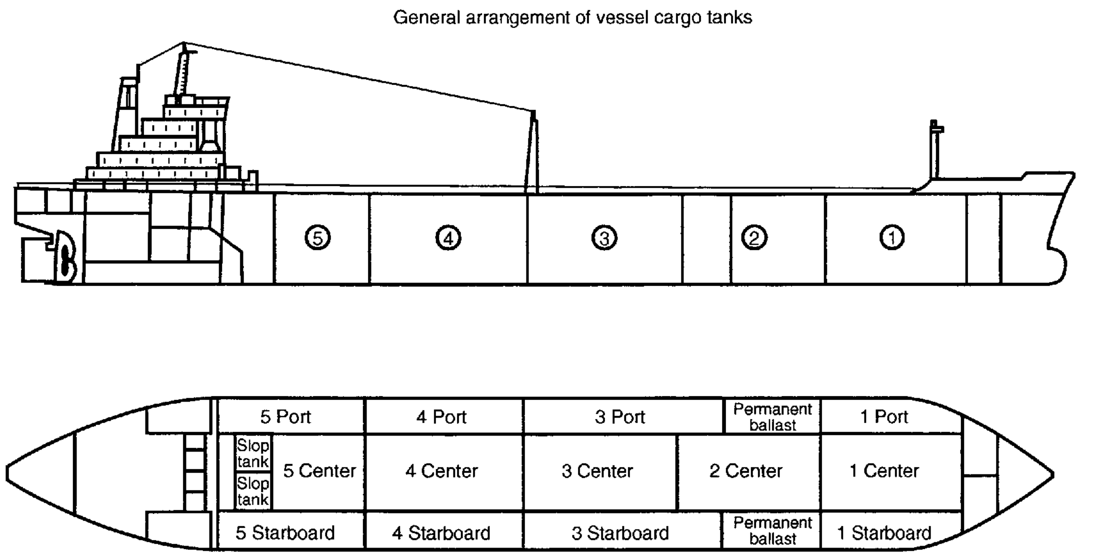


Figure B-1—Single Hull Ship

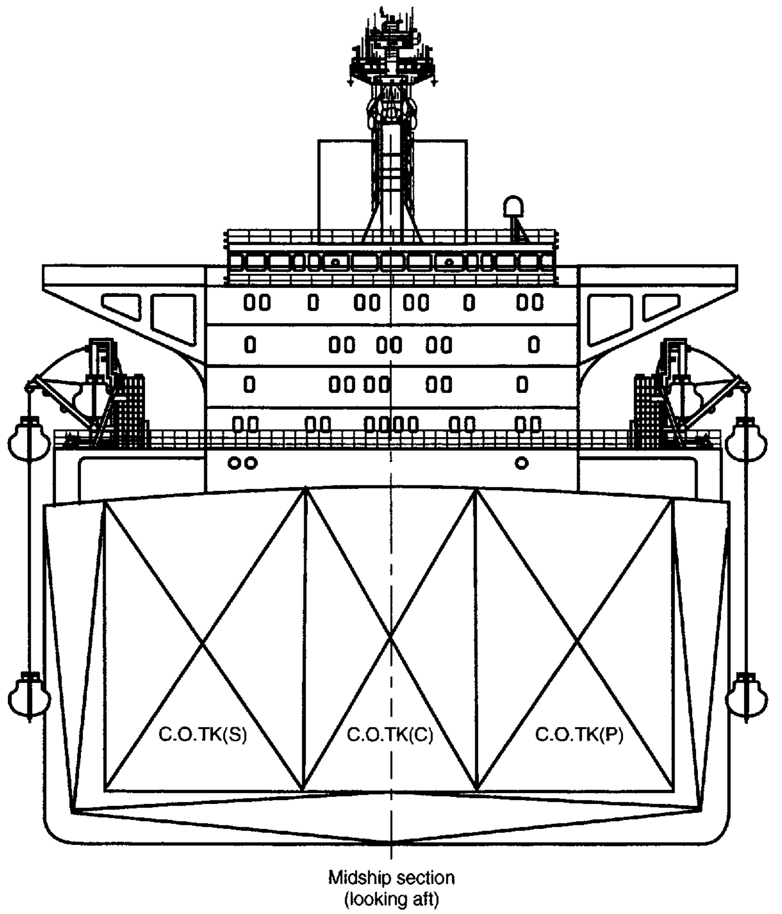


Figure B-2—Typical Double Hull Cross Section

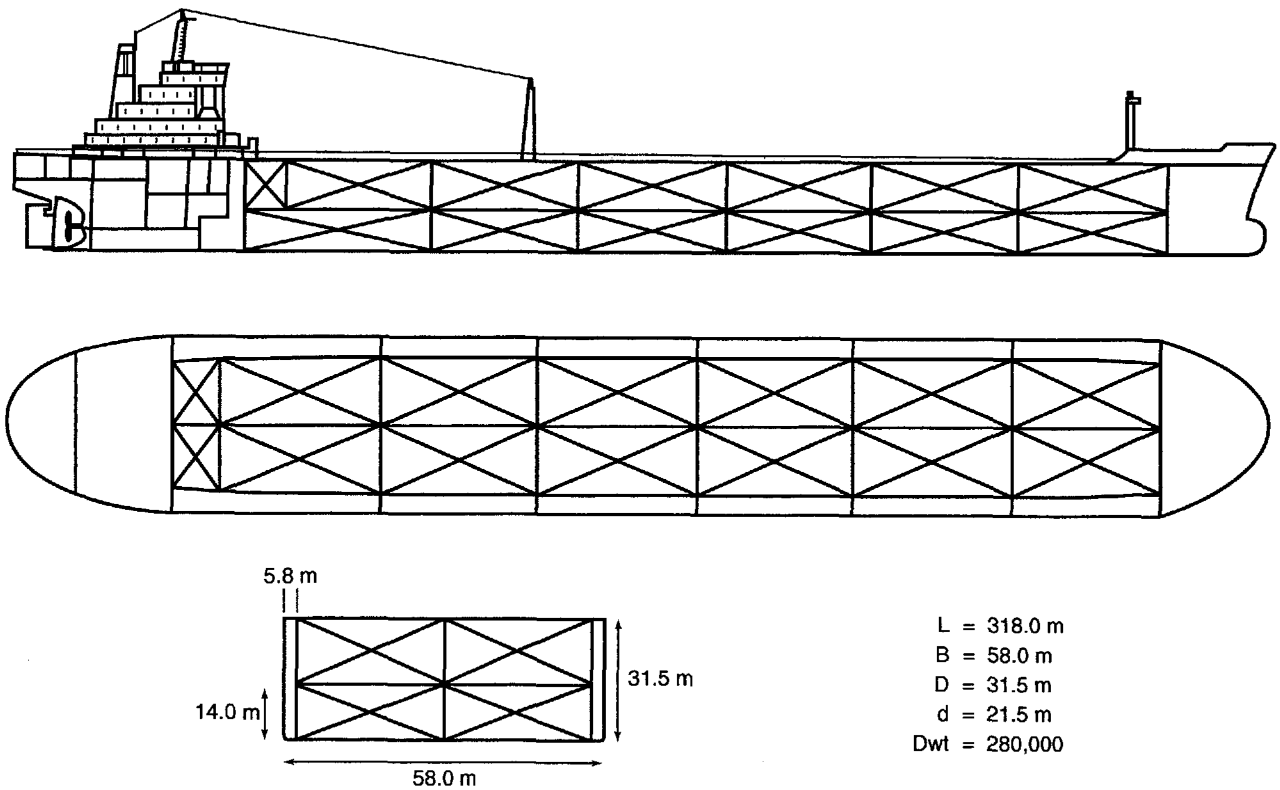


Figure B-3—Typical Mid-Deck VLCC Design

improved techniques and equipment that allow better measurement and sampling of cargoes on marine tank vessels.

B.2.3 Although this publication describes parties 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 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 must 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 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 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 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 must 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

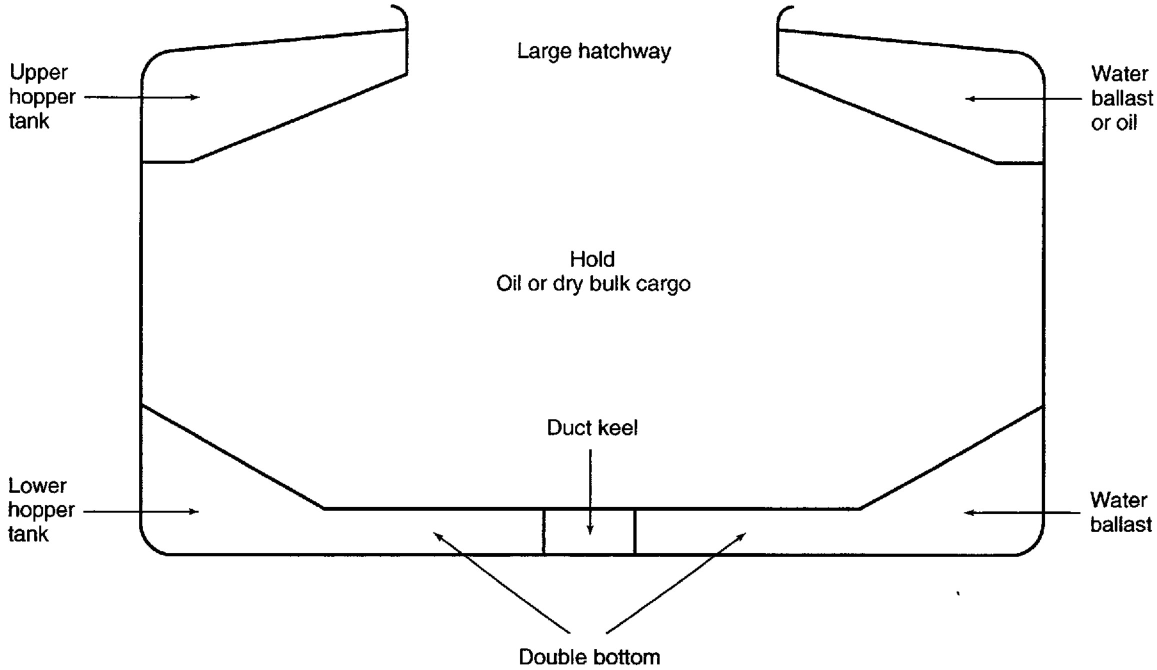


Figure B-4a—Typical OBO Cross Section

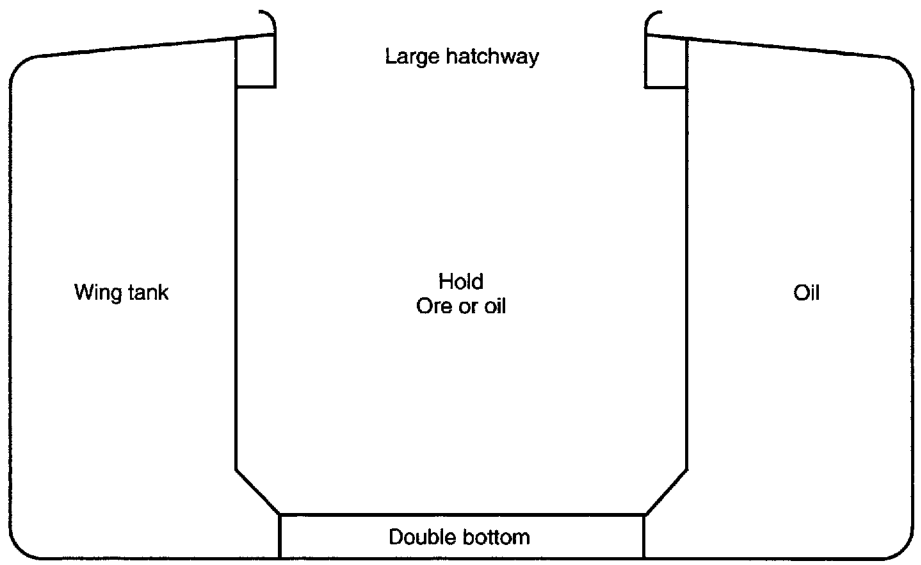


Figure B-4b—Typical ORO Cross Section

board the vessel by means of a dead-weight survey. To accomplish this, the salinity of the water in which the vessel is floating must 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.

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 ship 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 must 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 must 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. 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.

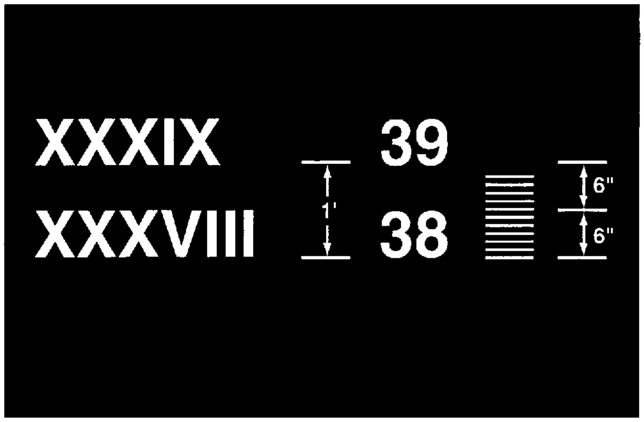


Figure B-5—Draft Readings: US Customary Unit

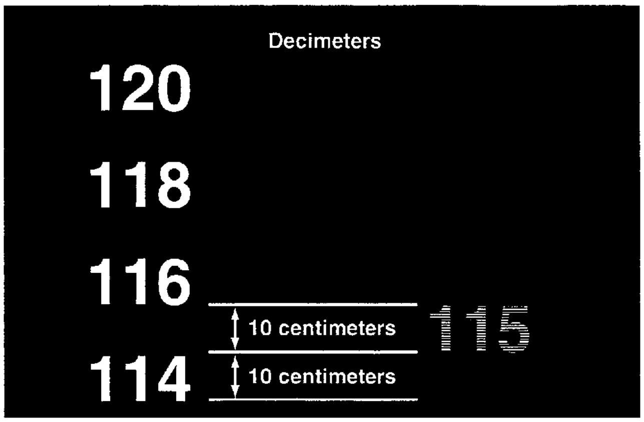
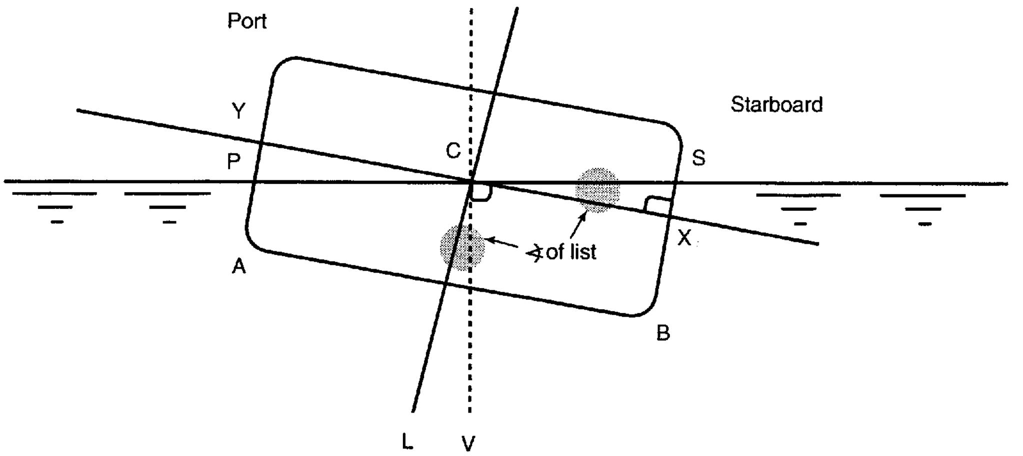


Figure B-6—Draft Readings: Metric Unit

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 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 so no rain or other external moisture is introduced to the containers.



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:

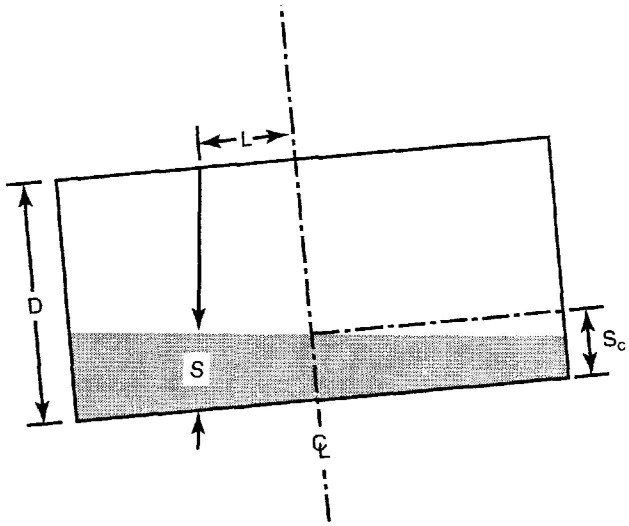
$$\text{Tangent } \Theta = \frac{(12.0 - 10.0)}{30.0} = 0.0667$$

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.

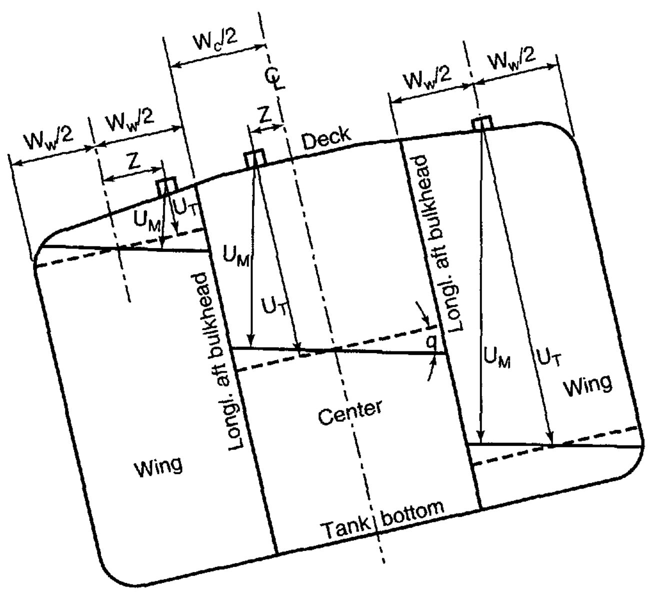
All of the above must be expressed in the same units of length.

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

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.

B.10 Alternate Procedures for Measurement of Small Quantities

B.10.1 ALTERNATE FREE WATER MEASUREMENT

B.10.1.1 When using an interface detecting PMU, water-finding paste may be placed on 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.

B.10.1.2 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, but when the procedure is used it is then like the procedure described in API MPMS Chapter 17.2.4.2.1.4.2. (See Figure 13.)

B.10.3 BRASS BOB PMU—ROB/OBQ 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, but when the procedure used is like that procedure described in 6.1.22 (see Figure 13).

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. For the best way to measure 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 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 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 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 MCTM purposes.

APPENDIX C—CONVERSION FACTORS

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

To Convert	To	Multiply by
	Length	
Metres	Yards	1.0936
	Feet	3.2808
	Inches	39.370
Yards	Metres	0.9144[a]
Feet	Metres	0.3048[a]
Inches	Centimetres	2.54[a]
	Weight	
Long tons	Pounds (avoirdupois)	2240.0[a]
	Short tons	1.12[a]
	Metric tons (tonnes)	1.01605
Short tons	Pounds (avoirdupois)	2000.0[a]
	Long tons	0.892857
	Metric tons (tonnes)	0.907185
Metric tons (tonnes)	Long tons	0.984206
	Short tons	1.10231
Pounds (avoirdupois)	Kilograms	0.453592
Kilograms	Pounds (avoirdupois)	2.20462

To Convert	To	Multiply by
	Volume[b]	
U.S. gallons	Cubic inches	231.0[a]
	Cubic feet	0.133681
	Imperial gallons	0.832674
	U.S. barrels	0.0238095
	Litres	3.78541
U.S. barrels	U.S. gallons	42.0[a]
	Cubic inches	9702.0[a]
	Cubic feet	5.61458
	Imperial gallons	34.9723
	Litres	158.987
Imperial gallons	Cubic inches	277.42
	Cubic feet	0.160544
	U.S. gallons	1.20095
	U.S. barrels	0.0285941
	Litres	4.54596
Cubic feet	Imperial gallons	6.22883
	U.S. gallons	7.48052
	U.S. barrels	0.178108
	Litres	28.3169
	Cubic metres	0.0283169
Cubic inches	Imperial gallons	0.00360465
	U.S. gallons	0.0043290
	Litres	0.0163871
Litres	Cubic inches	61.0238
	Cubic feet	0.0353147
	Imperial gallons	0.219969
	U.S. gallons	0.264172
	U.S. barrels	0.00628981
Cubic metres	Imperial gallons	219.969
	U.S. gallons	264.172
	U.S. barrels	6.28981
	Cubic feet	35.3147

[a]This relationship is exact by definition.
[b]These factors are solely for conversion at the same temperature.

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Table C-2—Conversion of Temperatures

Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit	Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit	Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit
–45.6	–50	–58.0	–45.6	–50	–58.0	–45.6	–50	–58.0
–45.0	–49	–56.2	–45.0	–49	–56.2	–45.0	–49	–56.2
–44.4	–48	–54.4	–44.4	–48	–54.4	–44.4	–48	–54.4
–43.9	–47	–52.6	–43.9	–47	–52.6	–43.9	–47	–52.6
–43.3	–46	–50.8	–43.3	–46	–50.8	–43.3	–46	–50.8
–42.8	–45	–49.0	–42.8	–45	–49.0	–42.8	–45	–49.0
–42.2	–44	–47.2	–42.2	–44	–47.2	–42.2	–44	–47.2
–41.7	–43	–45.4	–41.7	–43	–45.4	–41.7	–43	–45.4
–41.1	–42	–43.6	–41.1	–42	–43.6	–41.1	–42	–43.6
–40.6	–41	–41.8	–40.6	–41	–41.8	–40.6	–41	–41.8
–40.0	–40	–40.0	–40.0	–40	–40.0	–40.0	–40	–40.0
–39.4	–39	–38.2	–39.4	–39	–38.2	–39.4	–39	–38.2
–38.9	–38	–36.4	–38.9	–38	–36.4	–38.9	–38	–36.4
–38.3	–37	–34.6	–38.3	–37	–34.6	–38.3	–37	–34.6
–37.8	–36	–32.8	–37.8	–36	–32.8	–37.8	–36	–32.8
–37.2	–35	–31.0	–37.2	–35	–31.0	–37.2	–35	–31.0
–36.7	–34	–29.2	–36.7	–34	–29.2	–36.7	–34	–29.2
–36.1	–33	–27.4	–36.1	–33	–27.4	–36.1	–33	–27.4
–35.6	–32	–25.6	–35.6	–32	–25.6	–35.6	–32	–25.6
–35.0	–31	–23.8	–35.0	–31	–23.8	–35.0	–31	–23.8
–34.4	–30	–22.0	–34.4	–30	–22.0	–34.4	–30	–22.0
–33.9	–29	–20.2	–33.9	–29	–20.2	–33.9	–29	–20.2
–33.3	–28	–18.4	–33.3	–28	–18.4	–33.3	–28	–18.4
–32.8	–27	–16.6	–32.8	–27	–16.6	–32.8	–27	–16.6
–32.2	–26	–14.8	–32.2	–26	–14.8	–32.2	–26	–14.8
–31.7	–25	–13.0	–31.7	–25	–13.0	–31.7	–25	–13.0
–31.1	–24	–11.2	–31.1	–24	–11.2	–31.1	–24	–11.2
–30.6	–23	–9.4	–30.6	–23	–9.4	–30.6	–23	–9.4
–30.0	–22	–7.6	–30.0	–22	–7.6	–30.0	–22	–7.6
–29.4	–21	–5.8	–29.4	–21	–5.8	–29.4	–21	–5.8
–28.9	–20	–4.0	–28.9	–20	–4.0	–28.9	–20	–4.0
–28.3	–19	–2.2	–28.3	–19	–2.2	–28.3	–19	–2.2
–27.8	–18	–0.4	–27.8	–18	–0.4	–27.8	–18	–0.4
–27.2	–17	1.4	–27.2	–17	1.4	–27.2	–17	1.4
–26.7	–16	3.2	–26.7	–16	3.2	–26.7	–16	3.2
–26.1	–15	5.0	–26.1	–15	5.0	–26.1	–15	5.0
–25.6	–14	6.8	–25.6	–14	6.8	–25.6	–14	6.8
–25.0	–13	8.6	–25.0	–13	8.6	–25.0	–13	8.6
–24.4	–12	10.4	–24.4	–12	10.4	–24.4	–12	10.4
–23.9	–11	12.2	–23.9	–11	12.2	–23.9	–11	12.2
–23.3	–10	14.0	–23.3	–10	14.0	–23.3	–10	14.0
–22.8	–9	15.8	–22.8	–9	15.8	–22.8	–9	15.8
–22.2	–8	17.6	–22.2	–8	17.6	–22.2	–8	17.6
–21.7	–7	19.4	–21.7	–7	19.4	–21.7	–7	19.4
–21.1	–6	21.2	–21.1	–6	21.2	–21.1	–6	21.2
–20.6	–5	23.0	–20.6	–5	23.0	–20.6	–5	23.0
–20.0	–4	24.8	–20.0	–4	24.8	–20.0	–4	24.8
–19.4	–3	26.6	–19.4	–3	26.6	–19.4	–3	26.6
–18.9	–2	28.4	–18.9	–2	28.4	–18.9	–2	28.4
–18.3	–1	30.2	–18.3	–1	30.2	–18.3	–1	30.2
–17.8	0	32.0	–17.8	0	32.0	–17.8	0	32.0

Note: This table provides conversion values for temperatures in degrees Fahrenheit and degrees Celsius for each whole degree from –50° to +250°. The temperature to be converted is found in the center "temperature to be converted" column. If the temperature to be converted is in degrees Fahrenheit, its equivalent in degrees Celsius is found in the "degrees Celsius" column to the left. If the temperature to be converted is in degrees Celsius, its equivalent in degrees Fahrenheit is found in the "degrees Fahrenheit" column to the right.

Table C-2—Continued

Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit	Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit	Degrees Celsius	Temperature to Be Converted	Degrees Fahrenheit
37.8	100	212.0	65.6	150	302.0	93.3	200	392.0
38.3	101	213.8	66.1	151	303.8	93.9	201	393.8
38.9	102	215.6	66.7	152	305.6	94.4	202	395.6
39.4	103	217.4	67.2	153	307.4	95.0	203	397.4
40.0	104	219.2	67.8	154	309.2	95.6	204	399.2
40.6	105	221.0	68.3	155	311.0	96.1	205	401.0
41.1	106	222.8	68.9	156	312.8	96.7	206	402.8
41.7	107	224.6	69.4	157	314.6	97.2	207	404.6
42.2	108	226.4	70.0	158	316.4	97.8	208	406.4
42.8	109	228.2	70.6	159	318.2	98.3	209	408.2
43.3	110	230.0	71.1	160	320.0	98.9	210	410.0
43.9	111	231.8	71.7	161	321.8	99.4	211	411.8
44.4	112	233.6	72.2	162	323.6	100.0	212	413.6
45.0	113	235.4	72.8	163	325.4	100.6	213	415.4
45.6	114	237.2	73.3	164	327.2	101.1	214	417.2
46.1	115	239.0	73.9	165	329.0	101.7	215	419.0
46.7	116	240.8	74.4	166	330.8	102.2	216	420.8
47.2	117	242.6	75.0	167	332.6	102.8	217	422.6
47.8	118	244.4	75.6	168	334.4	103.3	218	424.4
48.3	119	246.2	76.1	169	336.2	103.9	219	426.2
48.9	120	248.0	76.7	170	338.0	104.4	220	428.0
49.4	121	249.8	77.2	171	339.8	105.0	221	429.8
50.0	122	251.6	77.8	172	341.6	105.6	222	431.6
50.6	123	253.4	78.3	173	343.4	106.1	223	433.4
51.1	124	255.2	78.9	174	345.2	106.7	224	435.2
51.7	125	257.0	79.4	175	347.0	107.2	225	437.0
52.2	126	258.8	80.0	176	348.8	107.8	226	438.8
52.8	127	260.6	80.6	177	350.6	108.3	227	440.6
53.3	128	262.4	81.1	178	352.4	108.9	228	442.4
53.9	129	264.2	81.7	179	354.2	109.4	229	444.2
54.4	130	266.0	82.2	180	356.0	110.0	230	446.0
55.0	131	267.8	82.8	181	357.8	110.6	231	447.8
55.6	132	269.6	83.3	182	359.6	111.1	232	449.6
56.1	133	271.4	83.9	183	361.4	111.7	233	451.4
56.7	134	273.2	84.4	184	363.2	112.2	234	453.2
57.2	135	275.0	85.0	185	365.0	112.8	235	455.0
57.8	136	276.8	85.6	186	366.8	113.3	236	456.8
58.3	137	278.6	86.1	187	368.6	113.9	237	458.6
58.9	138	280.4	86.7	188	370.4	114.4	238	460.4
59.4	139	282.2	87.2	189	372.2	115.0	239	462.2
60.0	140	284.0	87.8	190	374.0	115.6	240	464.0
60.6	141	285.8	88.3	191	375.8	116.1	241	465.8
61.1	142	287.6	88.9	192	377.6	116.7	242	467.6
61.7	143	289.4	89.4	193	379.4	117.2	243	469.4
62.2	144	291.2	90.0	194	381.2	117.8	244	471.2
62.8	145	293.0	90.6	195	383.0	118.3	245	473.0
63.3	146	294.8	91.1	196	384.8	118.9	246	474.8
63.9	147	296.6	91.7	197	386.6	119.4	247	476.6
64.4	148	298.4	92.2	198	388.4	120.0	248	478.4
65.0	149	300.2	92.8	199	390.2	120.6	249	480.2
65.6	150	302.0	93.3	200	392.0	121.1	250	482.0

Note: This table provides conversion values for temperatures in degrees Fahrenheit and degrees Celsius for each whole degree from –50° to +250°. The temperature to be converted is found in the center "temperature to be converted" column. If the temperature to be converted is in degrees Fahrenheit, its equivalent in degrees Celsius is found in the "degrees Celsius" column to the left. If the temperature to be converted is in degrees Celsius, its equivalent in degrees Fahrenheit is found in the "degrees Fahrenheit" column to the right.

APPENDIX D—TYPICAL PROPERTIES OF CRUDE OILS

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Table D-1—Typical Properties of Crude Oils

CAUTION: This table should be used as an informational guide only. It was prepared from data contained in "Guide to Export Crudes," which was published by the *Oil & Gas Journal.* It is used with their permission.

Crude Oil	Country of Origin	Gravity (°API)	Sulfur (Weight)	Pour Point (°F)
Aboozar (Ardeshir)	Iran	26.9	2.48	–30.0
Abu Al Bo Khoosh	Abu Dhabi	31.6	2.00	–24.5
Abu Dhabi Marine (see Umm Shaif)	Abu Dhabi	37.4	1.51	–30°C
Alba	UK, North Sea	20.0	1.33	–30°C
ANS (see Alaska North Slope)				
Alaskan North Slope (Sadlerochit)	USA	26.4	1.06	0.0
Amna (high pour)	Libya	36.1	0.15	+75.0
Arabian Heavy (Safaniya)	Saudi Arabia	27.9	2.85	–20.0
Arabian Light	Saudi Arabia	33.4	1.79	–30.0
Arabian Light—Berri	Saudi Arabia	37.8	1.19	–25.0
Arabian Medium—Khursaniyah	Saudi Arabia	28.5	2.85	–10.0
Arabian Medium—Zuluf/Marjan	Saudi Arabia	31.1	2.48	–20.0
Ardeshir (see Aboozar)				
Ardjuna	Indonesia, Java	35.2	0.11	+75.0
Argyll	UK (North Sea)	38.0	0.18	+42.8
Arimbi	Indonesia	31.8	0.20	+100.0
Ashtart	Tunisia	29.0	1.00	+48.2
Attaka	Indonesia, East Kalimantan	42.3	0.09	–10.0
Auk	UK (North Sea)	37.2	0.45	+50.0
Bachaquero	Venezuela	16.8	2.40	–10.0
Bach Ho (White Tiger)	Viet Nam	38.6	0.03 – 0.05	33°C
Badak	Indonesia	41.3	0.08	–15.0
Bahrgansar/Nowruz (Sirip Blend)	Iran	27.1	2.45	–27.4
Barrow Island	Australia	36.8	0.05	–30.0
Basrah Heavy	Iraq	24.7	3.50	–22.0
Basrah Light	Iraq	33.7	1.95	+5.0
Basrah Medium	Iraq	31.1	2.58	–22.0
Bass Strait (see Gippsland)				
BCF 24	Venezuela	23.5	1.85	–60.0
Beatrice	UK (North Sea)	38.7	0.05	+55.0
Bekapai	Indonesia, East Kalimantan	40.0	0.08	–5.8
Bekok	Malaysia	49.1	210 ppm	+26.0
Belayim	Egypt	27.5	2.20	+42.8
Berri (see Arabian Light)				
Beryl	UK (North Sea)	36.5	0.42	—
Bintulu	Malaysia	26.5	0.13	+23.0
Bombay High	India	39.4	0.17	+86.0
Bonny Light	Nigeria	36.7	0.12	—
Bonny Medium	Nigeria	25.2	0.23	–16.6
Boscan	Venezuela	10.1	5.50	+50.0

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Table D-1—Typical Properties of Crude Oils (Continued)

Crude Oil	Country of Origin	Gravity (°API)	Sulfur (Weight)	Pour Point (°F)
Bow River Heavy	Canada	26.7	21.0 g/kg	–58.0
Brae	UK (North Sea)	33.6	0.73	+21.2
Brass River	Nigeria	40.9	0.09	+35.0
Brega	Libya	40.4	0.21	+30.0
Brent	UK (North Sea)	38.2	0.26	+26.6
Brent Blend	UK (North Sea)	38.0	0.38	+5.0
Bu Attifel	Libya	43.6	0.03	+90.0
Buchan	UK (North Sea)	33.7	0.84	+42.8
Bunyu	Indonesia, East Kalimantan	31.7	0.09	+60.0
Burgan (Wafra)	Divided Zone	23.3	3.37	–5.0
Cabinda	Angola (Cabinda)	31.7	0.17	+65.0
Cano Limon	Colombia	30.8	0.47	60.0
Ceuta	Venezuela	31.8	1.20	–35.0
Champion Export	Brunei	23.9	0.12	< –32.8
Cinta	Indonesia, Sumatra	33.4	0.08	+105.0
Cold Lake Blend	Alberta, Canada	22.6	3.60	–50.0
Cormorant–North	UK (North Sea)	34.9	0.71	+53.6
Cormorant–South (Cormorant A)	UK (North Sea)	35.7	0.56	+21.2
Cyrus (Soroosh)	Iran	18.1	3.30	–10.0
Dai Hung (Big Bear)	Viet Nam	36.9	0.08	27°C
Dan	Denmark (North Sea)	30.4	0.34	< –45.0
Daqing (see Taching)				
Djeno Blend	Congo (Brazzaville)	26.9	0.33	+37.4
Dorrood (Darius)	Iran	33.6	2.35	–4.5
Dubai (Fateh)	Dubai	31.1	2.00	+15.8
Dukhan (Qatar Land)	Qatar	41.7	1.28	20.0
Dulang	Malaysia Offshore	39.0	0.037	84.0
Dunlin	UK (North Sea)	34.9	0.39	+42.8
Duri (Sumatran Heavy)	Indonesia, Sumatra	21.1	0.20	+54.0
East Zeit Mix	Egypt Offshore	39.0	0.89	30.0
Ekofisk	Norway (North Sea)	43.4	0.14	+10.0
El Borma	Tunisia	36.7	0.37	7.2°C
Emerald	UK, North Sea	22.0	0.75	–20.0
Eocene (Wafra)	Divided Zone	18.6	4.55	–20.0
Escravos	Nigeria	36.2	0.14	+10.0
Espoir	Ivory Coast	31.4	0.32	+5.0
Es Sider	Libya	36.7	0.37	+45.0
Federated Light and Medium	Canada (Alberta)	39.8	2.01 g/kg	+14.0
Fereidoon (see Foroozan)				
Flotta	UK (North Sea)	35.7	1.14	+21.0
Forcados Blend	Nigeria	29.7	0.29	4.0
Foroozan (Fereidoon)	Iran	31.3	2.50	35.0

Table D-1—Typical Properties of Crude Oils (Continued)

Crude Oil	Country of Origin	Gravity (°API)	Sulfur (Weight)	Pour Point (°F)
Forties	UK (North Sea)	36.6	0.30	+26.6
Fulmar	UK (North Sea)	39.3	0.26	+9.6
Galeota Mix (Trinidad Blend)	Triniad & Tobago	32.8	0.27	–5.0
Gamba	Gabon	31.8	0.11	+73.4
Gippsland (Bass Strait)	Australia	45.4	0.10	15°C
Gorm	Denmark (North Sea)	33.9	0.23	35.0
Gulf Alberta Light and Medium	Canada	35.1	9.80 g/kg	17.5
Gulf of Suez Mix	Egypt	31.9	1.52	+35.0
Gullfaks	Norway (North Sea)	28.6	0.44	50.0
Handil	Indonesia, East Kalimantan	32.8	0.08	+85.0
Hondo Blend	California, US	20.8	4.29	–5.0
Hondo	Monterey, California, US	19.4	4.70	–10.0
Hondo Sandstone	California, US	35.2	0.21	25.0
Hout	Divided Zone	32.8	1.91	–13.0
Iranian Heavy	Iran	31.0	1.65	–5.0
Iranian Light	Iran	33.8	1.35	–20.0
Isthmus	Mexico	32.8	1.51	–15.0
Jabiru	Australia	42.3	0.04	—
Jackson Blend	Australia	41.9	0.03	—
Jatibarang	Indonesia, Java	29.0	0.07	+110.0
Khafji	Divided Zone	28.5	2.85	–31.0
Khursaniyah/Abu Safah (see Arabian Medium)				
Kirkuk Blend	Iraq	35.1	1.97	–7.6
Kittiwake	UK, North Sea	37.0	0.65	–11.0
Kole Marine Blend	Cameroon	34.9	0.30	+21.2
Ku Paruk	Alaska, US	23.0	1.76	–50.0
Kuwait Export	Kuwait	31.4	2.52	+5.0
Labuan Blend	Malaysia, Sabah	33.2	917 ppm	+52.0
Lagomedio	Venezuela	31.5	1.17	–15.0
La Rosa Medium	Venezuela	25.3	1.73	< –50.0
Leona	Venezuela	24.1	1.50	–45.0
Lloydminster, Alberta & Saskatchewan	Canada	20.7	31.5	–32.0°C
Loreto	Peru	34.0	0.29	+34.0
Lucina Marine	Gabon	39.5	0.05	+59.0
Magnus	UK (North Sea)	39.3	0.28	+26.6
Mandji	Gabon	30.5	1.10	+37.4
Maureen	UK (North Sea)	35.5	0.55	+45.0
Maya	Mexico	22.0	3.32	0.0
Merey	Venezuela	17.4	2.20	–10.0
Minas (Sumatran Light)	Indonesia, Sumatra	34.5	0.08	+97.0
Miri Light	Malaysia	36.3	825 ppm	+34.0

Table D-1—Typical Properties of Crude Oils (Continued)

Crude Oil	Country of Origin	Gravity (°API)	Sulfur (Weight)	Pour Point (°F)
Montrose	UK (North Sea)	40.1	0.23	+15.0
Mubarek	Sharja, UAE	37.0	0.62	+10.0
Murban	Abu Dhabi	40.4	0.78	–11.2
Murchison,	UK & Norway, North Sea	38.0	0.027	7.2°C
Northwest Shelf Cond.	Australia	53.1	102 ppm	–36.0°C
Ninian Blend	UK (North Sea)	35.6	0.43	+35.0
Olmeca	Mexico	39.8	0.80	–39.0°C
Oman Export	Oman	36.3	0.79	–15.0
Oriente	Ecuador	29.2	1.01	+25.0
Oseberg	Norway	33.71	0.31	–6.0°C
Pennington	Nigeria	36.6	0.07	+43.0
Pulai	Malaysia	42.5	160 ppm	+23.0
Qatar Condensate (see Dukhan)				
Qatar-Land (see Dukhan)				
Qatar Marine	Qatar	35.3	1.57	+10.0
Qua	Nigeria	35.8	0.12	+45.0
Rainbow Light and Medium	Canada (Alberta)	40.7	5.00 g/kg	+36.5
Rangeland South Light and Medium	Canada (Alberta)	39.5	7.52 g/kg	40.0
Rostam	Iran	35.9	1.55	8.5
Sadierochit (see Alaska North Slope)				
Safaniya (see Arabian Heavy)				
Saharan Blend	Algeria	43.7	0.09	< 20.0
Salawati	Indonesia	38.0	0.49	–15.0
Salmon (Sassan)	Iran	33.9	1.91	–5.0
Salt Pond	Ghana	37.4	0.10	—
Sanga Sanga	Indonesia	25.7	0.17	+5.0
Sarir	Libya	38.3	0.18	+25.0
Sassan (Salmon)	Iran	33.9	1.91	–5.0
SCO	Canada	31.4	1500 ppm	—
Sepinggan-Yakin—Mixed 4:1	Indonesia, East Kalimantan	31.7	0.11	+20.0
Seria Light	Brunei	36.2	0.07	+35.0
Shadah Condensate	Shadah, UAE	49.7	0.10	–25.0
Shengli	People's Republic of China	24.2	1.00	+70.0
SIRIP Blend (see Bahrgansar/Nowruz)				
Sirri	Iran	30.9	2.30	+15.8
Sirtica	Libya	43.3	0.43	+26.6
Soroosh (Cyrus)	Iran	18.1	3.30	10.0
Souedie	Syria	24.9	3.82	–22.0
Soviet Export Blend	USSR	32.5	1.38	–9.4
Soyo Blend	Angola	33.7	0.23	+64.4
Statfjord	Norway, UK (North Sea)	38.4	0.27	+40.0
Sumatran Heavy (see Duri)				

Table D-1—Typical Properties of Crude Oils (Continued)

Crude Oil	Country of Origin	Gravity (°API)	Sulfur (Weight)	Pour Point (°F)
Sumatran Light (see Minas)				
Taching (Daqing)	People's Republic of China	33.0	0.08	+95.0
Tapis	Malaysia	44.3	230 ppm	+39.0
Tartan	UK (North Sea)	41.7	0.56	+16.0
Tembungo	Malaysia, Sabah	37.4	0.04	+25.0
Thistle	UK (North Sea)	37.0	0.31	+53.6
Tia Juana Light	Venezuela	32.1	1.10	–45.0
Tia Juana Heavy	Venezuela	12.1	2.70	+30.0
Trinidad Blend (Galeota Mix)	Trinidad	32.8	0.27	–5.0
Udang	Indonesia	38.0	0.05	100.0
Umm Shaif (Abu Dhabi Marine)	Abu Dhabi	37.4	1.51	22.0
Wafra (see Burgan & Eocene)				
Wainwright–Kinsella	Alberta, Canada	23.1	15.80	–39.0
Walio	Indonesia	34.1	—	—
West Sak	Alaska, US	22.4	1.82	–50.0
Zaire	Zaire	31.7	0.13	+80.0
Zakum (Lower Zakum/ Abu Dhabi Marine)	Abu Dhabi	40.6	1.05	5.8
Zarzaitine (El Borma)	Algeria	43.0	0.07	+10.4
Zueitina	Libya	41.3	0.28	+45.0
Zuluf/Madan (see Arabian Medium)				

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