Manual of Petroleum Measurement Standards Chapter 17.10

Measurement of Cargoes On Board Marine Gas Carriers

Part 2—Liquefied Petroleum and Chemical Gases

El Hydrocarbon Management HM 55

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Special Notes and Disclaimers

Foreword

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Introduction

This standard provides guidance to vessel and shore personnel regarding accepted methods for determining quantities of Liquefied Petroleum and Chemical Gas cargoes on board refrigerated or pressurized gas carriers. It includes recommended methods for measuring, sampling, documenting, and reporting quantities on board these vessels.

Accounting for quantities on refrigerated or pressurized gas carriers requires some additional steps and care which may be contained in specific commercial agreements, operational guidelines or regulations. Other requirements should be discussed at the key meeting (pre-transfer conference), as detailed in API *MPMS* Chapter 17.1, or as noted in this section. All should be referred to and considered during the measurement process for these cargoes. General considerations and precautions that should be taken during the measurement of these cargoes are as follows.

Prior to Loading

Personnel performing measurement procedures should be made aware of the specific relevant safety and operational requirements for the refrigerated or pressurized gas carrier and its cargo. Specific conditions of carriage should be determined prior to loading including any relevant terminal regulations and restrictions enforced at the discharge port. It should also be determined if the cargo being loaded will be placed into tanks already containing cargo or whether the vessel’s tanks need to first be prepared, which may include gassing-up and cooling down operations. The amount of cargo on board prior to loading (on board quantity [OBQ]) shall be measured, documented, and reported.

If tank inspection is required, it shall be carried out according to the procedure as detailed in API *MPMS* Chapter 17.8 or other defined operating instructions and in accordance with all appropriate safety guidelines. If the tank is to be gassed up and cooled down, one should account for the amount of product used in the process. See Section 8 for further discussion of special operational considerations.

During Loading

While loading the liquid cargo, vapor in the tanks will be displaced. Either the vapor is reliquefied on board the vessel or sent ashore for reliquefaction, flaring, or other combustion. The amount of vapor returned to the shore should be accounted for and the method of doing so agreed to by all parties.

After Loading

Ensure the cargo is at equilibrium at conditions with lines drained and no movement into or out of the tanks.

During Transit

During the transit from the load port to the discharge port, any vaporization of the cargo is reliquefied, contained at higher pressure, or vented, depending on vessel configuration and regulations. Such operations should be duly noted in the vessel’s logs and made available to concerned parties at the discharge port.

Prior to Discharge

Ensure the cargo is at equilibrium at conditions with lines drained and no movement into or out of the tanks.

During Discharge

Any vapors supplied by the discharge port or returned to the cargo tanks to maintain proper pressure should be monitored and their source noted in the cargo inspection report.

After Discharge

Vessels in continuous service will often intentionally sail from the discharge port with cargo left on board after discharge (heel) in order to keep their cargo tanks cold, gassed up and in a “ready to load” state at the next load port. If the tanks are to be emptied of liquid cargo (no liquid remaining on board [ROB]) at the discharge port, the method of vaporization and the amount of vapor discharged and remaining on board should be reported.

If cargo is left on board after discharge (ROB), then the amount of vapor and liquid left in the tanks should be measured, calculated, documented and reported. The variance between the ROB and the OBQ should be reported, and an appropriate protest filed as needed and the concerned parties notified.

Measurement of Refrigerated or Pressurized Cargoes on Board Marine Gas Carriers

Liquefied Petroleum and Chemical Gases

1 Scope

This standard details the steps needed to properly measure and account for the quantities of liquefied petroleum and chemical gas cargoes described in *IGC* Chapter 19, excluding liquefied natural gas (LNG), on board refrigerated and/ or pressurized gas carriers. This standard covers all measurement systems commonly used on refrigerated and/or pressurized gas carriers designed to carry those types of cargoes.

2 Normative References

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

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

API *MPMS* Chapter 3.6, *Measurement of Liquid Hydrocarbons by Hybrid Tank Measurement Systems*

API *MPMS* Chapter 7, *Temperature Determination*

API *MPMS* Chapter 7.3, *Fixed Automatic Tank Temperature Systems*

API *MPMS* Chapter 16.2, *Mass Measurement of Liquid Hydrocarbons in Vertical Cylindrical Storage Tanks by Hydrostatic Tank Gauging*

API *MPMS* Chapter 17.1, *Guidelines for Marine Cargo Inspection*

API *MPMS* Chapter 17.2, *Measurement of Cargoes On Board Tank Vessels*

API *MPMS* Chapter 17.8, *Guidelines for Pre-Loading Inspection of Marine Vessel Cargo Tanks*

ASTM D2598[1], *Standard Practice for Calculation of Certain Physical Properties of Liquefied Petroleum (LP) Gases from Compositional Analysis*

IMO Gas Codes[2], including amendments thereto:

> *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code) (generally applies to ships built after 17 July 1986)
>
> *IMO Code for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (*GC Code*) (generally applies to ships built on or after 31 December 1976 but prior to 17 July 1986)
>
> *IMO Code for Existing Ships Carrying Liquefied Gases* (generally applies to ships delivered before 31 December 1976.

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1

[1] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, www.astm.org.
[2] International Maritime Organization, 4 Albert Embankment, London, SE1 7SR, United Kingdom, www.imo.org.

aerating
The introduction of fresh air with an acceptable dew point into the tank to purge inert gases and to increase the oxygen content to approximately 21 % of volume so as to ensure a breathable atmosphere.

3.1.2
approved equipment
Equipment that meets all applicable regulatory requirements as safe for use in a specified hazardous atmosphere.

3.1.3
automatic tank gauge
ATG
An instrument that automatically measures and displays liquid levels or ullages in one or more tanks either continuously, periodically, or on demand.

3.1.4
automatic tank thermometers
ATT
Instruments that continuously measure temperature at a specific location in a tank and typically including precision temperature sensors, tank mounted transmitters for electronic signal transmission, and receiving device(s).

3.1.5
chemical gas
A classification of gases derived from or allied to the petroleum industry as described in Ch. 19 of the *IGC Code* maintained in a liquid state by the reduction of temperature and/or application of pressure.

3.1.6
closed system
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.

3.1.7
cool-down
The process of reducing the temperature of equipment such as piping, transfer arms and tanks to required operating temperatures.

3.1.8
drying
The process of reducing the moisture in the ship tank, piping, and equipment by displacement or dilution with dry air, an inert gas, or by the use of a drying system.

3.1.9
filling limit
That quantity of a tank, expressed as a percentage of the total quantity, which can be safely filled, with consideration of the possible expansion (and change in density) of the liquid. *IGC Code* stipulates that the quantity is at cargo reference temperature.

3.1.10
gassing-up
The process of replacing the atmosphere in a tank to achieve a suitable vapor composition or to allow cooling down and subsequent loading of liquid cargo.

3.1.11
heel (marine gas carrier)
The amount of liquid and vapor (ROB or OBQ) that is intentionally left in the vessel's cargo tanks after discharge and before loading to keep the tanks cool and gassed-up.

3.1.12
inerting
A procedure used to reduce the oxygen content of a vessel's cargo spaces by introducing an inert gas

such as nitrogen or carbon dioxide or a mixture of gases such as processed flue gas. [API *MPMS* 17.1]

3.1.13
letter of protest
A letter issued by any participant in a custody transfer citing any condition with which issue is taken and which serves as a written record that a particular action or finding was observed or questioned at the time of occurrence.

3.1.14
liquefied petroleum gas
LPG
A narrow boiling range mixture of hydrocarbons, typically maintained in the liquid state, consisting of propane, propylene, butanes, and butylenes, individually or in specified combinations, with limited amounts of other hydrocarbons and naturally occurring non-hydrocarbons.

3.1.15
notice of apparent discrepancy
A notice issued by any participant in a custody transfer citing any discrepancy in cargo quantities and which serves as a written record that such a discrepancy was found.

3.1.16
on board quantity
OBQ
The material in a vessel's cargo tanks and piping before the cargo is loaded.

NOTE For gas carriers, OBQ includes both liquid and vapor.

3.1.17
restricted system
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.

3.1.18
remaining on board
ROB
The material remaining in a vessel's cargo tanks and piping after the cargo is discharged.

NOTE For gas carriers, ROB includes both liquid and vapor.

3.1.19
standard, measurement
A material measure, measuring instrument, reference material (RM) or measuring system intended to define, realize, conserve or reproduce a unit or one or more values of a quantity to serve as a reference. [ISO *VIM*]

3.1.20
standard, reference
A standard, having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived. [ISO *VIM*]

NOTE A reference standard is usually a primary standard or a secondary standard.

3.1.21
saturated vapor pressure (equilibrium vapor pressure)
The pressure exerted by the vapor above the liquid in equilibrium at a given temperature.

3.1.22
verification
The process of evaluating an instrument's accuracy at a single point by comparing its reading to a reference standard or to a device of known accuracy.

3.2 Acronyms and Abbreviations

ATG	automatic tank gauge
ATT	automatic tank thermometer
HTG	hydrostatic tank gauge
HTMS	hybrid tank measurement system
ICS	International Chamber of Shipping
IMO	International Maritime Organization
ISGOTT	*International Safety Guide for Oil Tankers and Terminals*
ISO	International Organization for Standardization
IUPAC	International Union of Physics and Applied Chemistry
LEL	lower explosive limit
LFL	lower flammable limit
LNG	liquefied natural gas
LPG	liquefied petroleum gas
OBQ	on board quantity
OCIMF	Oil Companies International Marine Forum
PEGD	portable electronic gauging device
PTFE	polytetrafluoroethylene
PVF	polyvinylfluoride
RM	reference material
ROB	remaining on board
SDS	safety data sheet, formerly MSDS
SI	international system of units (système international d'unités)
SIGTTO	Society of International Gas Tanker and Terminal Operators Limited
VCM	vinyl chloride monomer
VIM	*International Vocabulary of Basic and General Terms in Metrology*

4 General Operating Safety Precautions and Regulatory Requirements

4.1 General

This section applies to all types of measurement on board refrigerated and/or pressurized gas carriers described in Chapter 19 of the *IGC Code*, excluding LNG. However, while these precautions represent safe operating practices, they should not be considered complete or comprehensive. In addition to those listed herein reference should be made to all safety precautions contained in any relevant governmental, local, or company operating guidelines.

Any party involved in cargo handling operations shall read and act on information contained within the appropriate safety data sheet (SDS) and supporting documents.

Nothing contained in this publication is intended to supersede any national or local regulatory requirements or recommended operating practices issued by the vessel's flag administration, classification societies, organizations such as the IMO, SIGTTO, OCIMF, or individual operating companies. Furthermore, this publication is not intended to conflict with any safety or environmental considerations, local conditions, or the specific provisions of any contract.

Accordingly, the latest editions of relevant IMO, SIGTTO, API, and OCIMF publications, as well as the latest editions of the ICS *Tanker Safety Guide—Liquefied Gas* and the *International Safety Guide for Oil Tankers and Terminals (ISGOTT)* and SIGTTO—*Liquefied Gas Fire Hazard Management*, should be consulted for applicable safety precautions.

Anyone working with the vessel's measurement equipment shall be at all times under the direction and supervision of the Master of the vessel or their designated representative. Any changes to measurement systems and changes that affect the structural integrity of the gas carrier shall require the approval of the vessel’s flag administration and/or Classification Society and shall require verification of accuracy by a competent metrological authority.

All described equipment shall meet minimum requirements as detailed by the vessel's flag administration, classification society or some port states.

4.2 Electrical and Operating Safety

Only approved equipment that meets all applicable regulatory requirements as intrinsically safe or otherwise approved for its intended use, including appropriate grounding, shall be used for measurement. Also, all measurement equipment shall be designed and installed to meet applicable national and international marine safety codes.

NOTE Users of this standard shall follow the requirements of the local jurisdiction.

4.3 Maintenance

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

4.4 Service Conditions

All measurement equipment shall be capable of withstanding the pressure, temperature, environmental and other operating conditions likely to be encountered in the vessel’s service.

4.5 Compatibility

All measurement equipment shall be constructed with the appropriate materials suitable for use with the specific LPG or chemical gas cargo being measured and in accordance with the IMO Gas Codes and other applicable regulations.

4.6 Personnel Protection

All personnel involved in cargo activities should wear the appropriate personal protective equipment (PPE) for the operation required and be trained in its proper use. All personnel involved in cargo activities should be informed and/ or aware of the inherent hazards of the cargo as required by the ICS *Safety Guide* and the SDS.

4.7 Letter of Protest

If any problems occur that could affect subsequent procedures at any stage of the transfer, all key persons involved should be notified promptly so that corrective action can be taken. Any action or refusal to act contrary to this procedure or specific prior contract agreements shall be reported to the persons concerned and may be documented by the issuance of a Letter of Protest.

5 Measurement Systems and Equipment

5.1 General

To determine the quantities of cargoes on board refrigerated and/or pressurized gas carriers, the amount of liquid and vapor in each tank shall be accurately determined. The equipment required to accomplish this includes a calibrated tank as well as devices to measure liquid level, pressure and temperature. In addition, trim and list shall be determined either manually or by instrumentation. The tank gauging systems used shall be closed or restricted as defined in Ch. 19 of the *IGC Code*. The most commonly used equipment is described herein. Certified systems other than these may be used for custody transfer measurement if the accuracy of each can be ascertained and if the parties involved agree to their use.

Equipment verification tolerances and display resolutions are listed in Table 1.

Table 1—Equipment Performance Criteria, LPG and Chemical Gas

Criteria	Verification Tolerance	Display Resolution
Level	±10 mm (0.4 in.)	1 mm (0.05 in.)
Pressure	±0.3 kPa (0.04 psi)	0.1 kPa (0.01 psi)
Temperature	±0.5 °C (1 °F)	0.1 °C (0.1 °F)
Draft Reading	±50 mm (2 in.)	10 mm (3/8 in.)
List (Clinometer)	±0.05 °	0.01 °
NOTE These specifications may not apply to barges and small vessels. See Annex A.		

5.2 Calibration Considerations

5.2.1 Calibration and Certification—Prior to Initial Use and Afterward

The measurement equipment used in custody transfer shall be calibrated by the manufacturer at the factory, or a test facility prior to delivery to the shipyard, dry dock, or the carrier. The equipment and system should be verified, and recalibrated as applicable there, to ensure the expected accuracy is maintained after installation.

Calibration shall cover the local and remote readout, and data transmission to ensure the equipment, which may be components of the measurement sub-system(s), delivers the specified accuracy. Calibration (and recalibration) shall be performed by a qualified technician and witnessed by an independent inspector. Upon successful calibration, the results shall be certified by the party witnessing the calibration and a certificate of calibration issued. Refer to the respective standards for the method and procedure. Subsequently, the measurement equipment and systems shall be recalibrated and recertified on a periodic basis, subject to contractual and/or metrological requirements.

The computer system, if used to directly communicate with measurement devices (sensors), shall be certified prior to initial use. It shall be recertified when modification or repairs are performed that affect the accuracy of the measurement data, including tank capacity tables used in the calculation of the cargo quantity or for custody transfer.

Calculation of quantity by a stand-alone computer shall be verified to comply with the agreed method and the procedure in the standards. Any discrepancy shall be noted and a letter of protest filed.

5.2.2 Frequency of Recalibration and Recertification

The frequency of periodic accuracy verification of the measurement equipment is sometimes agreed among the parties to the sales and purchase contract of liquefied gases and may be subject to national or local regulations and applicable API or International Organization for Standardization (ISO) standards. Periodic verification is typically scheduled to coincide with classification society inspections. The frequency should also take into consideration recommendations by the equipment manufacturer.

Recalibration and recertification is normally carried out while the ship is at the shipyard for dry docking, although in some uncommon cases, a measurement device could be recalibrated in the interim by a qualified third party (i.e. manufacturer or an independent calibration agency) after degassing a cargo tank.

The installation of a new ATG or automatic tank gauging system may also require adjustments to the tank capacity table, or the determination of a correction factor to account for a different gauge reference height and/or horizontal position of the ATG. Pressure transmitters can be calibrated if verification indicates that they are operating outside of tolerance, however, temperature sensors cannot normally be adjusted.

5.3 Verification of Measurement Equipment Between Dry Dockings

In addition to calibration during each dry docking, all measurement equipment used in custody transfer should be checked before use at each loading or discharge to ensure it is in good working condition.

The comparison of the primary and secondary measurement equipment within a tank should be performed as one means of assessing proper operation. The results of this comparison should be recorded and tracked by the vessel operator.

Other equipment may be verified while the ship is in service. For example, pressure sensor/transmitters may be verified against a reference standard device. Trim/list gauges, such as inclinometers, or draft gauges (if used for level corrections) may be verified/calibrated at even keel by comparison to manual draft measurements or other equivalent procedure.

Where equipment is suspect or has failed, secondary measurement equipment should be used in their place until such time as the equipment is repaired or verified to be in good working order. Measurement equipment that has been shown to be faulty when verified during normal operation shall be replaced prior to the next custody transfer if practical, or at the next dry docking.

Where the measurement equipment can be verified against a known value, the results of this verification should be recorded and tracked. If the primary measurement system is found to be out of calibration, use of the secondary measurement system should be considered in accordance with contractual agreement.

5.4 Independent Inspector Checks of Measurement Equipment During Transfer Operations

Prior to and during a custody transfer, an independent cargo inspector appointed by the involved parties should inspect the measurement equipment to ensure that they are fully functional and should identify any deficiencies. The independent cargo inspector shall also review the ship's records to determine whether the calibration certificates are valid and current.

Exceptions and malfunction of measurement equipment, if any, prior to and during a custody transfer should be immediately reported to the vessel operator and the involved parties promptly notified.

Upon specific request, on board testing, checks, or verification may be carried out on measurement devices in question, and the results should be documented.

5.5 Static Measurement Systems and Equipment

5.5.1 General

Static measurement systems and equipment are those individual systems and equipment that are used to measure cargo in the tank. They include the following in whole or in part.

5.5.2 Tank Capacity Tables

Accuracy in determining cargo tank quantities is directly related to the accuracy of the vessel’s capacity tables. Therefore, the vessel’s cargo tanks should be certified and calibrated in accordance with API, ISO, or other method defined by an industry standards body. Tank capacity tables shall be certified for accuracy and completeness by a recognized metrological entity. Though tank calibration on gas carriers may not change during the life of the vessel due to their robust construction, some administrations may require recalibration or calibration verification at set intervals. The calibration method used by the builder or other qualified body shall be clearly indicated within the tank capacity tables or included in the associated documentation. A set of tank capacity tables and related correction factors shall be available in the English language.

Each measurement system used to determine cargo tank quantities shall have a set of printed tank capacity tables that can be used to verify the quantities resulting from the on-board cargo calculation system. The tank capacity table level increments in the relevant loading range should be 3 mm or better, $^{1}/_{8}$ in. or 0.01 ft, but shall not exceed 10 mm, ¼ in. or 0.02 ft depending on the units of scale used. Each set of tables shall include corrections for trim, list, thermal effects, and any measurement equipment adjustments as may be necessary to accurately determine the volumes in the tank for the tank conditions at the time of measurement. In addition, each tank capacity table shall indicate the tank gauge reference height for float gauges, if in use, and the 100 % Tank Capacity. Tank capacity tables shall clearly identify the location of the reference level gauge and its backup level gauge, and whether any corrections are included for the height of portable closed or restricted system electronic gauging devices (PEGD) if vessels are so equipped.

Such tables shall be made available to personnel performing cargo measurements. If such tables are not made available or cannot be verified, a Letter of Protest noting the situation shall be documented and reported at the time of measurement.

When determining the suitability of the tank capacity tables, refer to the checklist in Annex D.

5.5.3 Liquid Level Measurement Equipment

5.5.3.1 General

Two independent means of determining liquid level should be available for each cargo tank. The primary and secondary level measurement systems shall be independent such that the failure of one will not affect the performance of the other. Each level measurement system on board the vessel should have its own certified capacity table. Where a single certified capacity table is provided for both measurement systems, separate correction tables should be included for each level gauging system (e.g. trim and list corrections). In addition, any adjustment necessary to address the relative position of the secondary gauge point should be identified. The systems shall include security to prevent unauthorized changes and provide an audit trail to record all changes. The actual types of systems installed shall be as per the applicable IMO Gas Code and suitable for the cargoes being carried.

NOTE Barges typically have only one method of determining liquid level in each cargo tank.

The parties involved, as deemed by contract or mutual agreement, shall select the primary level measurement system to be used to determine the quantity on board the vessel, provided the system is functioning properly and for which a certified capacity table exists. If certified tank capacity tables are not available a Letter of Protest should be filed and the method of quantity determination mutually agreed.

5.5.3.2 Automatic Tank Gauging Systems

5.5.3.2.1 General

The automatic tank gauging system shall meet the accuracy, installation, calibration, and verification requirements of applicable API, ISO, and relevant industry standards. The ATG shall also meet the requirements of the vessel's flag administration and classification societies. Examples of automatic level measurement technologies include, but are not limited to:

- radar (microwave) gauges,
- float gauges,
- hydrostatic tank gauges,
- hybrid tank measurement systems (HTMS),
- magnetic gauges.

5.5.3.2.2 Radar (Microwave) Gauges

A transmitter is mounted on the top of the cargo tank and emits radar waves vertically down towards the surface of the liquid. See Figure 1. The signal is reflected from the surface, received by the transmitter's antenna, and sent back to the control panel. The signal is then processed to determine the distance of the liquid surface from the transmitter and hence ullage. The installation of the radar level gauge transmitter on the tank dome is an important consideration. The position of the gauge mounting with respect to the tank's datum point may be subject to the effects of tank shell contraction/expansion due to temperature changes in the tank. Correction for tank shell contraction or expansion should be applied where necessary. Compensation for the effects of temperature, pressure, trim, list, and composition shall be made as appropriate to the equipment-specific method used to account for changes in the propagation velocity. See Section 7 for specific measurement procedures.

Since the radar level gauge transmitter is mounted external to the cargo tank, the microwave system allows for its maintenance while the cargo tank is in service. However, the antenna is mounted inside the tank and may require periodic maintenance or cleaning.

5.5.3.2.3 Float Gauges

Float operated level gauges consist of a float attached by a tape or wire to an indicating device that can provide local and/or remote readout. See Figure 2. The float may operate within a guide tube or a standpipe or be fitted with guide wires. Float gauges may have isolation valves fitted such that the float can be maintained, in a safe atmosphere, while the vessel is in service. The float shall be lifted from the liquid level when not in use; if left down, liquid sloshing, while at sea, may damage the tape-tensioning device.

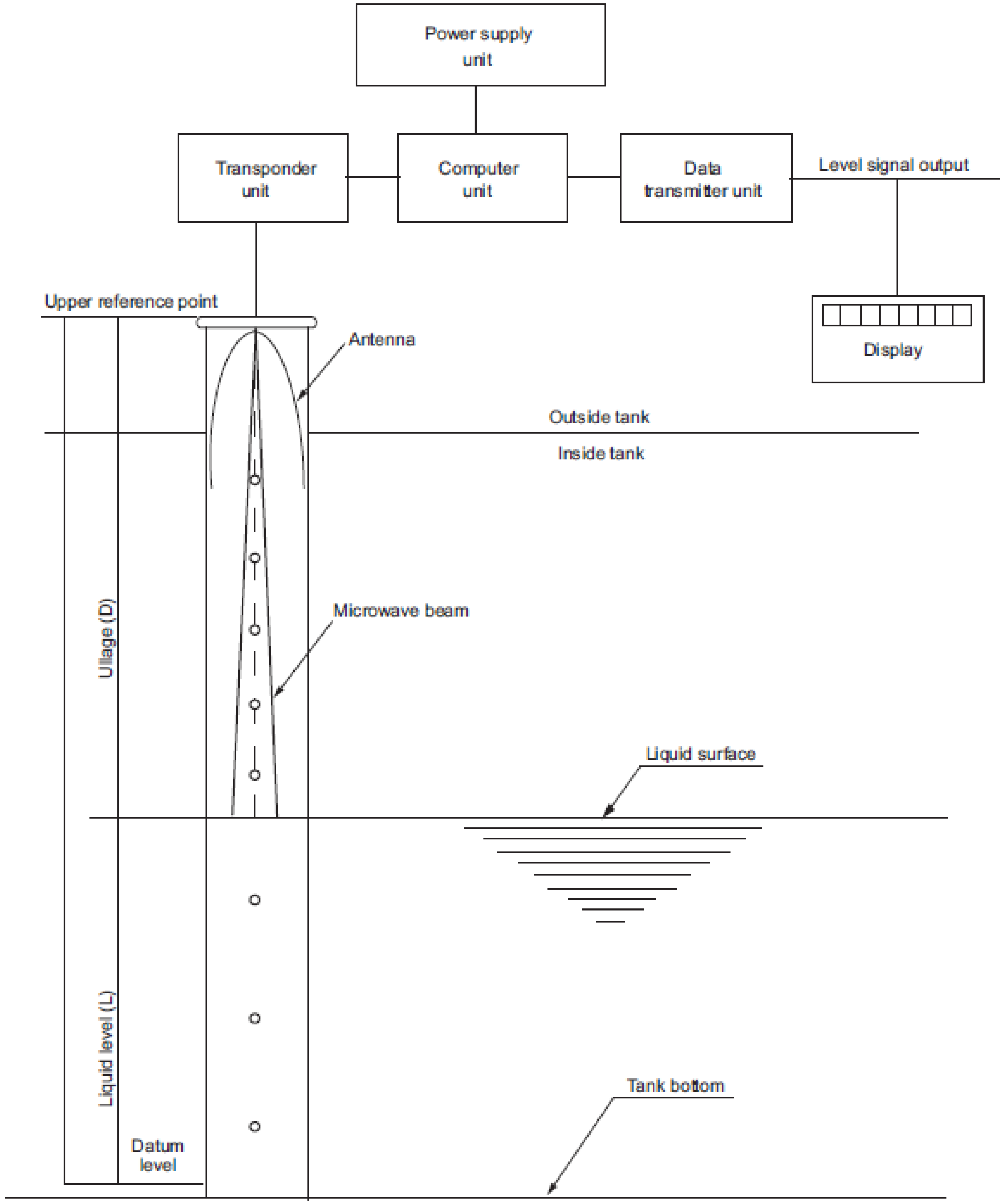

Figure 1—Microwave Type Level Gauge

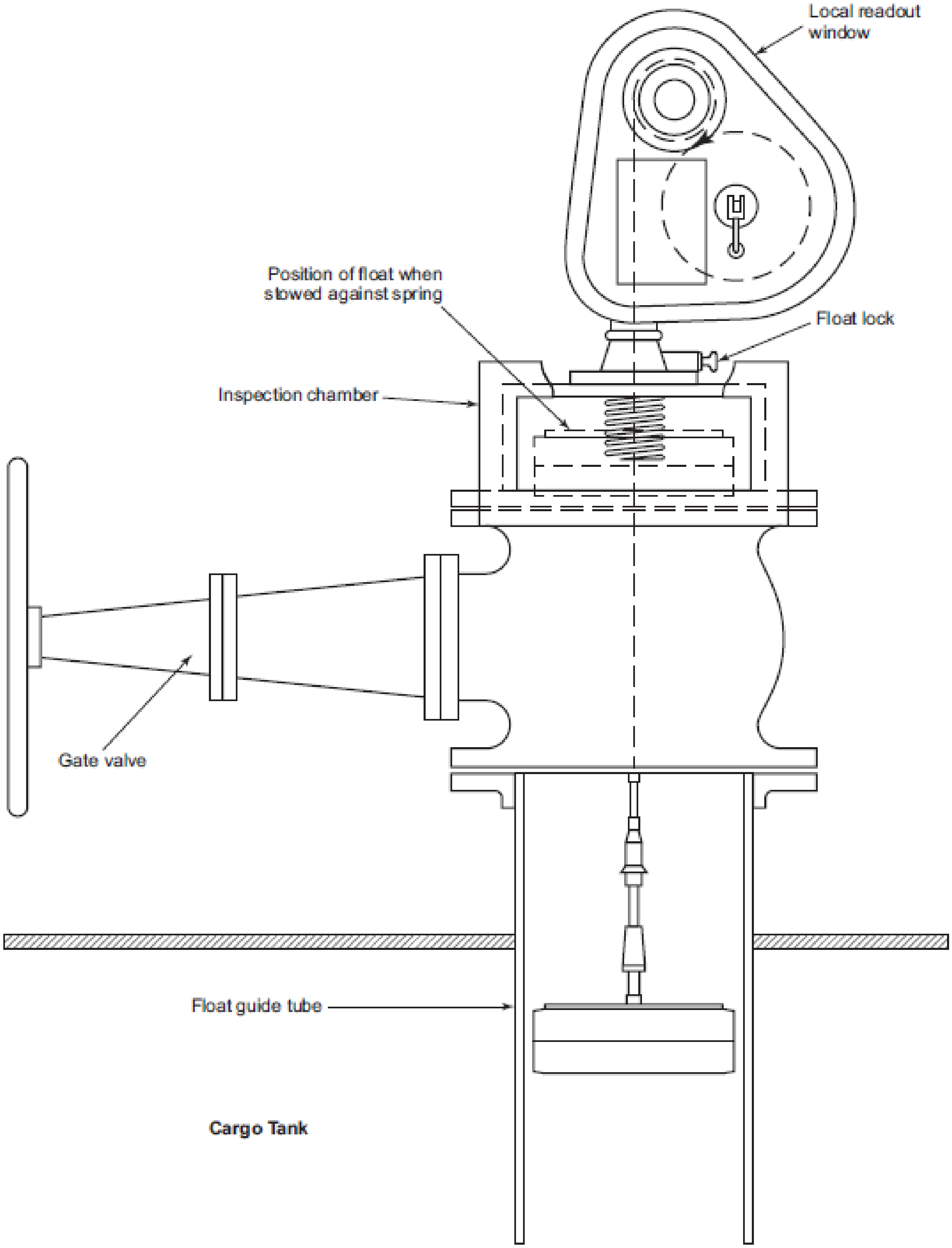

Figure 2—Float Gauge

With float gauges, it may be necessary to compensate for the change in the length of the wire and the change in the float buoyancy. The shrinkage of the tape or wire is affected by the temperature of the gaseous phase and the height of the liquid. It also may be necessary to consider the change in float buoyancy due cargo density at temperature. Compensation for the effects of temperature, trim, list, and density shall be applied to the observed readings. See Section 7 for specific measurement procedures.

5.5.3.2.4 Hydrostatic Tank Gauges (HTG)

Hydrostatic tank gauging is a method for the determination of total mass in the ship's tanks rather than the liquid level. The pressure is measured at several levels in the tank and the mass is calculated based on the pressures and tank capacity/calibration tables, which are typically programmed in the cargo calculation system. Since determination of cargo volume is often required, temperature sensors are installed as part of the system. If density is provided at reference temperature, the standard volume can be calculated without the cargo temperature. Other results, such as level, observed and standard volumes, and observed and reference density, can then be calculated based on the product type and temperature using the established industry standards for inventory calculations. Refer to API *MPMS* Ch. 3.5 and API *MPMS* Ch. 3.6.

A second hydrostatic tank gauging method is the bubbler system. The bubbler system, which may be found on some smaller vessels, uses a dip tube installed with the open end near to the bottom of the tank. A constant flow of gas, usually vaporized cargo, nitrogen or other inert gas, passes through the tube and the resultant gas pressure in the tube as compared with the pressure in the vapor space of a pressurized tank corresponds to the hydraulic head of the liquid in the vessel. The pressure in the bubbler tube varies proportionally with the change in the cargo tank liquid level. The use of bubbler systems may not provide sufficient accuracy for volume determination of LPG and chemical gas cargoes.

5.5.3.2.5 Hybrid Tank Gauges

A hybrid tank measurement system (HTMS) utilizes a method of combining direct product level measured by an automatic tank gauge (ATG), temperature measured by an automatic tank thermometer (ATT), and pressures from one or more pressure sensors. These measurements are used, together with the tank capacity table and applicable volume and density correction tables, to provide level, temperature, mass, observed and standard volume, and observed and reference density. The observed density is determined from hydrostatic pressure measured by the pressure sensor(s) and the product height above the bottom pressure sensor, as measured by the ATG. Total mass is computed from the density and the tank capacity table. Guidance for installation of the ATG, ATT and pressure sensors may be found in API *MPMS* Ch. 3.5 and API *MPMS* Ch. 7.3.

5.5.3.2.6 Magnetic Gauges

A magnetic level gauge includes a floating sensor and a guide pipe. The sensor, which contains magnet(s), rests on the liquid surface, and it travels vertically up and down along the guide. Magnetic level gauges may be of Reed-switch type, or magnetostrictive type. For Reed-switch type magnetic level gauges, an array of switches are embedded in the guide pipe, actuated by the magnetic field when the magnetic float/displacer nears. For magnetostrictive type gauges, the sensors consist of a flexible pipe and electronics head. The guide pipe acts as a protective sheath for the magnetostrictive materials that run the length of the pipe.

Some designs include temperature sensors in the guide pipe, which may also attach pressure sensors to provide a hybrid gauging system, or hybrid tank measurement system as described herein.

5.5.3.3 Manual Tank Gauges

Manual tank gauging equipment, i.e. rod-type gauges, slip-tube gauges, and tape-type magnetic gauges, are installed mostly on small cargo carriers and barges. See Annex A for details.

5.5.4 Temperature Measurement Equipment

Multiple point ATTs as defined in API *MPMS* Ch. 7.3, "Fixed Automatic Tank Temperature Systems," "Temperature Determination," should be used for temperature measurement. API *MPMS* Ch. 7 may provide guidance for calibration and field verification. The equipment shall meet the low temperature requirements for refrigerated applications and other requirements of the vessel's flag administration and classification societies. Typical uncertainties for temperature measurement devices on refrigerated and/or pressurized gas carriers are 0.5 °C.

There shall be a sufficient number of temperature sensors (e.g. resistance temperature detectors or thermistors) in each tank to obtain upper, middle and lower temperatures of the liquid phase when the tank is full. API *MPMS* Ch. 7.3 provides guidance on the number of elements and elevation of multiple point ATTs. The location of the sensors should consider the geometry of the cargo tanks so that the average cargo temperature is volume weighted. Where this is not possible, the mathematical average temperature may be used. The ATT system shall provide individual and average temperature for both liquid and vapor space. Small refrigerated and/or pressurized gas carriers such as barges are often equipped with fewer temperature sensors than specified in this paragraph.

In addition, at least one temperature sensor shall be located above the maximum fill height to remain in the vapor space. All temperature sensors in the vapor space should be used (in both opening gauge and closing gauge) to determine the average vapor temperature for calculating the liquid equivalent of the vapor quantity.

5.5.5 Pressure Measurement Equipment

A pressure sensor is required to measure the vapor space pressure. If the cargo tank is equipped with a HTG, or a HTMS, additional pressure sensors shall be required.

If the density of liquid is determined by the in-tank method by means of pressure sensors, one or more pressure sensor(s), which may be part of the HTMS or HTG system, are required with the lowest sensor located near the tank bottom.

The pressure sensor shall be calibrated or verified to meet the requirements set forth in API *MPMS* Ch. 3.6 or Ch. 16.2. The pressure sensors used for in-tank density measurement should be installed in accordance with the manufacturer's recommendations.

5.5.6 Density Determination

5.5.6.1 General

Density of the liquid and vapor cargo may be determined by:

— direct measurement (density meter, pressure hydrometer, in-tank measurement system);

— calculation from compositional analysis through the method described in ASTM D2598 or ASTM D2421 or other method or calculated from an equation of state or other algorithm such as the COSTALD (Corresponding STAtes Liquid Density), equation or the Francis formula; or

— published density table(s) as applicable for some chemical gases.

5.5.6.2 Direct Density Measurement

Density can be determined using laboratory devices and industry standard test methods such as those provided by ISO or ASTM International. Methods may include a pressure hydrometer or portable electronic density meter.

The overall density of the liquid in the tank may be determined in-situ by a HTMS, which typically consists of an automatic level gauge, one or more precision pressure sensors, and temperature sensors. Similar to the principle of a shore-based HTMS (see API *MPMS* Ch. 3.6), liquid level, static pressure (liquid and vapor), and temperature measured by the sensors can be used to calculate the liquid density in the tank. HTGs can also be used to determine the density of liquid in a cargo tank, between the two pressure sensors.

5.5.6.3 Density by Calculation from a Compositional Analysis

The density of the cargo (the density of both liquid and vapor) can be calculated from the composition of a sample using an equation of state. The densities of individual components of a cargo may be given in various publications for physical properties such as GPA 2145 or tables issued by the IUPAC.

5.5.6.4 Density from Tables

The density of the cargo at reference temperature may be determined from measured parameters such as temperature and observed density (at tank conditions) using tables or correlations developed by industry standards-writing organizations (such as API *MPMS* Ch. 11.1) or by other sources if mutually agreed.

5.5.7 Sampling

5.5.7.1 General

All sampling equipment shall be compatible with the cargo being sampled and other requirements of the vessel's flag administration, classification societies, and SDS. Sampling equipment can be divided into three usage categories; liquid, vapor and special sampling devices for non-compositional tests (e.g. copper strip corrosion sample devices), the testing of trace constituents using specific instruments, and physical property testing devices (e.g. vapor pressure cylinders, pycnometer, and pressure hydrometer).

5.5.7.2 Liquid Sample Containers

5.5.7.2.1 General

Liquid sample containers, and their valves, connections, and appurtenances, are typically constructed of non- magnetic 300-series stainless steel. Some cylinders may be internally coated with polytetrafluoroethylene (PTFE) or other material, as appropriate for the contents, to avoid corrosion or changes to the composition of the sample. Liquid sample containers include the pressure-balanced (floating) piston cylinder and the single cavity (two-valve) cylinder. Sample cylinder construction is dependent on the internal pressure and temperature of the product to be sampled. Select a cylinder with the appropriate pressure and temperature rating for the sampling service in which it will be used. The type of sample container used and its materials of construction as well as hoses and fittings can affect the validity of the sample as well as the accuracy of the analysis. Sample equipment, whether provided by the independent inspector or terminal operator, shall meet appropriate standards for construction, cleanliness, and suitability for use.

5.5.7.2.2 Pressure-balanced Piston Cylinders

A pressure-balanced (floating) piston cylinder can be used to sample pure and multi-component liquids and, when properly operated, maintains the sample as a single-phase liquid. See Figure 3. This device uses a piston inside of the sample cylinder to separate the sampled material from the backpressure gas (typically an inert gas such as helium). It is particularly difficult to sample refrigerated liquids that are near or below atmospheric pressure, unless the piston cylinder is safely cooled to the same temperature. Pressure-balanced piston cylinders are constructed from a honed metal tube equipped with end caps, valves, piston, a relief device to protect against over-pressure and a method of displaying the piston position. One side of the piston contains the sampled fluid and the other side contains an inert gas not present in the sampled material. The inert gas is vented slowly to allow the sample to enter the cylinder while maintaining a constant pressure on the sample. In addition to being referred to as pressure-balanced piston cylinders, these sample cylinders are also called floating piston cylinders or constant pressure cylinders. The sample is usually restricted to no more than 80 % of the cylinder volume. If the sample cylinder pressure exceeds the relief device setting and part of the sample cylinder contents are vented, the composition of the remaining sample is likely different from the original contents and should be discarded. Another sample should be drawn and procedures revised to avoid the circumstances that led to the over-pressure condition.

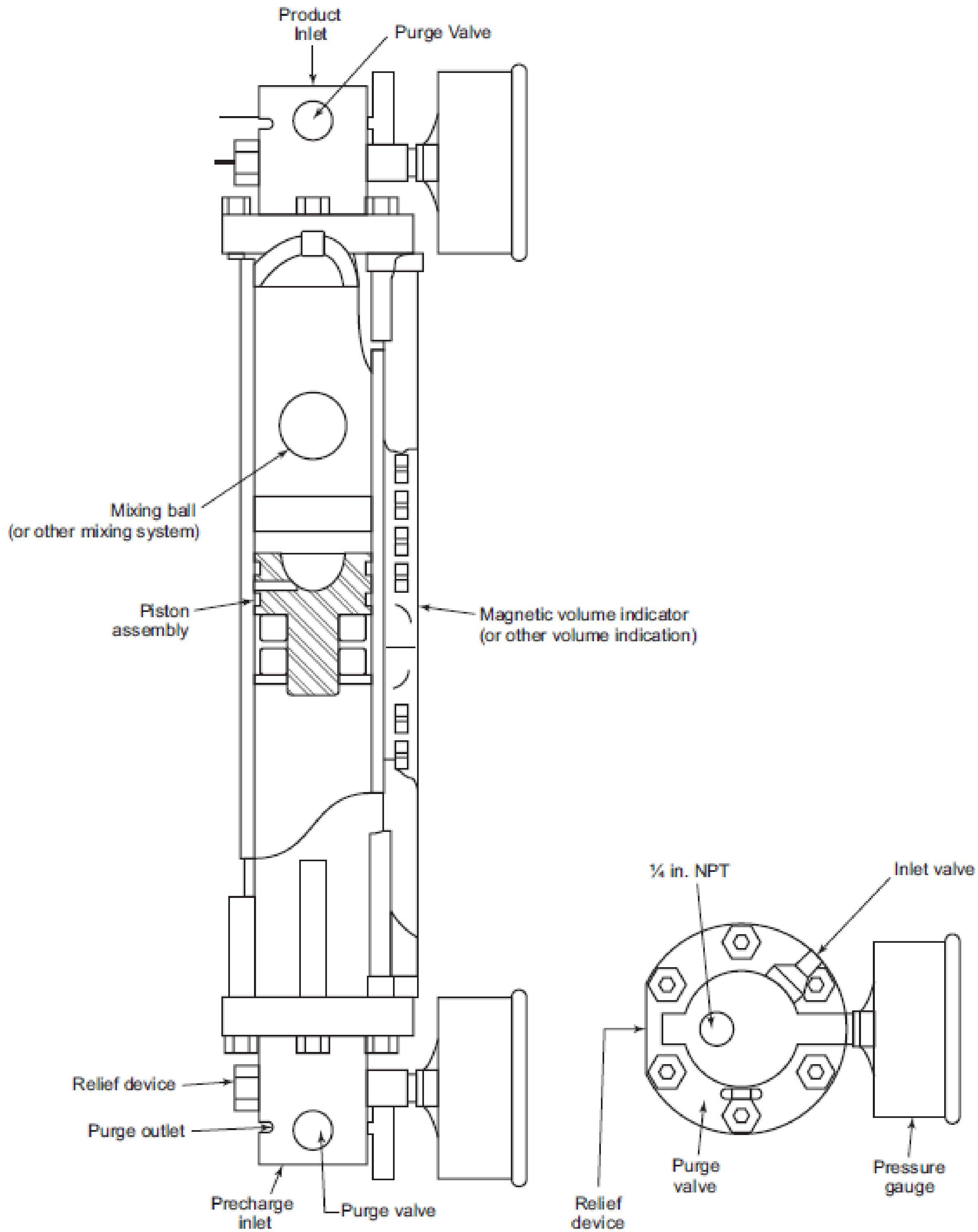

Figure 3—Typical Pressure-balanced Piston Cylinder

For details, refer to ASTM D3700 and GPA 2174.

5.5.7.2.3 Single Cavity Cylinder

Single cavity sample cylinders are appropriate for sampling liquids that are predominantly one component. See Figure 4. Where small concentrations of contaminants need to be quantified or where concentrations of volatile compounds other than the predominant component shall be quantified, a pressure-balanced piston cylinder is a better choice.

Single cavity sample cylinders are also known as constant volume cylinders or spun cylinders. They are usually equipped with two valves, one on each end, although some are built with only one valve. The two-valve cylinder is preferred to allow for thorough cleaning and purging. Liquid single cavity cylinders shall be equipped with a pressure relief device to protect the cylinder from failing due to over-pressure. Some single cavity cylinders in vapor service are equipped with a pressure relief device to protect the cylinder from failing due to over-pressure. If the sample cylinder pressure exceeds the relief device setting and part of the sample cylinder contents are vented, the composition of the remaining sample is likely different from the original contents and should be discarded. Another sample should be drawn, and procedures revised to avoid the circumstances that led to the over-pressure condition.

A single cavity sample cylinder may or may not have an ullage tube fitted into the cylinder. See Figure 5. An ullage tube allows for a quantity of the sample, typically 20 % of the liquid, to be excluded from the cylinder to provide vapor space in the cylinder for liquid expansion. When these cylinders are filled properly, oriented vertically, the liquid will reach the ullage tube and flow out the venting valve. This provides the 20 % vapor space required. If a single cavity sample cylinder is used to sample liquids, ullage shall be taken to avoid cylinder over-pressure. Cylinders without ullage tubes should be restricted to vapor use only.

For further details, refer to ASTM D1265, GPA 2174 and ISO 4257.

5.5.7.3 Vapor Sample Containers

5.5.7.3.1 General

Samples may be taken in vapor balloons, vapor bags, single cavity, or pressure-balanced piston sample cylinders. The type of sample container used and its materials of construction as well as hoses and fittings can affect the validity of the sample as well as the accuracy of the analysis. Sample equipment, whether provided by the independent inspector or terminal operator, shall meet appropriate standards for construction, cleanliness, and suitability for use. Additional information and guidance may be provided in GPA 2166, API *MPMS* Ch. 14.1 and ISO 10715.

5.5.7.3.2 Vapor Balloon

A vapor balloon sample container is constructed of an elastic material and typically contains an inlet and an outlet connection that allows for purging. See Figure 6. When the sample source has sufficient pressure, a minimum of about 140 kPa gauge (20 psig), vapor can be drawn without the use of a pumping device. When a pumping device needs to be used to transfer the sample to the vapor balloon, the user should be aware of the difficulty of keeping air out of the sample and the need to consider the effect air contamination would have on the results of the subsequent tests. The sample should be analyzed within 24 to 48 hours due to the permeability of the vapor balloon.

5.5.7.3.3 Vapor Bag

Vapor samples may also be drawn in a sample bag typically constructed of a non-elastic material such as PTFE or polyvinylfluoride (PVF) that is fitted with a single connection and may also contain a fitting for a syringe port with a PTFE lined septum for extracting the vapor contents for analysis. See Figure 7. Bag sizes may range from 0.5 L to 100 L. Vapor bags can be used when the sample source pressure is lower than required for vapor balloons, but generally not less than approximately 15 kPa gauge (2 psig) without the use of a sample pump. When a pumping device is used to transfer the sample to the vapor bag, the user should be aware of the difficulty with keeping air out of the sample and needs to consider the effect air contamination would have on the results of the subsequent tests. The sample should be analyzed within 24 hours to 48 hours due to the permeability of the vapor bag.

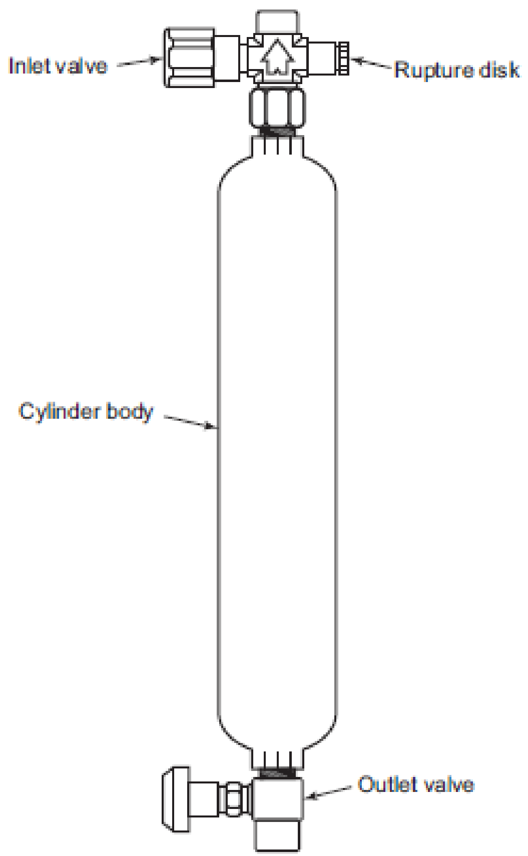

Figure 4—Typical Single Cavity Sample Cylinder

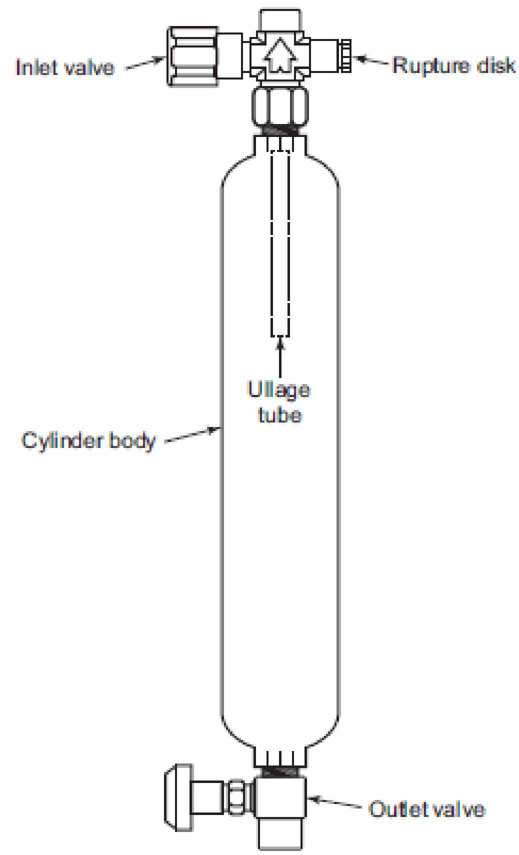

Figure 5—Single Cavity Cylinder with Ullage Tube

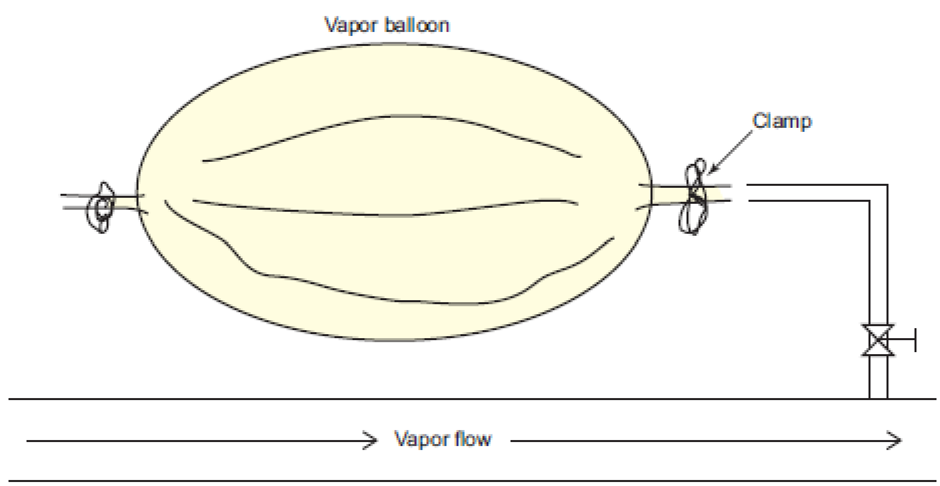

Figure 6—Typical Vapor Balloon

5.5.7.3.4 Single Cavity Cylinder

Refer to 5.5.7.2.3 for details of the single cavity cylinder. Vapor samples at near-atmospheric pressure are difficult to sample using single cavity cylinders because it is difficult to capture a sufficient quantity of the sample at the low operating pressures. Vapor balloons or vapor bags are better choices in this case. Single cavity sample cylinders are better choices than vapor balloons or vapor bags when the sample is retained for periods greater than 48 hours or where the risk of a vapor release due to container rupture or leakage has significant consequences. It may be necessary to use a portable vacuum pump to evacuate sampling manifolds and connections to ensure representative sampling.

5.5.7.4 Other Sampling Devices

Other liquid sampling devices include specially designed copper strip corrosion sample containers, vapor pressure cylinders, pressure pycnometers and pressure hydrometers for single-purpose tests. Refer to ASTM D1838, ASTM D1267, API *MPMS* Ch. 14.6 and API *MPMS* Ch. 9.2/ASTM D1657 for details of the copper strip, vapor pressure, pressure pycnometer and pressure hydrometer devices.

Spot samples may be tested for some components, including trace analysis using length-of-stain tubes, gas content using lower explosive limit or gas detectors, oxygen content using oxygen detectors and trace oxygen analyzers, and moisture content using dew point instruments. Refer to manufacturer's instructions and appropriate industry standards for use and applicability.

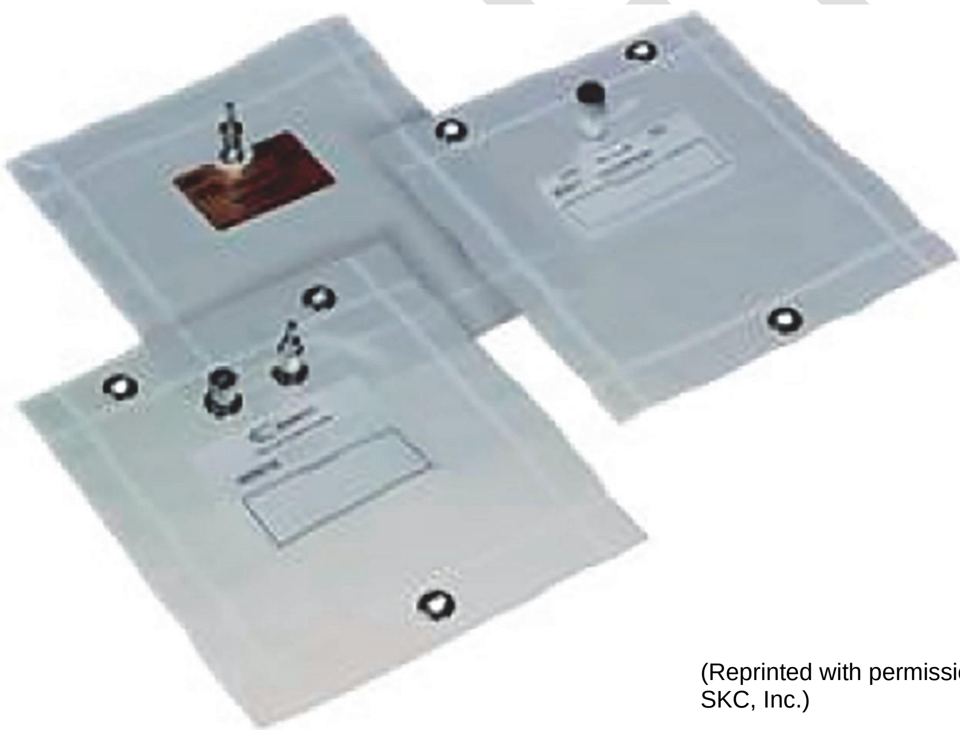

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Figure 7—Typical Vapor Bag

5.6 Dynamic Measurement Equipment

At the time of publication of this standard, technologies, such as Coriolis and ultrasonic flow meters, are available, but are not yet in common usage for LPG or chemical gas custody transfer measurement. These and other technologies continue to develop and are becoming more widely used in LPG or chemical gas service. These systems may be used for custody transfer subject to agreement by all parties involved. Refer to API *MPMS* Chapters 4, 5, and 6 for further details.

6 Measurement Procedures

6.1 General

This section describes the procedures to measure the parameters needed to determine the quantity of cargo loaded or discharged on board a refrigerated and/or pressurized gas carrier.

6.2 Static Measurement

6.2.1 General

To calculate the quantity of cargo in the vessel's tanks at the time of measurement, the following parameters shall be determined within the tolerances described in Table 1 for the various measurement systems:

a) the liquid level in the tank;

b) the volume of vapor in the tank;

c) the average temperature of the liquid;

d) the average temperature of the vapor;

e) the pressure of the vapor space in the tank;

f) the compositions of liquid and vapor;

g) the representative cargo densities for liquid and vapor; and

h) any other information needed to make corrections to measurements device readings.

The vessel's draught should be determined, ideally by reading the draught marks, and recorded along with the sea conditions. A comparison should be made with the vessel's declared readings and any differences resolved.

The use of any measurement equipment fitted on board the vessel to achieve these objectives requires observance of all appropriate safety procedures as well as the manufacturer's specific instructions. All level gauge readings, pressures and temperatures should be observed and recorded concurrently. Before commencement of measurement, trim (if possible) 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 shall be recorded and corrections made for their effect on measurement and/or volumes. Refer to 8.4 and C.8.

Before taking shipboard measurements, confirm the following.

1) All cargo operations have been stopped.

2) The conditions of the cargo lines, drained or full, have been noted. The cargo lines should be in the same condition prior to and post cargo transfer operations.

3) No liquid or vapor is being moved into, out of, or within the vessel including any gas to ship engines or compressors if used.

4) Sufficient time has elapsed for the cargo to stabilize and reach equilibrium conditions of temperature and pressure. Refer to Annex D for a detailed checklist.

6.2.2 Determination of Liquid Level

6.2.2.1 General

Before using any of the vessel's gauging equipment, it shall be agreed in the key meeting which measurement system is deemed the primary measurement system. The manufacturer's operating instructions as well as the appropriate vessel personnel should be consulted to determine the specific operational instruction for the equipment to be used on the vessel. All shipboard procedures described in this standard should be performed by or in the presence of the ship's master or their designated representative.

In addition to the foregoing, the following guidelines should also be followed.

a) Confirm the vessel's ATG system is working by comparison to secondary systems or other means. Determine whether the ATG 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 the capacity tables.

c) Ensure that the measurement equipment has stabilized and adjusted to the temperature of the cargo being measured. Some radar systems are equipped with electronic filtering systems that dampen level fluctuations. Refer to manufacturer's instructions for the time required for the filter to stabilize before taking measurements.

d) Gauge readings shall require obtaining either two consecutive gauge readings to be identical, or three consecutive readings within a range of 3 mm (⅛ in.). If the first two readings are identical, this reading shall be reported to the nearest 1 mm or to the nearest 1/16 in. When three readings are taken, all three readings shall be within the 3 mm (⅛ in.) range and readings averaged to 1 mm (1/16 in.). If the tank contents are determined to be in motion and waiting for equilibrium is not possible, all tank measurements should be recorded, and all parties advised. If the situation cannot be resolved, the conditions should be documented in the inspection report and, if appropriate, a letter of protest should be issued.

e) 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 and averaged Refer to 8.3 for further details.

f) Some ATGs can determine an average gauge measurement. Where such readings are to be used for custody transfer purposes the average should consist of no less than six observations over a period of 1 minute. Use of the average measurement should be noted on the ullage report.

g) Read and record level gauge to the nearest graduation (1 mm, 1/16 in). See API *MPMS* Ch. 3.4 and API *MPMS* Ch.17.2. If the system automatically converts gauges to volumes, record them also. If phase change at the surface of the liquid is suspected, allow sufficient time for the cargo to stabilize and reach equilibrium conditions.

h) Make all necessary corrections to the recorded level, such as those caused by trim, list, temperature effects, density, etc.

Some refrigerated and/or pressurized gas carrier cargo tanks have split bulkheads with gauging devices on both sides of the tank. In this situation, specific instructions as to obtaining liquid level gauges contained in the tank capacity tables should be followed. In some cases, different levels may exist on each side of the tank and some tanks have capacity tables for each side. It is preferred to equalize the levels in both sides of the tanks, although alternative means such as calculating the volume for each side of the tank or averaging levels may be used if agreed to by all parties.

If compliance with any of the foregoing steps cannot be achieved, then reasons should be noted and the appropriate Letter of Protest filed.

6.2.2.2 Automatic Level Gauging

6.2.2.2.1 General

Automatic level gauging systems provide a gauge of the level continuously displayed for the operator's use and reference. In many cases, a computer processes the information, including averaging of the level readings over time, correcting for temperature and pressure, and drawing on computer-based gauging tables to produce a printed document containing all the ship-generated information required for the custody transfer. Modern computer-based systems usually can accept trim and list data either manually or from external sensors and automatically apply the corrections.

6.2.2.2.2 Radar (Microwave) Gauges

Once the tank level is stabilized, observe, and record the primary level gauge readings from the control panel. For some microwave level gauges, a temperature compensation of the microwave guide pipe is necessary.

6.2.2.2.3 Float Gauges

The float shall be checked for accuracy under operating conditions by raising the float or displacer until it reaches the top stowed position (its datum point) and noting the readout. If this test is satisfactory the level readings can be taken.

If the level indication is unusual, the float may be stuck. In this situation, the operator should raise and lower the float again in an attempt to obtain the expected reading.

NOTE Float gauges are stowed in their fixed upper position when sailing so that the tape or wire does not break due to liquid movements.

Release the float and allow the float gauge to stabilize with the liquid level. Allow the tape or wire and the float gauge to thermally stabilize. Thermal stability will exist when the average level gauge no longer drifts. If equipped with a transmitter, also record the level gauge readings from the digital display in the cargo control room for comparison purposes.

The readings made on the float gauge system should be corrected using appropriate tables or equations (refer to Table 3) to account for:

- density and temperature effects on float buoyancy;
- temperature of the gaseous phase; and
- the coefficient of contraction of the material in the tape or wire if the tape or wire is not made of Invar.

6.2.2.2.4 Magnetic Gauges

Magnetic gauges are a type of float gauge commonly found on barges.

Refer to 6.2.2.2.3 for guidance.

6.2.2.2.5 Hydrostatic Tank Gauging

The accuracy of level calculated by an HTG can be affected by density and thermal stratification of the liquid in the cargo tank, primarily due to the limited number and the discrete locations of the pressure and temperature sensors.

The HTG sensors should be positioned and the system be configured based on the geometry of the cargo tank, and the expected operations procedure (filling, emptying, and normal level) to minimize this effect. The HTG method and principle for shore tank application are described in API MPMS Ch. 16.2.

6.2.2.2.6 Hybrid Systems

The hybrid tank measurement system (HTMS) calculation is described in Appendix A of API *MPMS* Ch. 3.6.

6.2.2.3 Manual Level Gauging

Manual gauging requires human input or interaction with the equipment to determine the liquid level. For manually determining the liquid level by float gauge, refer to the applicable portions of 6.2.2.2.3. Manual tank gauging equipment, i.e. rod-type gauges, slip-tube gauges, and tape-type magnetic gauges, are installed mostly on small cargo carriers and barges. See Annex A for details.

6.2.3 Determination of Vapor Space Volume

Calculate the vapor volume at tank conditions by subtracting the liquid volume at observed temperature from the 100 % tank capacity including dome volumes where applicable. For details, see Section 7.

6.2.4 Determination of Temperature

6.2.4.1 General

The temperatures in each tank shall be determined at the same time as the liquid levels. Each temperature sensor shall be read and recorded. Temperature sensor readings in each tank shall be averaged for those in the liquid phase and again for those in the vapor phase. If it is inconclusive as to whether a sensor is in the vapor-liquid interface zone or if there is any doubt about the accuracy of a sensor, the reading should be disregarded.

To check the validity of a temperature reading, compare the sensor readings in the liquid phase of the same or other cargo tank(s). Alternatively, if the cargo is in equilibrium and its composition and pressure is known, the observed temperature can be compared to the expected temperature based on an appropriate enthalpy diagram or equation of state.

6.2.4.2 Temperature of Liquid

The temperature of the liquid shall be measured by using the temperature sensor(s) immersed in the liquid cargo at the time of measurement. Determine which sensors are in the liquid cargo and which are in the vapor space based on the liquid level from the gauging system. Where there are multiple temperature sensors submerged in liquid, disregard any temperature sensor that is affected by boiling action at the vapor-liquid interface. Sensors at the extremities of the tank (e.g. sump) may not be representative of the cargo conditions and should be excluded when not representative. Refer to API *MPMS* Ch. 7 for the method of determining and averaging temperature and other details.

NOTE If there are no temperature sensors submerged in the liquid, subject to agreement of the parties involved, the temperature of the liquid may be determined by use of:

— the closest temperature sensor; and

— the temperature of liquid in an adjacent tank in the same service and conditions.

The method used and the number and location of the temperature sensors shall be noted in the inspection report.

6.2.4.3 Temperature of Vapor

The temperature of the vapor shall be measured using the temperature sensor(s) in the vapor phase of the tank at the time of measurement. Use the ATG or manual gauging results to select the temperature sensors above the vapor/ liquid interface. Where there are multiple temperature sensors in the vapor space, disregard any temperature sensor that is affected by boiling action at the vapor-liquid interface. Sensors at the extremities of the tank (e.g. dome) may not be representative of the cargo conditions and should be excluded when not representative. Refer to API *MPMS* Ch. 7 for the method of determining and averaging temperature and other details.

NOTE If there are no temperature sensors in the vapor space, subject to agreement of the parties involved, the temperature of the vapor may be determined by use of:

— the vapor temperature of an adjacent tank in the same service and conditions; and

— the temperature in the vapor space after sufficient cargo has been discharged.

The method used and the number and location of the temperature sensors shall be noted in the inspection report.

6.2.5 Measurement of Pressure

6.2.5.1 General

The pressure of the cargo tanks shall be measured at the same time as the measurement of the tank's levels and temperatures using the agreed upon system. If individual tank pressures are not attainable, a common header pressure should be determined by equalizing all the tanks into a common header and recording the pressure.

For systems measuring gauge pressure, obtain the atmospheric pressure as appropriate at the same time as the tank pressure is measured.

6.2.5.2 Measurement of Atmospheric Pressure

Atmospheric pressure shall be measured or otherwise assumed to be reference base pressure, such as 101.325 kPa, or as set by contract.

6.2.6 Determination of Density

The algorithm for calculating in-tank liquid density, if determined by an HTMS, shall be consistent with the methodology in API *MPMS* Ch. 3.6.

Density determination by laboratory analysis and by calculation depends on sampling and analysis as discussed in this standard and in applicable industry standards for analysis and testing.

6.2.7 Sampling Procedures

6.2.7.1 General

The purpose of sampling is to determine the composition and associated physical properties of the cargo, including both the liquid and the vapor phases of the cargo as appropriate for vessel and contractual requirements. Samples are used to ensure the cargo meets the specifications set for the material transported and/or to determine the quantity of the cargo in terms of its mass and/or volume.

Each sample shall be representative of the cargo in one of its forms, either vapor or liquid. For the samples to be representative, flow-weighted continuous sampling is recommended where possible. An average of more than one spot sample, or in some cases a spot sample of a single, thoroughly mixed tank, may be used as appropriate for the situation. Sampling equipment and techniques, as well as sample handling, directly affect the accuracy of the analytical results. In addition, the analyses and tests expected to be performed on the liquid samples and the vapor samples can be different depending on the cargo type.

The sample point should be equipped with a sample probe extending into approximately the center third of the manifold piping. Cargo tanks on board barges and other fully pressurized tanks may be equipped with one or more slip tubes. The position of the slip tube can be adjusted in the cargo tank, and depending on the liquid level, will allow for sampling liquid or vapor. In some cases, the tanks on board barges and other fully pressurized tanks may be equipped with one or more sample lines extending to a fixed depth in the cargo tank. Samples taken through fixed lines will provide either vapor or liquid at that level. If the cargo is suspected to be stratified, consider whether representative samples can be obtained from the fixed sample lines or if alternate sample means, such as a flow- proportional composite sampler on shore, shall be employed. If it is deemed that the sample taken may not be representative of the cargo being measured, then such situation and potential reasons for it shall be noted in the appropriate cargo document(s).

6.2.7.2 Cargo Considerations

Liquid and vapor sampling equipment and techniques are important for cargo quantification and judging whether cargo meets product specifications and safety standards. In normal operation, the carriers described in this standard have tanks that may contain:

- air;
- inert gases;
- liquid from current or previous cargo;
- vapor from current or previous cargo;
- contaminants; and
- mixtures of any of the above.

Sampling equipment and techniques depend on:

- pressure of the cargo;
- temperature of the cargo;
- analytical procedure required;

— cargo phase, vapor or liquid; and

— vessel design.

6.2.7.3 Analysis Considerations

In LPG and chemical gas service, one or more samples shall be used to determine the composition, cargo density and to determine that the cargo meets product specifications. It may be necessary to sample the gas phase in addition to the liquid phase, such as when the cargo tank had contained inert gas or a different cargo, or when the possibility of contamination exists. The cargo sample may be used for items such as:

— composition;

— determination of density by calculation or measurement; and

— specification compliance.

NOTE For some cargoes, the previous cargo vapors, the inert gas, or other contaminants in even small concentrations can adversely affect the new cargo.

6.2.7.4 Gas Carrier Considerations

The type of gas carrier design impacts liquid sampling procedures. See Table 2. Gas carriers can be classified into five groups: fully pressurized, semi-pressurized (semi-refrigerated), ethylene, fully refrigerated, and LNG. A special consideration is that barges are generally fully pressurized and are not fitted with cargo pumps, but are instead unloaded with vapor displacement from a shore compressor.

Table 2—Typical Gas Carrier Types and Influence on Sampling (Excluding LNG)

Ship Design Type	Product or Service	Temperature (typical design)	Gauge Pressure (typical design)	Comments
Fully pressurized	Propane, butanes, chemicals, ammonia	Ambient	1800 kPa (260 psi)	Discharged using ship pumps or shore compressors
Semi-pressurized (Semi-refrigerated)	Propane, butanes, chemicals, ammonia	–48 °C	700 kPa (100 psi)	Discharged using ship pumps
Ethylene	Ethylene	–104 °C	700 kPa (100 psi)	Discharged using ship pumps
Fully refrigerated	Propane, butanes, chemicals, ammonia	–48 °C	70 kPa (10 psi)	Discharged using ship pumps

6.2.7.5 Liquid Sampling Procedures

6.2.7.5.1 General

For gas carriers equipped with cargo pumps, sample the liquid cargo in each tank by circulating the cargo tank with a cargo pump for a minimum of 15 minutes. Ensure the sample point, hoses, and containers are flushed with the product to be sampled.

6.2.7.5.2 Pressure-balanced Piston Cylinder

If the sample is required for determination of minor component concentrations, or in cases where high vapor pressure is involved, the pressure-balanced piston cylinder sampling procedure of ASTM D3700 and GPA 2174 is recommended. Low cargo temperature (more than approximately 15 °C below ambient) and low cargo pressure (near atmospheric pressure) may affect the ability of the user to successfully capture a representative liquid sample using a pressure-balanced piston cylinder if additional care is not taken. The use of a vacuum pump may be required.

6.2.7.5.3 Single Cavity (Two-valve) Cylinder

The purging and sampling procedures of ASTM D1265, GPA 2174 or ISO 4257 should be used to obtain samples in single cavity cylinders. A modification to the procedure of ISO 4257 and ASTM D1265 provides an alternative to purge and fill a single cavity cylinder. This modification may be suitable for high purity samples or when low concentrations of components are to be determined and traces of previous product in the container could affect the analysis.

6.2.7.6 Vapor Sampling Procedures

6.2.7.6.1 General

Sample the vapor cargo in each tank after properly purging the sample point, the sample tubing, hoses and sample container. Vapor samples are required for gassing-up and cargo tank preparation. The vapor composition prior to loading and after discharge is sometimes assumed to be the same composition as the liquid. Additional guidance may be provided in GPA 2166, API *MPMS* Ch. 14.1 and ISO 10715.

6.2.7.6.2 Vapor Balloon

Refer to manufacturer's instructions for sampling. Purge the balloon with an inert gas by inflating and deflating the balloon at least three times. When drawing the vapor sample, and where allowed, inflate and deflate the balloon with the cargo vapor at least three times. Analyze the sample within 24 to 48 hours after sampling. Vapor balloons are not suitable for long-term storage such as is needed for retained samples. Caution should be taken with vapor samples contained in a vapor balloon due to the potential of the balloon to rupture, as well as the permeation of the vapor through the balloon walls. Do not transport in a closed vehicle.

Vapors from low-pressure cargo tanks may be difficult to capture and the use of a vapor sample pump may be used. Exercise caution to not contaminate the sample with air or other components such as the remnants of the previous sample.

6.2.7.6.3 Vapor Bag

Refer to manufacturer's instructions for sampling. Purge the bag with an inert gas by inflating and deflating the bag at least three times. When drawing the vapor sample, and where allowed, inflate and deflate the bag with the cargo vapor at least three times. Analyze the sample within 24 to 48 hours after sampling. Vapor bags are not suitable for long-term storage such as is needed for retained samples. Caution should be taken with vapor samples contained in a vapor bag due to the potential of the bag to rupture, as well as the permeation of the vapor through the bag walls. For these reasons, do not transport in a closed vehicle.

Vapors from low-pressure cargo tanks may be difficult to capture and the use of a vapor sample pump may be used. Exercise caution to not contaminate the sample with air or other components such as the remnants of the previous sample.

6.2.7.6.4 Single Cavity Cylinder

Single cavity cylinders can be used in high-pressure through low-pressure conditions (assuming a vapor sample pump is used) to draw, analyze, and retain samples for an extended period of time.

6.2.7.7 Other Sampling Devices

6.2.7.7.1 General

Refer to the appropriate industry standards and/or manufacturer's instructions for these devices and tests.

6.2.7.7.2 Copper Strip Corrosion Cylinder

Refer to ASTM D1838 for sampling and test procedures.

6.2.7.7.3 Vapor Pressure Cylinder

Refer to ASTM D1267 for sampling and test procedures.

6.2.7.7.4 Pressure Pycnometer

Refer to API *MPMS* Ch. 14.6 for sampling and measurement procedures and calculations. The pressure pycnometer is normally not used on cargoes at temperatures below 0 °C.

6.2.7.7.5 Pressure Hydrometer

Refer to API *MPMS* Ch. 9.2/ASTM D1657 for sampling and test procedures.

6.2.7.7.6 Length-of-Stain Tubes

Length-of-stain tubes are used as part of the cleanliness inspection particularly around the ship's cargo handling equipment including cargo pumps, booster pumps, compressors, condensers, heat exchangers, filters, expansion valve, i.e. any place where vapor from a previous cargo could be trapped and contaminate the subsequent cargo. Also, length-of-stain tubes are frequently used during the purging and tank conditioning process to verify that the prior cargo contents will not violate contractual specifications of the final cargo loaded.

Length-of-stain tubes can be used at the sample source as well as on a vaporized liquid sample or a vapor sample in a sample cylinder. Refer to the manufacturer's written instructions for humidity concerns, compounds interfering with the measurement, how to read the tube, the number of sample pump strokes to be used and the impact on the measured result. The user should take note of the manufacturer's accuracy statement for the test.

6.2.7.7.7 Gas Detector/Lower Flammable Limit (LFL) Detector

The measurement of hydrocarbon vapors on vessels and terminals falls into two categories.

1) The measurement of hydrocarbon gas in air at concentrations below the lower flammable limit (LFL). This is to detect the presence of flammable (and potentially explosive) vapors and to detect concentrations of hydrocarbon vapor that may be harmful to personnel. These readings are expressed as a percentage of the LFL and are usually recorded as %LFL. The instruments used to measure %LFL are catalytic filament combustible gas indicators, which are usually referred to as Flammable Gas Indicators or Explosimeters. LFL is also referred to as LEL, Lower Explosive Limit. Due to the nature of the meter these cannot be used in an oxygen deficient atmosphere e.g. if the tank is inerted.

2) The measurement of hydrocarbon gas as a percentage by volume of the total atmosphere being measured. On board a tanker, this is usually carried out to measure the percentage of hydrocarbon vapor in an inerted atmosphere. Instruments used to measure hydrocarbon vapors in an inert gas atmosphere are specially developed for this purpose. The readings obtained are expressed as the percentage of hydrocarbon vapor by volume and are recorded as %VOL. The instruments used to measure percentage hydrocarbon vapors in inert gas are non-catalytic heated filament gas indicators and are usually referred to as tankscopes. Modern developments in gas detection technology have resulted in the introduction of electronic instruments using infrared sensors, which when suitably designed, can perform the same function as the tankscope.

6.2.7.7.8 Oxygen Detector/Trace Oxygen Analyzer

Oxygen detector/trace oxygen analyzer instruments are used during cleanliness inspections, purging, and gassing-up operations. Refer to the manufacturer's written instructions for calibration, operation, and use.

6.2.7.7.9 Moisture/Humidity Instruments

Moisture/humidity instruments are used during purging and gassing-up operations. Refer to the manufacturer's written instructions for calibration, operation, and use.

6.3 Dynamic Measurement Procedures

At this time, static measurement is the only way to determine the cargo volumes on board vessels; however, if a flow meter is installed in a loading or discharge facility to measure the product volume and/or mass for verification or custody transfer purposes, the following are examples of items that shall be considered:

—reliability, linearity, range of operational tolerances;

—cargo temperature effects;

—cargo flow rate effects;

—quality determination;

—meter proving;

—vessel/shore line inventory;

—temperature and pressure measurement; and

—sampling and analysis of product.

7 Cargo Quantity Determination

7.1 General

Vital components of good measurement of cargo on board refrigerated and/or pressurized gas carriers are the:

—use of proper tables and algorithms;

—accurate recording of the basic data obtained through physical measurement; and

—cargo laboratory analysis.

After the relevant observations and measurements shown on the checklist (see Annex D) have been made, quantity calculations shall be performed.

7.2 Shipboard Readings

Measurement data should be gathered and recorded in a systematic manner and archived in accordance with contract and regulations. Checklists of measurement and related tasks to be performed are provided in Annex D and example forms for recording data are in Annex B.

Figure 8 is a guide as to the information needed and steps to be performed to gather the readings on board an LPG or chemical gas carrier and is applicable to the opening and to the closing process. Specific cargoes may require special considerations, calculations, and/or additional steps.

7.3 Calculation Overview

International system of units (SI) are typically used in the quantification of pressurized and/or refrigerated cargoes. Example calculations using these units are found in 7.4. It is still possible, however, to find ships with tank calibrations and instruments reporting in U.S. Customary units (USC). In this case the basic calculations remain the same but the user shall ensure that all data conform to the same system. For the USC system, this requires temperatures in degrees Fahrenheit, relative density in 60 °F/60 °F form, volumes in barrels and/or cubic feet and mass (weight) in long tons. In some countries, cargo determination may be made in cubic meters at 15 °C, while other countries may quote cargo determination in cubic meters at 20 °C.

Even in the SI system of measurement, procedures can vary and some of these variations are identified below. It is possible in one cargo shipment to find that units and calculation procedures differ at the loading terminal, on the ship and at the receiving terminal. Efforts should be made to use the same methods and units on the ship, at the load port and at the discharge port to avoid discrepancies caused by unit and reference base condition conversions.

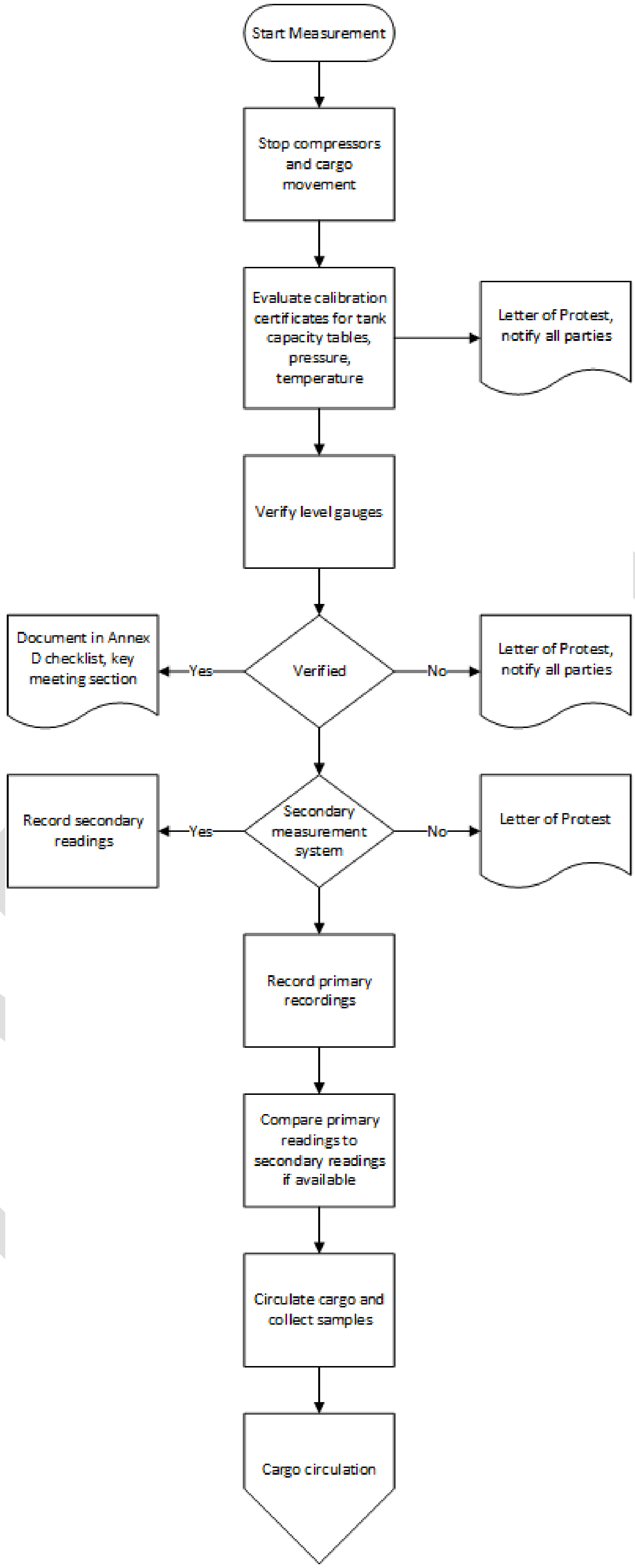

Figure 8—Measurement Process Flow Chart

To determine the volume at a measured liquid level that falls between the printed values in the capacity table, interpolate between the level immediately above and below the measured level. Do not use the fractional tables. Liquid density is usually determined based on the analysis of representative samples or measurements taken at the load port for the loaded cargo and at the discharge port for the discharged cargo from tests or analysis performed onshore. It is important that the reference temperature be noted for the density. Unless otherwise noted, density is considered to be absolute density, i.e. density in vacuum.

The overview of the cargo calculation process is illustrated in Figure 9.

7.4 Liquefied Petroleum Gas (LPG) and Chemical Gas Calculations

7.4.1 Information Provided by Survey

The following information is obtained during the vessel survey:

1) tank pressure,
2) vapor temperature,
3) liquid temperature,
4) liquid level, and
5) trim and list of the vessel by draft.

7.4.2 Tank Capacity Table Information

Tank capacity tables show the volume corresponding to each tank height measured. Measurements should be taken in the same units used in the tables. If for any reason readings are taken in other units of measurement, appropriate unit conversions shall be made. When tank capacity tables are not presented in the prescribed graduations (minimum 1 mm or 0.05 in.), and when gauge readings fall between the values in the tables, interpolate the level to the display resolution in Table 1. Fractional tables on the tank capacity tables shall not be used.

The observed reference height should be compared with the gauge reference height given in the tables and recorded (see Annex C). Trim or list corrections shall be applied as indicated in the appropriate vessel tables (see 6.2 and Annex C).

The following information is provided from the vessel's certified tank capacity tables:

1) 100 % tank capacity;
2) corrections to the observed liquid level measurement for any applicable factors, including but not limited to:
    a) trim or list,
    b) temperature correction to gauging device (tape or wire correction),
    c) float correction (buoyancy) according to liquid density of the cargo, and
    d) other device or vessel specific corrections (e.g. pressure correction) to the observed level measurement;
3) liquid volume at varying levels; and
4) temperature and pressure correction factors related to the tank shell.

NOTE There are two methods presented in this standard for applying pressure and temperature correction factors, Method A adjusts the cargo and Method B adjusts the tank shell capacity. The method to be used is driven from the shrinkage tables produced when the cargo tank was calibrated.

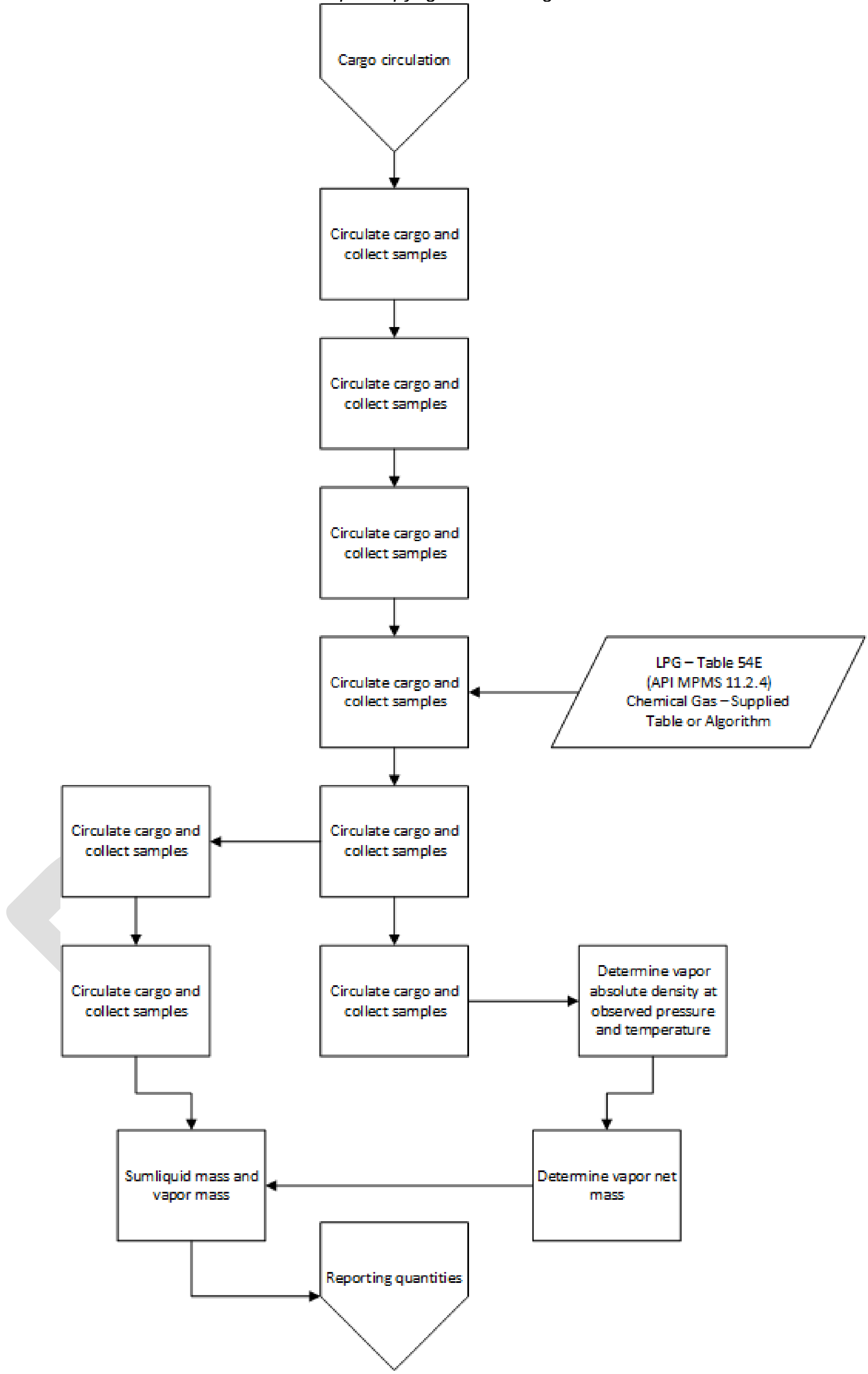

Figure 9—Overview of Cargo Calculation Process Flow Chart

Table 3—Typical Corrections for a Float Gauge

Actual temperature	°C	–45.00
Observed level	mm	4523
Trim correction	mm	–22
List correction	mm	0
Float correction	mm	–2
Pressure correction for level	-	1.000023
Tape temperature correction	mm	–6
Corrected level	mm	4494
NOTE Other corrections may apply to devices other than float gauges.		

7.4.3 Calculation of Quantity

7.4.3.1 Liquid Volume and Density

Liquid volume and density correction algorithms and tables vary by the cargo type. Volume correction tables or algorithms are necessary to convert the observed cargo volumes being measured to standard volume at an agreed reference temperature, typically 15 °C, 60 °F, or 20 °C. When making these calculations, use the tables or algorithms as specified in the sales contract or as otherwise agreed. For cargo reconciliation purposes, quantities should be compared using the same standard temperature and volume correction tables/algorithms.

LPG cargo calculations shall use API *MPMS* Ch. 11.2.2, 11.2.4, and 11.2.5 unless otherwise specified by regulation, agreement or contract.

NOTE API *MPMS* Ch. 11.2.4 replaced the ASTM-IP Petroleum Measurement Tables and the ASTM D1250 tables.

For chemical gases, the vapor in the cargo tank is typically considered to be at equilibrium with the liquid. Table 4 lists typical vapor and liquid correction tables and algorithms for some common chemical gases.

Table 4—Chemical Gas Typical Vapor and Liquid Correction Tables and Algorithms

Butene	ASTM DS4A
Ethylene	API *MPMS* Ch. 11.3.2.1 (IUPAC 88)
Ethane	As appropriate and/or per commercial agreement
Ammonia	*Liquid density/Vapour pressure*, VDI-Forsch Heft 596, J. Ahendts, H.D Baehr Vapor density, Redlich Kwong equation of state (cubic form); *Applied Hydrocarbon Thermodynamics*, Wagne C. Edmiwter, Volume 2
1,3 Butadiene	ASTM D1550
Propylene	*International Thermodynamic Tables of the Fluid State, Propylene* (IUPAC), S. Angus, B. Armstrong, K.M. De Reuck, Pergamon Press, 1980

VCM	*Thermodynamic properties of Vinyl Chloride/British Chemical Engineering*, Vol. 3, 1958 Redlich Kwong Equation of State (cubic form)/Applied Hydrocarbon thermodynamics, Wagne C. Edmister, Vol II Adapted Goodrich formula

7.4.3.2 Mass

Liquid mass is calculated as the product of the liquid volume and the liquid density, with volume and density at the same reference temperature condition. There are two approaches to calculate the liquid mass:

— multiplying the liquid density at reference temperature (often 15 °C) by the liquid volume corrected to the same reference temperature using the appropriate volume correction algorithm or table; or

— multiplying the liquid density at observed temperature by the liquid volume at the observed temperature. Liquid density at observed temperature is calculated using the appropriate algorithm or table if starting from liquid density at reference temperature.

Vapor mass is calculated as the product of vapor volume and the vapor density at the same pressure and temperature conditions. Vapor density comes from one of several methods described in 5.5.6.

The ideal gas formula is based on the perfect gas law and is appropriate at pressures near atmospheric conditions as follows in Equation 1:

$$\text{Vapor Density}\left(\frac{kg}{m^3}\right)=\frac{288.15}{273.15+T\left({}^{\circ}C\right)}\times\frac{P\left(\text{bar absolute}\right)}{1.01325}\times\frac{\text{Molar Mass}}{23.6451\left(\frac{m^3}{kmol}\right)} \qquad (1)$$

When pressure is not near atmospheric, it is appropriate to include a correction for compressibility (Z) either in the form of the following equation, a published table or from an equation of state as shown in Equation 2.

$$\text{Vapor Density}\left(\frac{kg}{m^3}\right)=\frac{288.15}{273.15+T\left({}^{\circ}C\right)}\times\frac{P\left(\text{bar absolute}\right)}{1.01325}\times\frac{\text{Molar Mass}}{23.6451\left(\frac{m^3}{kmol}\right)}\times\frac{1}{Z} \qquad (2)$$

Derived calculations to other units of mass, weight or volume may be carried out as per latest editions of API *MPMS* Ch. 11.5.1, 11.5.2, and 11.5.3 or as required by industry standards, contracts, or agreements.

7.4.3.3 Calculation Example for Propane

Each tank requires an individual calculation for volume based on the measured variables. These example calculations, Table 5 and Table 6, multiply the liquid density at reference temperature by the liquid volume corrected to the same reference temperature.

Table 5 (Method A) is an example calculation resulting in the total mass and volumes at certain base conditions based on cargo-corrected volume for tank thermal expansion/contraction. This approach applies pressure and temperature correction factors to liquid and vapor volume.

Table 6 (Method B) is an example calculation resulting in the total mass and volumes at certain base conditions based on tank capacity-correction for tank thermal expansion/contraction. This approach applies pressure and temperature correction factors to total tank capacity so it can be apportioned to the liquid and the vapor volume.

7.4.3.4 Calculation Example for Ethylene

Each tank requires an individual calculation for volume based on the measured variables. These example calculations, Table 7 and Table 8, multiply the liquid density at observed temperature by the liquid volume at the observed temperature.

Table 7 (Method A) is an example calculation resulting in the total mass and volumes at certain base conditions based on cargo-corrected volume for tank thermal expansion/contraction. This approach applies pressure and temperature correction factors to liquid and vapor volume.

Example for LPG Cargo

Method A

VESSEL MEASUREMENT REPORT

Vessel		Cargo	Propane	Date / Time
Terminal		Client		
Port		Operation		

		Tank no.		1	2	
1		Cargo Tank Capacity	m^3	1933.580	1364.890	<-- Tank Number/ Compartment Number
1		Cargo Tank Capacity	m^3	1933.580	1364.890	<-- Cargo Tank Capacity at 100%
2		Molecular Mass		44.097	44.098	<-- From cargo analysis or GPA 2145
3		Pressure, absolute	bar	11.400	11.600	<-- Pressure as observed from primary measurement system
4		Temperature	°C	-32.8	-32.9	<-- Avg Vapor Temperature as recorded from primary measurement system
5	V	Volume	m^3	63.902	94.100	<-- Vapor Volume (TOV) = Cargo Tank Capacity - Liquid Total Observed Volume
6a	A	Press. Corr. Fact. Ctsvp		1.000000	1.000000	<-- Cargo tank shell correction corresponding to vapor space at tank pressure
6b	P	Temp. Corr. Fact. Ctsvt		0.998243	0.998243	<-- Cargo tank shell correction corresponding to vapor space at vapor temperature
7	O	Corrected Volume	m^3	63.790	93.935	<-- Vapor TOV * Ctsvt * Ctsvp
8	R	% Cargo		100.00	100.00	<-- Percentage Vapor as Cargo (Lab Analysis)
9		Cargo Volume	m^3	63.790	93.935	<-- Corrected Volume * % Cargo
10		Density	kg/m^3	0.027485	0.027940	<-- Calculated vapor density at 15 °C from Ideal Gas Formula or Equation of State
11		Mass	MT vac	1.753	2.625	<-- Cargo Volume * Density at 15 °C
12		Temperature	°C	-39.6	-39.8	<-- Tank Average Liquid Temperature as recorded from primary measurement system
13	L	Corr. Ullage	m	8.951	8.535	<-- Corrected Ullage after Tape, Float , Trim Correction
14	I	Total Observed Volume	m^3	1869.678	1270.790	<-- Liquid Total Observed Volume as obtained from Tank Capacity Tables
15a	Q	Pressure Corr. Fact. Ctslp		1.000000	1.000000	<-- Cargo tank shell correction corresponding to liquid at tank pressure
15b	U	Temp Corr. Fact. Ctslt		0.998016	0.998016	<-- Cargo tank shell correction corresponding to liquid at liquid temperature
16	I	Corrected Volume	m^3	1865.969	1268.269	<-- Liquid TOV * Ctslt * Ctslp
17	D	C_{TL}		1.13802	1.13847	<-- Temperature correction for Cargo from API MPMS 11.2.4 Algorithm (Table 54E)
18		Cargo Volume	m^3	2123.510	1443.886	<-- Corrected Volume * API MPMS 11.2.4 (Table 54E Factor)
19		Density	kg/m^3	0.50930	0.50930	<-- Density of Cargo at 15 °C (in vacuum) from lab analysis
20		Mass liquid	MT vac	1081.504	735.371	<-- Liquid Cargo Volume at 15 °C * Density of Cargo 15 °C
21		Total Mass	MT vac	1083.257	737.998	<-- Liquid at 15 °C + Vapor at 15 °C

Atmospheric Pressure	bar	1.01325	
Relative Density @ 60 °F		0.50900	API MPMS 11.5.3.4.3
Draft Forward	m	11.40	
Draft Aft	m	11.50	
List	°	NIL	
Average Molecular Mass		44.098	
Shore Line Condition		FULL	
Average Absolute Density @ 15 °C		0.50930	API MPMS 11.5.3.4.3
Vapor density source		Ideal Gas	
Liquid C_{TL}		Table 54E	
Lb/US Gal (Air)		4.23422567	API MPMS 11.5.3.4.10(b)
Lb/US Gal (Vac)		4.24359899	API MPMS 11.5.3.4.10(a)

In Air @ 60 °F			In Vacuum @ 15 °C		
Total on board			Total on board		
MT	1817.230	[illegible]	MT	1821.253	[illegible]
LT	1788.536	API MPMS 11.5.3.4 [illegible]	LT	1792.489	API MPMS 11.5.3.4.8(a)
ST	2003.161	API MPMS 11.5.3.4 [illegible]	ST	2007.588	API MPMS 11.5.3.4.8(a)
Lb	4006306.79		Lb	4015175.56	
US Gal @ 60 °F	946172.24	API MPMS 11.5.3.4 [illegible]	m^3 @ 15 °C	3575.993	API MPMS 11.5.3.4.7 (a)
Bbl @ 60 °F	22527.91	API MPMS 11.5.3.4 [illegible]	L @ 15 °C	3,575,992.5	MT * 1000 / Abs Density at 15 °C

For intraconversion per API MPMS 11.5.3 to convert from 15 °C to 60 °F (15.5556 °C)

C_{TL} 0.99842 Table 54E - API MPMS 11.2.4

Table 5—LPG Example Calculation Method A, Correction Applied to Cargo Volume

Example for LPG Cargo

Method B

VESSEL MEASUREMENT REPORT

Vessel		Cargo	Propane	Date/Time
Terminal		Client		
Port		Operation		

				1	2	
		Tank no.		1	2	<-- Tank Number/ Compartment Number
1		Capacity	m^3	1933.580	1364.890	<-- Cargo Tank Capacity at 100%
2		Total tank height	m	22.000	22.000	<-- Cargo Tank total height
3		Level-weighted Avg temperature	°C	-1.54	-1.14	<-- Volume average temperature from ullage
4a		Temp. Corr. Fact.		0.999453	0.999453	<-- Shell Shrinkage Factor at level-weighted average temperature
4b		Press. Corr. Fact.		1.000000	1.000000	<-- Shell Shrinkage Factor at tank pressure (Vapor)
5		Molecular Mass		44.097	44.098	<-- From cargo analysis or GPA 2145
6		Pressure, absolute	bar	7.700	7.300	<-- Pressure as observed from primary measurement system
7	V	Temperature	°C	-0.6	0.1	<-- Avg Vapor Temperature as recorded from primary measurement system
8	A	Corrected Capacity	m^3	1932.522	1364.143	<-- Cargo Tank Capacity * Temp. Corr. Fact * Press. Corr. Fact.
9	P	Corrected Volume	m^3	62.844	94.048	<-- Vapor Corrected Capacity - Liquid Corrected Volume
10	O	% Cargo		100.00	100.00	<-- Percentage Vapor as Cargo (Lab Analysis)
11	R	Cargo Volume	m^3	62.844	94.048	<-- Corrected Volume * % Cargo
12		Density	kg/m^3	0.017014	0.016191	<-- Calculated vapor density at 15 °C from Ideal Gas Formula or Equation of State
13		Mass	MT vac	1.069	1.523	<-- Corrected Volume * Density at 15 °C
14		Temperature	°C	-2.9	-3.1	<-- Average Liquid Temperature as recorded from primary measurement system
15	L	Corr. Ullage	m	8.951	8.535	<-- Corrected Ullage after Tape, Float , Trim Correction
16	I	Volume (TOV)	m^3	1869.678	1270.790	<-- Liquid Volume as obtained from Tank Capacity Tables
17	Q	Corrected Volume	m^3	1868.655	1270.095	<-- Liquid TOV * Temp. Corr. Fact * Press. Corr. Fact.
18	U	C_{TL}		1.04888	1.04941	<-- Temperature correction for Cargo from API MPMS 11.2.4 Algorithm (Table 54E)
19	I	Volume	m^3	1959.995	1332.850	<-- Corrected Volume * API MPMS 11.2.4 (Table 54E Factor)
20	D	Density	kg/m^3	0.50930	0.50930	<-- Density of Cargo at 15 °C (in vacuum)
21		Mass	MT vac	998.225	678.821	<-- Corrected Liquid Volume at 15 °C * Density of Cargo 15 °C
22		Total Mass	MT vac	999.294	680.344	<-- Liquid at 15 °C + Vapor at 15 °C

Atmospheric Pressure	bar	1.01325	
Relative Density at 60/60 °F		0.50900	API MPMS 11.5.3.4.3
Draft Forward	m	11.40	
Draft Aft	m	11.50	
List	°	NIL	
Average Molecular Mass		44.0975	
Shore Line Condition		FULL	
Absolute Density @ 15 °C		0.50930	API MPMS 11.5.3.4.3
Vapor density source		Ideal Gas	
Liquid C_{TL}		Table 54E	
Lb/US Gal (Air)		4.23422567	API MPMS 11.5.3.4.10(b)
Lb/US Gal (Vac)		4.24359899	API MPMS 11.5.3.4.10(a)

In Air @ 60 °F		
Total on board		
MT	1675.928	[illegible]
LT	1649.465	[illegible]
ST	1847.401	[illegible]
Lb	3694788.77	
US Gal @ 60 °F	872800.81	[illegible]
Bbl @60 °F	20776.21	[illegible]

In Vacuum @ 15 °C		
Total on board		
MT	1679.638	[illegible]
LT	1653.111	[illegible]
ST	1851.484	[illegible]
Lb	3702967.93	
m^3 @ 15 °C	3297.934	[illegible]
L @ 15 °C	3,297,934.4	[illegible]

For intraconversion per API MPMS 11.5.3 to convert from 15 °C to 60 °F (15.5556 °C)

C_{TL} 0.99842 Table 54E - API MPMS 11.2.4

Table 6—LPG Example Calculation Method B, Correction Applied to Tank Shell

Example for Chemical Gas Cargo

Method A

VESSEL MEASUREMENT REPORT

Vessel		Commodity	Ethylene	Date / Time
Terminal		Client		
Port		Operation		

				1	2	
		Tank no.		1	2	<-- Tank Number / Compartment Number
1		Cargo Tank Capacity	m^3	3263.618	3263.589	<-- Cargo Tank Capacity at 100%
2		Molecular Mass		28.060	28.060	<-- From cargo analysis or GPA 2145
3		Pressure, absolute	bar	0.020	0.030	<-- Pressure as observed from primary measurement system
4		Temperature	°C	-101.0	-102.0	<-- Avg Vapor Temperature as recorded from primary measurement system
5	V	Volume	m^3	163.058	161.000	<-- Vapor Volume (TOV) = Cargo Tank Capacity - Liquid Total Observed Volume
6a	A	Press. Corr. Fact. Ctsvp		1.000000	1.000000	<-- Cargo tank shell correction corresponding to vapor space at tank pressure
6b	P	Temp. Corr. Fact. Ctsvt		0.998750	0.998730	<-- Cargo tank shell correction corresponding to vapor space at vapor temperature
7	O	Corrected Volume	m^3	162.854	160.796	<-- Vapor TOV * Ctsvt * Ctsvp
8	R	% Cargo		100.00	100.00	<-- Percentage Vapor as Cargo (Lab Analysis)
9		Cargo Volume	m^3	162.854	160.796	<-- Corrected Volume * % Cargo
10		Density	kg/m^3	0.002434	0.002306	<-- Vapor density at observed temperature from IUPAC-88
11		Mass	MT vac	0.396	0.371	<-- Cargo Volume * Density at Observed Temperature
12		Temperature	°C	-101.2	-102.5	<-- Tank Average Liquid Temperature as recorded from primary measurement system
13	L	Corr. Ullage	m	12.127	12.124	<-- Corrected Ullage after Tape, Float, Trim Correction
14	I	Total Observed Volume	m^3	3100.560	3102.589	<-- Liquid Total Observed Volume as obtained from Tank Capacity Tables
15a	Q	Pressure Corr. Fact. Ctslp		1.000000	1.000000	<-- Cargo tank shell correction corresponding to liquid at tank pressure
15b	U	Temp Corr. Fact. Ctslt		0.997840	0.997900	<-- Cargo tank shell correction corresponding to liquid at liquid temperature
16	I	Corrected Volume	m^3	3093.863	3096.074	<-- Liquid TOV * Ctslt * Ctslp
17	D	C_{TL}		1.00000	1.00000	<-- C_{TL} Not used in this example due to Density Factors at Observed Temperature
18		Cargo Volume	m^3	3093.863	3096.074	<-- Corrected Volume
19		Density	kg/m^3	0.56420	0.56610	<-- Density of Cargo at Observed Temperature (in vacuum) from IUPAC-88
20		Mass liquid	MT vac	1745.558	1752.687	<-- Liquid Cargo Volume at Observed Temperature * Density of Cargo at Observed Temperature
21		Total Mass	MT vac	1745.954	1753.058	<-- Liquid Mass + Vapor Mass

Atm. Pressure	bar	1.01325	
Relative Density @ 60 °F		0.36023	API MPMS 11.5.3.4.3
Draft Forward	m	11.40	
Draft Aft	m	11.50	
List	°	NIL	
Average Molecular Weight		28.0600	
Shore Line Condition		FULL	
Average Absolute Density @ 15 °C		0.37100	
Vapor density source		IUPAC-88	
Liquid density source		IUPAC-88	
Lb/US Gal (Air)		2.99376336	API MPMS 11.5.3.4.10(b)
Lb/US Gal (Vac)		3.00332262	API MPMS 11.5.3.4.10(a)

In Air @ 60 °F		
Total on board		
MT	3487.875	[illegible]
LT	3433.133	[illegible]
ST	3845.109	[illegible]
Lb	7689448.14	
US Gal @ 60 °F	2568488.96	[illegible]
Bbl @ 60 °F	61154.50	[illegible]

In Vacuum @ 15 °C		
Total on board		
MT	3499.012	Sum Line 21
LT	3443.750	API MPMS 11.5.3.4.9(a)
ST	3857.001	API MPMS 11.5.3.4.8(a)
Lb	7714001.01	
m^3 @ 15 °C	9431.299	API MPMS 11.5.3.4.7 (a)
L @ 15 °C	9,431,299.2	MT * 1000 / Abs Density at 15 °C

For intraconversion per API MPMS 11.5.3 to convert from 15°C to 60 °F (15.5556 °C)		
C_{TL}	0.97002	= (fluid density 15.5556 °C / fluid density at 15 °C) from COSTALD

Table 7—Chemical Gas Example Calculation Method A

Example for Chemical Gas Cargo

Method B

VESSEL MEASUREMENT REPORT

Vessel		Commod	Ethylene	Date / Time	
Terminal		Client			
Port		Operation			

		Tank no.		1	2	<-- Tank Number/ Compartment Number
1		Capacity	m^3	3263.618	3263.589	<-- Cargo Tank Capacity at 100%
2		Total tank height	m	14.000	14.000	<-- Cargo Tank total height
3		Level-weighted Avg temperature	°C	-101.17	-102.43	<-- Volume average temperature from ullage
4		Temp. Corr. Fact.		0.998750	0.998730	<-- Shell Shrinkage Factor at level-weighted average temperature
5		Press. Corr. Fact.		1.000000	1.000000	<-- Shell Shrinkage Factor at tank pressure (Vapor)
6a		Molecular Mass		28.060	28.060	<-- From cargo analysis or GPA 2145
6b		Pressure, absolute	bar	0.020	0.030	<-- Pressure as observed from primary measurement system
7	V	Temperature	°C	-101.0	-102.0	<-- Avg Vapor Temperature as recorded from primary measurement system
8	A	Corrected Capacity	m^3	3259.538	3259.444	<-- Cargo Tank Capacity * Temp. Corr. Fact * Press. Corr. Fact.
9	P	Corrected Volume	m^3	158.978	160.795	<-- Vapor Corrected Capacity - Liquid Corrected Volume
10	O	% Cargo		100.00	100.00	<-- Percentage Vapor as Cargo (Lab Analysis)
11	R	Cargo Volume	m^3	158.978	160.795	<-- Corrected Volume * % Cargo
12		Density	kg/m^3	0.002434	0.002306	<-- Vapor density at observed temperature from IUPAC-88
13		Mass	MT vac	0.387	0.371	<-- Cargo Volume * Density at Observed Temperature
14		Temperature	°C	-101.2	-102.5	<-- Average Liquid Temperature as recorded from primary measurement system
15	L	Corr. Ullage	m	12.127	12.124	<-- Corrected Ullage after Tape, Float, Trim Correction
16	I	Volume (TOV)	m^3	3100.560	3102.589	<-- Liquid Volume as obtained from Tank Capacity Tables
17	Q	Corrected Volume	m^3	3096.684	3098.649	<-- Liquid TOV * Temp. Corr. Fact * Press. Corr. Fact.
18	U	C_{TL}		1.00000	1.00000	<-- C_{TL} Not used in this example due to Density Factors at Observed Temperature
19	I	Volume	m^3	3096.684	3098.649	<-- Corrected Volume
20	D	Density	kg/m^3	0.56420	0.56610	<-- Density of Cargo at observed temperature (in vacuum) from IUPAC-88
21		Mass	MT vac	1747.149	1754.145	<-- Liquid Cargo Volume at Observed Temperature * Density of Cargo at Observed Temperatun
22		Total Mass	MT vac	1747.536	1754.516	<-- Liquid Mass + Vapor Mass

Atm. Pressure	bar	1.01325	
Relative Density at 60/60F		0.36023	API MPMS 11.5.3.4.3
Draft Forward	m	11.40	
Draft Aft	m	11.50	
List	°	NIL	
Average Molecular Mass		28.0600	
Shore Line Condition		FULL	
Average Absolute Density @ 15 °C		0.37100	
Vapor density source		IUPAC-88	
Liquid density source		IUPAC-88	
Lb/US Gal (Air)		2.99376336	API MPMS 11.5.3.4.10(b)
Lb/US Gal (Vac)		3.00332262	API MPMS 11.5.3.4.10(a)

In Air @ 60 °F			In Vacuum @ 15 °C		
Total on board			Total on board		
MT	3490.905	[illegible]	MT	3502.052	Sum Line 21
LT	3436.116	[illegible]	LT	3446.742	API MPMS 11.5.3.4.8(a)
ST	3848.450	[illegible]	ST	3860.352	API MPMS 11.5.3.4.8(a)
Lb	7696128.86		Lb	7720703.06	
US Gal @ 60 °F	2570720.51	[illegible]	m^3 @ 15 °C	9439.493	API MPMS 11.5.3.4.7 (a)
Bbl @ 60 °F	61207.63	[illegible]	L @ 15 °C	9,439,493.3	MT * 1000 / Abs Density at 15 °C

For intraconversion per API MPMS 11.5.3 to convert from 15 °C to 60 °F (15.5556 °C)		
C_{TL}	0.97002	= (fluid density 15.5556 °C / fluid density at 15 °C) from COSTALD

Table 8—Chemical Gas Example Calculation Method B

Table 8 (Method B) is an example calculation resulting in the total mass and volumes at certain base conditions based on tank capacity-correction for tank thermal expansion/contraction. This approach applies pressure and temperature correction factors to total tank capacity so it can be apportioned to the liquid and the vapor volume.

8 Measurement-related Operational Notes

8.1 General

Because of the wide variation in physical properties of hydrocarbon and chemical cargoes, special consideration shall be given to the properties of the cargo in question when performing measurement activities on board gas carriers and barges.

In addition, conditions existing at the time of measurement sometime require special attention to allow the task at hand to be performed properly. Some of those considerations are addressed in this section.

8.2 General Operations

8.2.1 General

The following operational items may have to be considered when measuring and/or accounting for cargo volumes. With vessels in continuous service carrying the same cargoes, most of these steps are only performed when cleaning tanks for repair, inspection, or shipyard visit.

However, on some vessels these operations are performed for each voyage. In some of these operations, some amounts of cargo volumes from ship's or shore tanks may have to be used and/or disposed of to accomplish the task. The following illustrates a typical cycle a vessel goes through during the loading and discharging process. It assumes that the vessel is at the beginning of a cycle, i.e. newly built, leaving dry dock or changing cargo service, and starts with tanks gas-free.

8.2.2 Tank Inspection

Tank inspection may be required prior to the commencement of the loading operations to ensure the tank is, in all respects, ready to receive, carry and discharge the cargo being shipped. The tank inspection verifies cleanliness and suitability for cargo and determines that there is no foreign material that will affect the operation and cargo handling. Refer to API MPMS Ch. 17.8 for further details.

For vessels in continuous service, this operation is normally carried out at the building yard/refit yard prior to it entering/reentering into service, since en route to the first loading port it would go through the drying/inerting cycles below. The tank shall be Certified Gas-free for tank entry. Refer to industry standards for safe operation such as *ISGOTT*.

NOTE Tanks equipped with bulkheads or baffles require a gas-free certificate for each space being entered.

8.2.3 Drying

The tanks shall be dried to remove moisture by using ambient or heated inert gas from the ship or shore and/or through use of an air-drying system.

8.2.4 Inerting

After the tanks have been approved for carriage of cargo, the oxygen should be removed from the tanks. This is done by inerting by displacement.

8.2.5 Gassing-up

Once the tank atmosphere is acceptable, inert gas shall be displaced with warm gas vapors of the cargo to be loaded. This vapor can come from the shore or from other tanks on the vessel.

8.2.6 Cool-down

For refrigerated and semi-refrigerated vessels, once the tank is "gassed-up" with the vapor of the cargo to be loaded the tanks shall be cooled down to an appropriate loading temperature, as set by operating parameters or contractual agreement, to prevent excessive cargo vaporization and undue stresses on vessel tanks and piping. This is usually achieved by receiving a quantity of cargo from the shore or from tanks on the vessel. Usually the tank(s) shall be cooled down before the quantity in the tank can be accurately determined. The method of cooling down the tanks and the source of the cargo used for the process should be noted and accounted for in the cargo inspection report.

8.2.7 Loading

Receiving cargo from the shore or lightering vessel usually causes vaporization of cargo in the tanks of the vessel being loaded. This cargo is usually vented to the shore or reliquefied by the vessel. The process of filling the tanks, capturing the vaporized cargo and handling it according to the policy of the terminal and requirements of the cargo continues until the vessel is loaded.

In addition, gas carriers and barges have filling limits as determined by the following formula from the IGC Code, as shown in Equation 3.

$$LL = \frac{FL \times \rho_R}{\rho_L} \quad (3)$$

where

LL is the % load limit;

FL is the filling limit (usually 98 %), see note;

ρ_R is the relative density of cargo at reference temperature;

ρ_L is the relative density of cargo at loading temperature and pressure.

The reference temperature for this formula is the temperature corresponding to the saturated vapor pressure of the cargo at the set pressure of the relief valves.

NOTE The IGC Code allows the vessel's flag administration to set a higher filling limit (FL) than the limit of 98 % specified at the reference temperature, taking into account the shape of the tank, arrangements of pressure relief valves, accuracy of level and temperature measurement and the difference between the loading temperature and the temperature corresponding to the saturated vapor pressure of the cargo at the set pressure of the pressure relief valve.

8.2.8 Cargo In-transit

During the transit from the load port to the discharge port, any vaporization of the cargo is either reliquefied or vented depending on vessel configuration and regulations.

8.2.9 Discharging of Liquid Cargo

Depending on the type of cargo and the vessel's trade, the cargo tanks will either be completely emptied or left with some cargo (ROB) still on board. In the latter case, the ROB should be compared to the on board quantity (OBQ) measured at loading to establish possible loss or gain.

8.2.10 Puddle Heating

Many refrigerated and/or pressurized gas carriers have puddle-heating coils on the bottom of the tanks that allows any remaining liquid cargo to be vaporized to empty the tanks.

8.2.11 Removing Vapor Left in Tank

Once all the liquid is vaporized, the remaining vapor shall be removed from the tanks if the next cargo is of a different grade and/or tanks are to be cleaned and entered. The first stage of this operation is usually filling the tanks with the appropriate type of inert gas. As the vapor in the tanks is also cargo, the amount of vapor shall be accounted for as well as where it went after it was removed from the tanks.

8.2.12 Aerating

If the tank is to be entered for inspection, the inert gas shall be removed and replaced by fresh air. Once this is performed the tanks may be entered upon issuance of the Gas Free Certificate and other safety precautions are taken and verified.

8.3 Measurement on Board Gas Carriers in an Exposed Environment

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 observed readings should be taken and averaged. The successive gauges shall be taken as quickly as is practical and a description and extent of the adverse measurement conditions recorded.

8.4 Vessels Not on Even Keel (Out-of-Trim)

Depending upon the shape of the tank and the location of the measurement points, liquid cargo may not be measurable at the usual gauge points prior to loading or after discharge when the marine tank vessel is not on even keel. In these circumstances, more extensive methods of liquid determination may have to 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. If the vessel's trim or list adversely affects measurement, note this on a Letter of Protest and notify the appropriate parties.

A vessel's trim and list shall be considered when the on-board cargo volumes are calculated. The ullages or innages that are taken or the volumes that are determined to be in the tanks shall be adjusted according to the instructions in the capacity tables. If no adjustments are available, a note to that effect should be made on the ullage report. Measurements may be mathematically adjusted if tank geometry permits, and the vessel measurements are known. Refer to C.8 for details.

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. For vessels with square tanks, when the cargo surface does not touch all bulkheads of the tank, wedge tables or a wedge formula may have to be used to determine the volumes present in the tank. On a prismatic or cylindrical tank, wedge or other appropriate tables supplied by the owner should be used to determine the volumes present in the tank.

8.5 Static Accumulator Cargoes

Some cargoes tend to accumulate a static charge during the loading or discharge process and may need a relaxation time for the charge to dissipate before measurement equipment can be safely introduced into the tank. 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*, ICS *Tanker Safety Guide* (Liquefied Gas), relevant SIGTTO publications and the cargo's SDS for full details.

Annex A

(informative)

Barge or Small Vessel Considerations

A.1 General

The measurement criteria in the foregoing sections of this standard should apply to all LPG and Chemical Gas carriers. However, it is recognized that some barges or small vessels may have fewer measurement devices than would be found on larger vessels. In this case, the tolerances and equipment below may apply.

For the purpose of this Annex, a barge is a marine vessel that is not self-propelled, a small vessel is a marine vessel that is self-propelled, and neither have reliquefaction capability on board.

A.2 Tank Capacity Tables

When the tank capacity tables for barges and small vessels do not meet the requirements in 5.5.2, a Letter of Protest noting the situation shall be documented and reported at the time of measurement.

When determining the suitability of the tank capacity tables, refer to the checklist in Annex D.

A.3 Measurement Device Tolerances

Automatic level gauging devices may be found on barges and small vessels. When this is the case, refer to the body of the document for the description and operation of radar, magnetostrictive, and float gauging devices. However, some barges and small vessels are equipped with other devices that do not meet the tolerances listed in Table A.1 for level measurement. Table A.1 provides the tolerances that can be expected for slip tube, rod-type magnetic and tape- type magnetic gauges.

Table A.1—Measurement Device Tolerances for Barges and Small Vessels

	Verification Tolerance	Display Resolution
Level Gauges		
Slip-tube gauge	12 mm (½ in.)	6 mm (¼ in.)
Rod-type magnetic gauge	6 mm (¼ in.)	3 mm (⅛ in.)
Tape-type magnetic gauge	12 mm (½ in.)	6 mm (¼ in.)
Pressure—analog	±20 kPa (2 psi)	10 kPa (1 psi)
Temperature—analog	±1 °C (2 °F)	0.5 °C (1 °F)

A.4 Manual Level Measurement Equipment

A.4.1 General

Manual level measurement technologies in use include, but are not limited to rod-type gauges, slip-tube gauges, and tape-type magnetic gauges and shall comply with the vessel's flag administration and classification society regulations.

A.4.2 Rod-type Magnetic Gauge

Rod-type magnetic gauging devices consist of a movable gauge rod with a magnet at the bottom of the rod and a float-magnet assembly that floats on the liquid surface that magnetically couples to the rod. See Figure A.1 and API *MPMS* Ch. 3.2 for details.

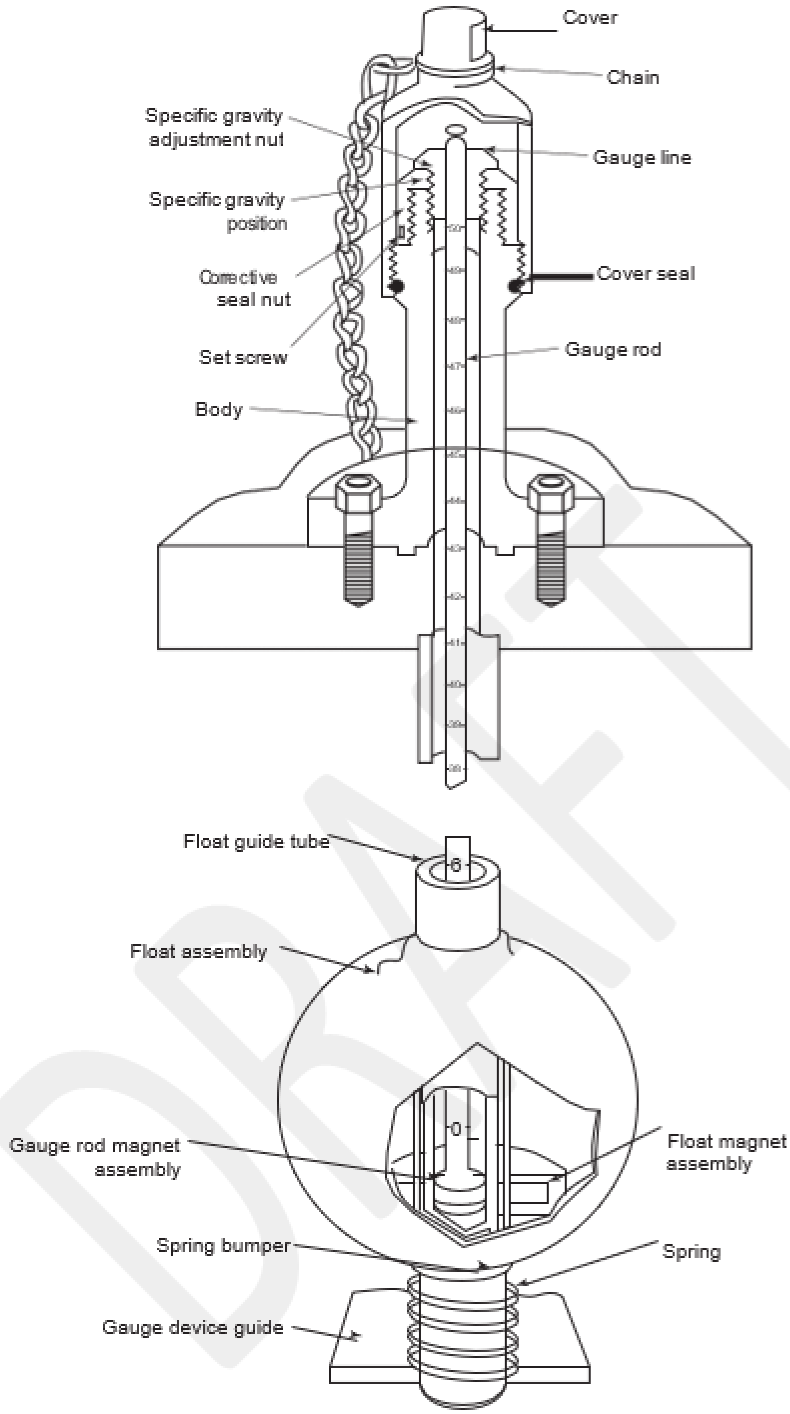

Figure A.1—Rod-type Magnetic Gauging Device

The level of the float on the liquid surface will change with a change in the density of the product being measured. Rod-type gauges shall have a relative density (specific gravity) adjustment scale to compensate for product density changes. Refer to the manufacturers' buoyancy correction for the level gauge. Refer also to Appendix D of API *MPMS* Ch. 12.1.2 for magnetic gauge offset determination.

The minimum liquid level required to lift the float may be 6 in. or more. The quantity of liquid below the minimum level cannot be measured with the magnetic level gauge.

A.4.3 Slip Tube

A slip tube is a restricted type of gauging device so named because a small amount of cargo vapor or liquid is released to atmosphere during level measurement. See Figure A.2. A slip tube has an orifice at its upper end through which liquid or vapor is released during gauging. The IMO Gas Codes limit the size of this orifice to 1.5 mm (1/16 in.) in diameter, unless an excess flow valve is fitted. The lower end of the slip tube is open to the cargo tank environment. The device slides up and down through a gland fitted in the tank dome. The observed differences between either liquid or vapor venting from the orifice gives an indication of when the liquid level has been reached and by reading the markings on the tube itself the actual liquid level is read. Because of the considerable depth of many tanks, there may be multiple slip tubes fitted to a tank to cover a specific range, such as upper, middle and lower tank levels.

A slip tube is the only level measurement method capable of gauging free water in the cargo tank.

A.4.4 Tape-type Magnetic Gauge

Tape-type magnetic gauging devices use a graduated tape in place of the rod-type gauge. See API *MPMS* Ch. 12.1.2 for the requirements regarding buoyancy correction and for the limitation on minimum measurable level.

Refer to Figure A.3 and API *MPMS* Ch. 3.2 for further details.

A.5 Manual Level Gauging Procedures

A.5.1 General

Where the gauge reference point to be used for quantity calculations is not clearly indicated on the tank capacity tables and there is more than one device in each tank, the level shall be read and recorded for all devices. Typically the reading from the device having the latest technology is preferred, but all readings should be evaluated against each other and against available historical records. The same gauging device should be used at the load port and the discharge port.

Manual gauging requires human input and/or interaction with the equipment to determine the liquid level. Such systems include the following.

A.5.2 Rod-type Magnetic Gauge

To use the rod-type magnetic gauging system, remove the protective cover and pull up on the gauge rod until magnetic linkage is felt. Read and record the gauge at the top of the relative density adjustment bushing, if so equipped.

A.5.3 Slip Tubes

The manufacturer’s instructions for location of the slip-tube gauge point, use of the equipment, and safe operation shall be followed. When all protective devices are released, the slip tube should slide into its sleeve. As the tube is lowered and the bottom of the tube reaches the liquid surface, liquid is forced out of the upper end of the tube by the tank pressure. The appearance of liquid indicates that the surface of the liquid has been contacted. Read the liquid level, to the nearest graduation, at the slip-tube gauge point specified by the manufacturer.

A.5.4 Tape-type Magnetic Gauge

The tape-type magnetic gauging device uses a graduated tape in place of the rod. Otherwise, the principle of operation is the same as in the rod-type magnetic gauge. Open the protective cover. Rotate the handwheel until magnetic linkage is felt, then read and record the gauge through the window at the top of the device.

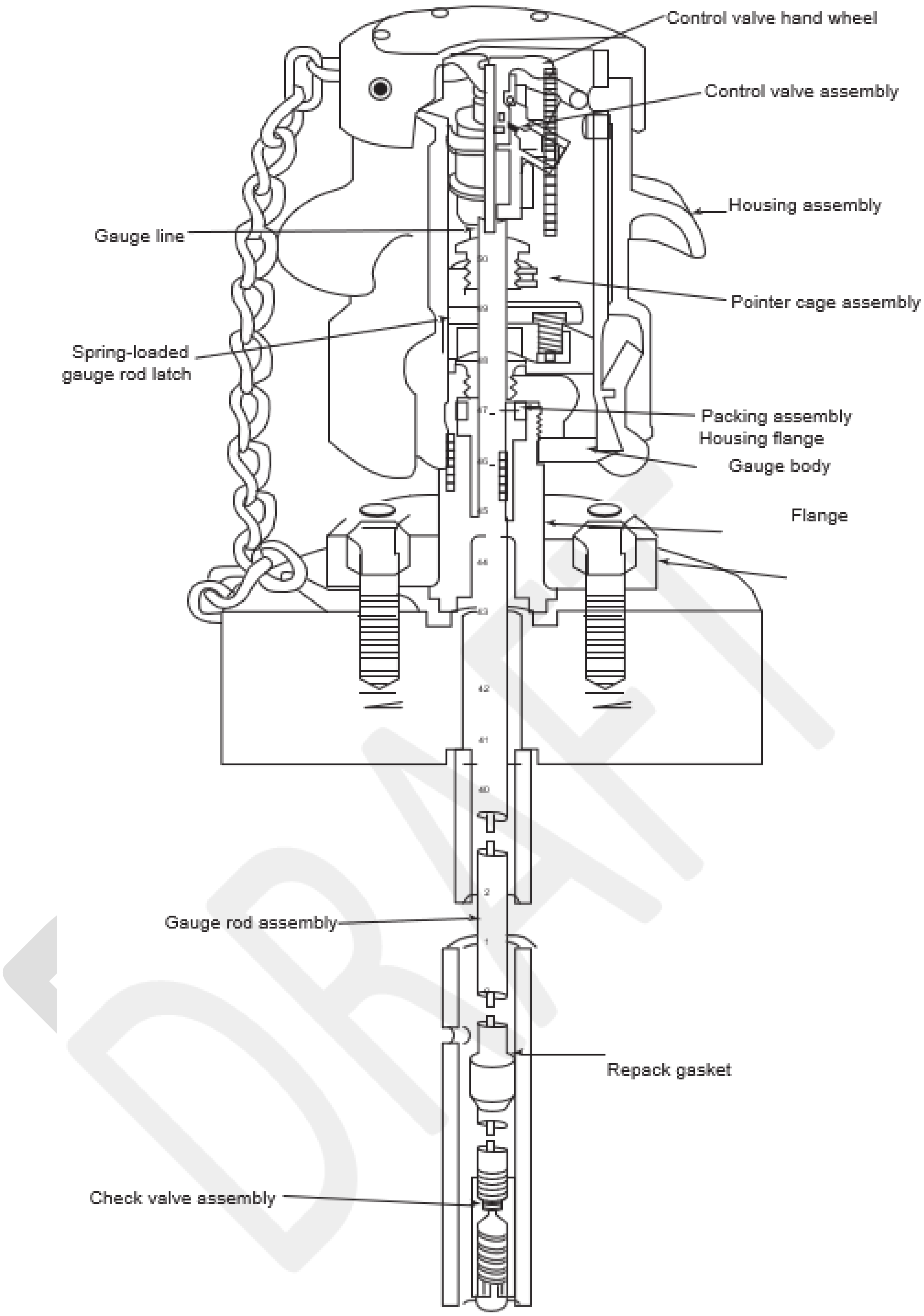

Figure A.2—Slip-tube Gauging Device with Quick-release Cover

Annex B

(informative)

Example Forms

B.1 General

The following example forms are designed to provide a standard comprehensive format to record and report essential data obtained during the marine cargo inspection procedure. The forms are designed to facilitate computation and thereby reduce computational errors and assist in checking for errors. The training of new measurement personnel is also facilitated through the use of standard forms. These forms are designed for simple voyage and as such may not be suitable for all contingencies. Measurement personnel may use other forms and explanations where required to fully document the transfer operation.

The following forms are freely offered to all companies to use, with or without company identification logos. Example forms:

— Figure B.1 Vessel Quantity Report ROB/OBQ

— Figure B.2 Report of Shore Quantity

— Figure B.3 Time Log

— Figure B.4 Vessel Discharge Record

— Figure B.5 Laboratory Report of Quality

— Figure B.6 Cargo Quantity Options Certificate

— Figure B.7 Sample Receipt

— Figure B.8 Letter of Protest and/or Notice of Apparent Discrepancy

Method A

VESSEL MEASUREMENT REPORT

Vessel		Cargo		Date / Time
Terminal		Client		
Port		Operation		

		Tank no.		1 Port	1 Stbd	2 Port	2 Stbd	3 Port	3 Stbd	4 Port	4 Stbd
1		Cargo Tank Capacity	m^3								
2		Molecular Mass									
3		Pressure, absolute	bar								
4		Temperature	°C								
5	V	Volume	m^3								
6a	A	Press. Corr. Fact. Ctsvp									
6b 7	P	Temp. Corr. Fact. Ctsvt									
8	O	Corrected Volume	m^3								
9	R	% Cargo									
10		Cargo Volume	m^3								
11		Density	kg/m³								
12		Mass	MT vac								
13		Temperature	°C								
14	L	Corr. Ullage	m								
15a 15b	I	Total Observed Volume	m^3								
16	Q	Pressure Corr. Fact. Ctslp									
17	U	Temp Corr. Fact. Ctslt									
18	I	Corrected Volume	m^3								
19	D	C_{TL}									
20		Cargo Volume	m^3								
21		Density	kg/m³								
		Mass liquid	MT vac								
		Total Mass	MT vac								

Atmospheric Pressure	bar		
Relative Density @ 60 °F			API MPMS 11.5.3.4.3
Draft Forward	m		
Draft Aft	m		
List	°		
Average Molecular Mass			
Shore Line Condition			
Average Absolute Density @ 15 °C			API MPMS 11.5.3.4.3
Vapor density source			
Liquid C_{TL}			
Lb/US Gal (Air)			API MPMS 11.5.3.4.10(c) API
Lb/US Gal (Vac)			MPMS 11.5.3.4.10(a)

In Air @ 60 °F		
Total on board		
MT		
LT		[illegible]
ST		[illegible]
Lb		
US Gal @ 60 °F		[illegible]
Bbl @ 60 °F		

In Vacuum @ 15 °C		
Total on board		
MT		
LT		SUM (E30:F30)
ST		API MPMS 11.5.3.4.9(a) API MPMS 11.5.3.4.8(a)
Lb		
m³ @ 15 °C		API MPMS 11.5.3.4.7 (a)
L @ 15 °C		MT * 1000 / Abs Density at 15 °C

	For interconversion per API MPMS 11.5.3 to convert from 15 °C to 60 °F (15.5556 °C)
C_{TL}	Table 54G - API MPMS 11.2.4

Figure B.1—Vessel Quantity Report ROB/OBQ

	S H O R E M E A S U R E M E N T R E P O R T			
Tank no.			Commodity	Butadiene
Terminal			Operation	
Port			Client	
Date			Client	
			OPEN	CLOSE
VAPOR	Capacity	Gal	642485.00	642485.00
	Cap. Shrinkage		1.000000	1.000000
	Corr. Capacity	Gal	642485.00	642485.00
	Pressure	Psi	21.40	17.00
	Vapor Temperature	°F	63.90	67.00
	Volume	Gal	76046.00	620467.00
	% Product		100.00	100.00
	Product Volume	Gal	76046.00	620467.00
	Vapor	Factor	0.00851	0.00896
	Volume @ 60°F	Gal	647.15	5559.38
LIQUID	Liquid Temperature	°F	63.90	67.00
	Ullage/Innage	Ft-In	16' 10 5/8"	35' 06 3/4"
	Side Gauge	Ref Only	0.0000	0.0000
	Volume	Gallons	566439.00	22018.00
	Shrinkage	Factor	1.000000	1.000000
	Corr. Volume	Gal	566439.00	22018.00
	Volume Correction	Factor	0.9963	0.9936
	Volume @ 60°F	Gal	564343.18	21877.08
	Total Vol @ 60°F	Gal	564990.33	27436.46

Figure B.2—Report of Shore Quantity

Time Log

Port / Terminal		Office	Ph
Vessel	Voyage #	Inspector(s)	
Date		File	
Cargo		Client	Ref

☐ At Loading ☐ At Transfer ☐ At Discharge

Date	Hour	
Delays and Stoppages		

Figure B.3—Time Log

VESSEL DISCHARGE RECORD

VESSEL:
PRODUCT:
LOCATION:

YOUR REF:
OUR REF:
DATE:

Date Time	Vessel Tanks	Gauge m	MT	Total MT	Total Per/Hr	Date Time	Vessel Tanks	Gauge m	MT	Total MT	Total Per/Hr	Date Time	Vessel Tanks	Gauge m	MT	Total MT	Total Per/Hr
4-13-07 2100	1c 2c	14.230 14.300	2316.00 2325.00	4641.00	4,641.00												
4-13-07 2200	1c 2c	14.000 14.100	2290.00 2294.00	4584.00	57.00												
4-13-07 2300	1c 2c	13.100 12.950	2200.00 2195.00	4395.00	189.00												
4-14-07 0000	1c 2c	12.500 12.200	2137.00 2122.00	4259.00	136.00												
4-14-07 0100	1c 2c	11.970 11.950	2045.00 2040.00	4085.00	174.00												
4-14-07 0200	1c 2c	11.250 11.200	1954.00 1945.00	3899.00	186.00												

COMPANY

Figure B.4—Vessel Discharge Record

Analysis Report

Vessel: Reference:

Product: Date:

Location:

Description:

Sample ID:

Sample Date:

Method / Test	Results	Units	Method / Test	Results	Units
ASTM D2163			**ASTM D5504**		
Composition			Hydrogen Sulfide	<0.1	ppmw
Ethane	2.74	Liq Vol%			
Propylene	0.09	Liq Vol%	**ASTM D1838**		
Propane	96.17	Liq Vol%	Copper Corrosion	1A	
Isobutane	0.61	Liq Vol%			
Normal Butane	0.20	Liq Vol%	**ASTM D2598**		
Trans-2-butene	0.07	Liq Vol%	Calculated vapor	187.1	psig
Cis-2-butene	0.06	Liq Vol%	pressure at 100 °F		
Isopentane	0.02	Liq Vol%			
Normal Pentane	0.02	Liq Vol%	**ASTM D2158**		
Hexanes & heavier	0.02	Liq Vol%	Residue on evaporation	0	mL/100mL
Total:	100.00		Oil stain	Passes	
			R Number	0	
Total Olefins	0.22	Liq Vol%	O Number	0	
			ASTM D1837		
			95 % Evaporation Temperature	-40	°C
			95 % Evaporation Temperature	-40	°F

Figure B.5—Laboratory Report of Quality

CARGO QUANTITY OPTIONS CERTIFICATE		
VESSEL:	DATE:	
TERMINAL:	PORT:	
	CARGO QUANTITY	
PRODUCT	SHORE ORDER	VESSEL REQUIRED
1)		
2)		
3)		
4)		
5)		
VESSEL REQUIREMENT ESTABLISHED BY VESSEL'S OFFICER.		
	INSPECTOR:	
	VESSEL'S OFFICER:	

Figure B.6—Cargo Quantity Options Certificate

Sample Report					
Vessel:			Reference:		
Product:			Date:		
Location:					
Quantity	**Location Taken**		**Distribution**	**Seal Number**	

Figure B.7—Sample Receipt

Port / Terminal		Office	Ph
Vessel	Voyage #	Inspector(s)	
Date		File	
Cargo		Client	Ref

☐ LETTER OF PROTEST (A)

☐ NOTICE OF APPARENT DISCREPANCY (B)

☐ At Loading ☐ At Transfer ☐ At Discharge | ☐ Shore ☐ Vessel

☐ To the Master and / or Owners and / or Agents of the Vessel:

☐ To the Terminal Representative of:

On behalf of our principal(s), we hereby notify you that on the (day of) (month) (year)

at (hr) the following was observed:

(A) Accordingly you may be held responsible for the loss and damage thereby sustained, as well as any consequential loss and damage arising therefrom.

(B) Accordingly you are hereby notified that further investigation is intended to resolve this discrepancy.

Receipt Acknowledged:

For Vessel	For Terminal	Inspector

Figure B.8—Letter of Protest and/or Notice of Apparent Discrepancy

Annex C
(informative)

Additional Instructions and Cautionary Notes

C.1 General

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

C.2 Different Types of Ships and Barges

C.2.1 General

There are various types of ships and barges used to carry refrigerated/pressurized cargoes. 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. Before going on board, it should be determined whether it is a pressurized, refrigerated or combination type vessel. This will assist in the type of equipment to be used. When going on board a vessel for the first time, the vessel's general arrangement plans should be reviewed to see where all the tanks and measurement points are located.

C.2.2 Fully Pressurized Vessels

These types of vessels carry their cargoes at ambient temperature. They are fitted with Type "C" pressure tanks having a typical design gauge pressure of about 1800 kPa and several vessels have design gauge pressures up to about 2000 kPa. Therefore, no thermal insulation or reliquefaction capability is needed. The design pressure of their tanks makes them very heavy and as a result these types of vessels tend to be small and in the 500 m^3 to 5000 m^3 range. They are used primarily to carry LPG and ammonia cargoes. As their cargoes are at ambient temperature, the cargo temperature might be different at discharge than at load and special allowances should be made when this occurs. When equipped with a loading heater, these ships can load from a fully refrigerated terminal.

C.2.3 Semi-pressurized/Semi-refrigerated Vessels

Semi-pressurized ships have Type "C" tanks usually designed for a maximum working gauge pressure up to 800 kPa. The tanks have a reduced wall thickness due to the reduced pressure requirements but as the cargoes are carried at a colder temperature the tanks shall have insulation and the vessel may have refrigeration/reliquefaction capability. This type of vessel usually carries a variety of cargoes such as LPG, vinyl chloride, propylene, ethylene, and butadiene. This type of ship is the most popular of the smaller size vessels because of its cargo handling flexibility. The capacities of these vessels usually range in size from 2000 m^3 to 20,000 m^3.

The tanks on these types of vessels are usually made from low temperature steels to provide for carriage temperatures of –48 °C, which is suitable for most LPG cargoes. They can also be made from special alloyed steels or aluminum to allow for the carriage of ethylene at –104 °C (see also ethylene ships). This type of vessel can load from or discharge to either pressurized or refrigerated storage facilities.

C.2.4 Ethylene Vessels

Ethylene ships are usually specially built for specific ethylene trades but may also routinely carry LPG cargoes. Ethylene is normally carried in its fully refrigerated condition at its atmospheric boiling point of –104 °C. Normally, Type "C" pressure tanks fitted with thermal insulation are used on these types of vessels. A high-capacity reliquefaction system is also necessary. These vessels are usually small and in the size range of from 1000 m^3 to 12,000 m^3.

Fully refrigerated vessels carry their cargoes at approximately atmospheric pressure. They are designed to transport large quantities of LPG and ammonia and usually range in sizes from 20,000 m^3 to 85,000 m^3.

Some of the medium sized vessels are also certificated as an oil tanker and may carry clean petroleum products when they are not carrying the refrigerated cargoes.

A typical fully refrigerated ship has up to six cargo tanks. Each tank is fitted with transverse wash plates, while a longitudinal bulkhead on the centerline is provided to reduce free surface so improving ship stability. The tanks are usually supported on wooden chocks and are keyed to the hull to allow for expansion and contraction as well as to prevent tank movement under static and dynamic loads. The tanks are also provided with anti-flotation chocks to avoid lifting in case of ballast tank leakage. Because of the low-temperature carriage conditions, thermal insulation and reliquefaction equipment shall be fitted.

To improve a fully refrigerated ship's operational flexibility, cargo heaters and booster pumps are often fitted to allow discharge into pressurized storage facilities. This will normally be accomplished at reduced discharge rates.

Where Type "A" tanks are fitted, a complete secondary barrier is required. The hold spaces must be inerted when carrying flammable cargoes. Ballast is carried in double bottoms and in topside (saddle) tanks or, when fitted, inside ballast tanks.

C.3 Types of Cargo Tanks

C.3.1 General

Refrigerated and pressurized gas carriers require tanks as based on the type of cargo they are designed to carry and as specified by the IMO Gas Codes. The tank types as defined by the Codes are as follows.

C.3.2 Integral Tanks

Integral tanks form a structural part of the ship's hull and are influenced in the same manner and by the same loads that stress the adjacent hull structure. Integral tanks should normally not be pressurized in excess of 25 kPa (gauge) and may be used for products provided the boiling point of the cargo is not below –10 °C.

C.3.3 Independent Tanks

C.3.3.1 General

Independent tanks are self-supporting; they do not form part of the ship's hull and are not essential to the hull strength. There are three categories of independent tanks.

C.3.3.2 Type "A" Tanks

Tanks that are designed primarily using recognized standards or classical ship-structural analysis procedures.

C.3.3.3 Type "B" Tanks

Tanks that are designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics.

C.3.3.4 Type "C" Tanks

These are tanks meeting pressure vessel criteria and having a specified design vapor pressure. They are also referred to as pressure vessels.

C.4 Training

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

Although this publication describes procedures 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 or other relevant industry standards and recommended practices such as those found in ISO, GPA, OCIMF, and/or SIGTTO publications. Appropriate training in shipboard operations and safety practices should be provided to all personnel working on board any vessel.

C.5 Discrepancies between ATG Readings and Reference Measurements

Certain ATGs have procedures for verifying ATG readings at fixed reference points. As an example, for float gauges this may be at the fully retrieved position and the maximum extended gauge position. The reading for each ATG check position should be compared to the printed reference measurement shown in the vessel's calibration tables or other manufacturer's documentation.

ATG observed readings at the fixed reference point should be recorded and compared for each tank with any differences and reasons for them noted on the inspection report. If the value for a fixed reference point is not specified in the capacity tables, a note should be included in the cargo documents indicating how it was obtained.

C.6 Lack of and/or Poor Maintenance of Equipment

Before any custody transfer occurs, vessel operators, cargo inspectors, customs officials, and others involved in marine bulk cargo transactions shall be made aware of the specific requirements for, and the condition of, all measuring equipment and devices used in the transfer.

C.7 Failure of Measurement Equipment

Equipment that is known to be defective, out of calibration, or in poor operating condition shall not be used. Should the vessel's primary measurement equipment, such as temperature, pressure or level gauges, fail, a verified secondary system may be used. If there is no secondary system available, all parties shall be notified and alternate methods used as agreed.

If the comparison of measurements fail to meet the expected error as determined by the root sum squared combination of measurement uncertainties, using uncertainties established in this standard, or by other mutual agreement, a Letter of Protest should be filed and steps should be taken to verify the performance of the two systems. For statistical evaluation, refer to API *MPMS* Ch. 13.1.

C.8 Draft Readings and Trim and List Corrections

C.8.1 General

Draft readings are used to determine the following:

a) the depth of the vessel in the water;

b) the trim and list of the vessel;

c) whether the vessel is loaded correctly.

Draft marks are displayed in U.S. Customary or SI units. The numerals for USC units are 6 in. high and are spaced 6 in. apart. Readings are made from the bottom of the numerals and estimated to the inch (see Figure C.1).

Figure C.1—Draft Readings: U.S. Customary Units

The numerals for SI units are displayed in even decimeters, are 10 cm high, and are spaced 10 cm apart. Readings are made from the bottom of the numerals and estimated to the centimeter (see Figure C.2).

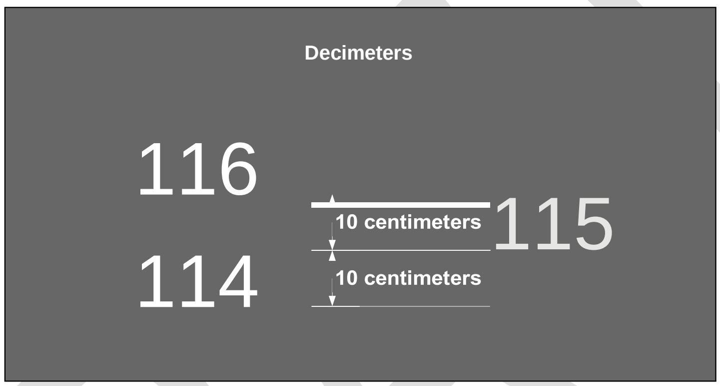

Figure C.2—Draft Readings: SI Units

Vessel draft readings should be physically observed. However, if this is not possible, draft may be determined using automatic draft measuring systems, e.g. pressure sensors or electro-pneumatic systems. The method of obtaining draft should be recorded in the cargo documentation.

C.8.2 Determination of List

All attempts should be made to correct any list the vessel may have prior to taking measurements. If this cannot be done, a vessel's list can be accurately determined in two ways:

a) by reading the appropriate clinometer on the vessel's centerline; or

b) by reading the differences between starboard and port drafts and calculating the list.

When a vessel is not on even keel at the time of gauging, the vessel's trim or list shall be taken into account to accurately determine the liquid volumes on board. To do so, the instructions found in the vessel's trim/list tables shall be followed to make the required adjustments for any trim or list noted. If the vessel does not have such trim or list tables, apply the appropriate correction as per API *MPMS* Ch. 17.4

Because a clinometer measures list/trim only at its installed location, physical draft readings may be more reflective of the overall list/trim of the vessel.

C.8.3 Determination of Trim and List by Mechanical Devices

Most vessels have systems for measuring vessel trim and list by mechanical devices such as clinometers (trim and list) or draft gauges. When used for level correction, such devices should be verified when the vessel is at even keel in dry dock or appropriately versus manual draft measurements.

C.9 Vessel Experience Factor (VEF)

C.9.1 General

VEF for these vessels can be determined using the principles in API *MPMS* Ch. 17.9. VEF shall consider both the vapor and the liquid quantities. However, due to the nature of these cargoes, the following factors make it more difficult to meet the requirements of a qualifying voyage as described in Ch. 17.9:

- lack of a uniform calculation methodology port-to-port;
- variable vapor quantification during loading/discharging;
- the conditions of the vessel;
- the conditions of the shore;
- bill of lading source information not verifiable or incorrectly represented; and
- the availability of valid and reliable information.

C.9.2 ROB/OBQ vs Heel

Heel is the quantity of cargo remaining on board (ROB) that is used to maintain the desired temperature and gaseous state in the cargo tank to be in a suitable state to load upon arrival. This quantity is variable. A comparison of heel after discharge to the heel prior to the next loading may be required.

C.9.3 Reconciling Shore Quantities

Isolate the tank(s) and lines involved in the transfer from the rest of the facility. At the time of gauging before and after the transfer, stop the movement of liquid and vapor into, out of, or within the shore tank(s) and shut down compressors and refrigeration equipment during the gauging process. If a condition cannot be met, it should be noted and a letter of protest filed.

C.10 Verification Capabilities

Verification before each use provides confidence in the measured values. Each device should be verified prior to use for custody transfer. Many times, this may not be technically feasible because valves or other devices are not currently fitted in a way that would allow for an independent measurement standard. When a device is unable to be verified, a letter of protest may be used to document the condition.

Verification should encompass the entire system from the source device through the final readout device. Verification is a process that compares the measured value from the device in service to an independent measure of that is traceable to a national metrological institute and has lower uncertainty than the device under test. For instance, the pressure indicated by a transmitter in service on the tank is be compared to the pressure measured using a certified pressure gauge. The difference between the two readings is compared to the tolerance listed in Table 1. If the difference exceeds the tolerance, the device should be calibrated. After calibration, the device is again compared to the known standard and verified to produce results within the acceptable tolerance.

Similarly, each measured temperature sensor is compared to the temperature measured by an independent device at the same or similar conditions experienced in service.

Level gauge verification requires independently determining the distance from the tank gauge reference height to the level and comparing that reading to the level gauge under test. The independently determined distance may require correction for temperature effects, trim, list, and the location of the test port.

In addition to verifying the intrinsic measurement of level, pressure, and temperature, the user may also choose to verify the tank capacity table and the gauge reference height.

C.11 Comparison Capabilities

Comparison is between similar devices, for instance the comparison between a primarily level gauge in a tank to the secondary level gauge in the same tank provides information that can indicate that both are functional. It may also provide a level of confidence that the result is correct. In addition, comparing temperature sensors within the same tank can be useful.

Annex D
(informative)

Checklists

Table D.1—Marine Measurement Checklist

Inspector:	______________	**Vessel Name:**	______________
Load Port:	______________	**Port Name:**	______________
Discharge Port:	______________	**Cargo(es):**	______________
		Date:	______________

LPG/Chemical Gas Inspection Checklist

If an item listed below was completed in accordance with the procedures, check "yes" and supply details as required; if not, check "no" and explain under the comment section. Check "N/A" if an item is not applicable.

#	Item	Yes	No	N/A	Comments & Details
Vessel particulars					
1	Vessel name				
2	Type or classification of vessel				
3	Flag/registry/class				
4	Tank(s) configuration (number and design)				
5	Cargo tank(s) segregation / Vapor segregation				
6	Cargo (to be loaded/discharged)				
7	Quantity (including appropriate min/max and stops)				
8	Quality (source of analysis)				
9	Inspection company in attendance				
10	Sea conditions (for offshore activities)				
Key Meeting (Pre-transfer conference): Shore before loading/discharge operations					
11	Previous cargo in shore line(s)				
12	Line preparations made (purged, cleaned, laid-down, cooled-down etc.)				
13a	Line sizes; vapor				
13b	Line sizes; liquid				
14a	Shore tanks to be utilized (number and type)				
14b	Date of last tank(s) calibration				
14c	Certificates available				
15a	Shore meter(s) to be utilized (number and type)				
15b	Date of last proving				
15c	Shore density meter (densitometer) to be utilized (number and type)				

15d	Date of last calibration				
16a	Type of shore tank(s) level gauging equipment used				
16b	Date of last calibration				
16c	Type of shore tank(s) temperature equipment used				
16d	Date of last calibration				
16e	Type of shore tank(s) pressure equipment used				
16f	Date of last calibration				
17	Was cargo to be sampled adequately circulated?				
18	Sample(s) taken (number and type)				
19	Sampling equipment / source				
20	Sample(s) analyses to be performed				
21	Shore flare to be used during cargo transfer?				
22	Flare measurement and sampling capabilities				
23	Personnel in attendance—key meeting (and role/position)				
Key Meeting (Pre-transfer Conference); Vessel before Loading/Discharge Operations					
24	Obtain last 3 cargoes, verify compatibility with nominated cargo				
25	Stowage arrangements this voyage				
26	Cargo tank(s) preparations made (purged, cleaned, method of cleaning etc.)				
27a	Cargo tanks cooled and ready to load?				
27b	If no, has gas-up and cool-down quantity been determined?				
28	Were cargo lines adequately cooled?				
29a	Tank capacity tables				
29b	Date of last calibration				
29c	Certified by what metrological body?				
29d	Separate certified tables available for primary/secondary measurement systems?				
30	Was physical and visual inspection of cargo tank(s) required?				
31	Intended pumping rate and any restrictions				
Primary Vessel Measurement System					
32a	Cargo tank(s) level gauges				
32b	Date of last calibration and last verification				
32c	Temperature equipment (type and number)				
32d	Date of last calibration and last verification				
32e	Pressure devices (type and number)				
32f	Date of last calibration and last verification				
32g	Secondary vessel measurement system				
32h	Cargo tank(s) level gauges				
32i	Date of last calibration and last verification				

32j	Temperature equipment (type and number)				
32k	Date of last calibration and last verification				
32l	Pressure devices (type and number)				
32 m	Date of last calibration and last verification				
33	Inquire about antifreeze at last port/ this port				
34	Was cargo to Be sampled adequately circulated and/or mixed?				
35	Sampling				
36	Sample(s) taken (number and type)				
37	Sampling equipment/source				
38	Sample(s) analyses to be performed				
39	Personnel in attendance—key meeting (and role/position)				
Opening Survey					
Shore Measurements					
40	Confirm the tank(s) involved in the transfer are isolated from the facility.				
41	Confirm that no liquid or vapor is being moved into, out of, or within the shore tank(s) and that compressors are not in use				
42	All shore tank(s) measurements taken as per industry standards				
43	All level gauge readings, temperatures and pressures recorded				
44	Opening meter readings recorded				
45	Cargo density, relative density and molecular weight provided				
46	Source of analytical data				
47	Opening calculations made prior to transfer				
48	Any necessary stop gauges set and confirmed with terminal personnel				
Vessel Measurements					
49	Confirm that no liquid or vapor is being moved into, out of, or within the vessel and that compressors are not in use				
50	All level gauge readings, temperatures and pressures recorded				
51	All vessel tank(s) measurements taken as per industry standards				
52	Vessel trim and list recorded				
53	Cargo density, relative density and molecular weight provided				
54	Source of analytical data				
55	Opening calculations made prior to transfer				
56	Intransit differences between load and discharge ports checked and within normal tolerance				
57	Any abnormally high intransit difference investigated				

58	Any necessary stop gauges set and confirmed with the vessel personnel				
During Cargo Loading/Discharge Operations					
59	Was the transfer continuous throughout				
60	Any delays or stoppages noted				
61	Was the cargo transferred at the contractually agreed temperature and rate				
62	Were meters proved/ witnessed during movement if used				
63	Shore flare used at any time				
64	Duration of flaring				
65	Any other incidents noted that may have affected measurement accuracy				

Closing Survey					
Shore Measurements					
66	Confirm the tank(s) involved in the transfer are isolated from the facility.				
67	Confirm that no liquid or vapor is being moved into, out of, or within the shore tank(s) and that compressors are not in use				
68	All shore tank(s) measurements taken per industry standards				
69	All level gauge readings, temperatures and pressures recorded				
70	Closing meter readings recorded/ copy of reports obtained				
71	Final calculations made on completion of transfer				
72	Did the terminal meet the agreed stop gauge				
Vessel Measurements					
73	Confirm that no liquid or vapor is being moved into, out of, or within the vessel and that compressors are not in use				
74	All vessel tank(s) measurements taken per industry standards				
75	All level gauges readings, temperatures and pressures recorded				
76	Vessel trim and list recorded				
77	Final calculations made on completion of transfer				
78	Did the vessel meet the agreed stop gauge				
79	ROB left on Board or were vessel tanks completely emptied				
Cargo Loading/Discharge Custody Transfer Reconciliation					
80	Vessel and shore quantities within acceptable variation				
81	Any Incident(s) or occurrence(s) noted that may have affected measurement accuracy				

82	Did ROB/OBQ measurement variance exceed acceptable limits?				
If the measured quantities are outside Acceptable Limits;					
83	Were the shore and vessel measurements re-inspected				
84	Were all calculations re-checked and agreed				
85	Was a Letter of Protest or Notice of Apparent Discrepancy issued				
Comments:					

Annex E
(informative)

Physical Characteristics and Fire Considerations

Personnel involved in the handling of liquefied gases, should be familiar with their physical and chemical characteristics, including potential for fire, explosion, cryogenic burns (frostbite), 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.

The SIGTTO publication *Liquefied Gas Fire Hazard Management*, should be consulted to ensure familiarity with characteristics and hazards of LPG and chemical gas cargoes, all fire protection and firefighting equipment on board refrigerated and/or pressurized gas carriers and the appropriate fire hazard management plan.

API Publ 2217A, *ISGOTT*, and any applicable regulations should be consulted when entering into confined spaces.

Information regarding particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the safety data sheet.

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