Voyage Analysis and Reconciliation of Cargo Quantities

1 Scope

This standard covers guidelines for the reconciliation of marine cargo quantities. These guidelines are intended to provide a basis for analyzing and reconciling the quantity differences (gains/losses) resulting from marine custody transfer movement(s) of bulk liquid hydrocarbon cargoes (e.g. crude oil, petroleum products, liquid chemicals, bio-feeds, bio-fuels, and liquid petroleum gases). As such, the guidelines are complementary to, but do not replace, normal inspection procedures.

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.

The following documents may be referenced to supplement the information presented in this chapter:

2.1 API/EI Joint Documents

API *MPMS* Chapter 17.6/EI HM70, *Guidelines for Determining the Fullness of Pipelines Between Marine Vessels and Shore Facilities*

API *MPMS* Chapter 17.9/EI HM49, *Vessel Experience Factor*

2.2 API Documents

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

API MPMS Chapter 17.3, *Guidelines for Identification of the Source of Free Waters Associated with Marine Petroleum Cargo Movements*

3 Definitions

For the purposes of this document, the following definitions, acronyms, and abbreviations apply.

3.1 Terms and Definitions

3.1.1
apparent loss
A difference in quantity that is not related to a physical loss.

3.1.2
cargo reconciliation
Independent comparison of quantity delivered to a vessel calculated from shore measurements to the quantity received by the vessel calculated from vessel measurements with the goal of achieving relative agreement.

3.1.3
complex voyage
Any voyage other than a single-grade cargo movement from one load port to one discharge port.

3.1.4
physical loss or gain
An actual loss/gain of cargo (sometimes referred to as “real loss/gain”).

3.1.5
simple voyage
A single-grade cargo movement from one load port to one discharge port.

3.1.6
theoretical discharge port shore quantity
The vessel delivered quantity (TCV–ROB) divided by the vessel's experience factor (VEF).

3.1.7
theoretical load port shore quantity
The vessel received quantity (TCV–OBQ) divided by vessel's experience factor (VEF).

3.1.8
total calculated volume
TCV
The gross standard volume (GSV) plus the free water (FW).

3.1.9
vessel experience factor
VEF
A compilation of the history of the total calculated volume (TCV) vessel measurements, adjusted for onboard quantity (OBQ) or remaining onboard (ROB), to the TCV shore measurements. Separate VEF's should be developed for both load and discharge terminals. Preferably, information used in calculating a VEF should be based on documents that follow accepted industry standards and practices, such as inspection company reports.

3.1.10
vessel-to-vessel transfer
The movement of cargo from one vessel to one or more other vessels.

3.1.11
volume correction factor
VCF
The ratio of the density of a liquid at a given temperature and pressure to its density at a reference temperature and pressure.

3.1.12
voyage analysis report
VAR
A report allowing for consistent organization and calculation of basic marine cargo data.

3.2 Acronyms and Abbreviations

ANP Brazilian National Agency of Petroleum, Natural Gas and Biofuels

API American Petroleum Institute

ASTM ASTM International[1]

COW crude oil washing

EI Energy Institute

FW free water

GOST standards administered by the Euro-Asian Council for Standardization, Metrology and Certification

[1] Formerly the American Society for Testing and Materials

GSV gross standard volume

ISO International Institute for Standardization

MPMS Manual of Petroleum Measurement Standards

NSV net standard volumes

OBQ on-board quantity

PVV pressure-vacuum vent

ROB remaining on-board

S&W sediment and water

TCV total calculated volume

VAR voyage analysis report

VCF volume correction factor

VDR vessel discharge ratio

VEF vessel experience factor

VEFD vessel experience factor discharge

VEFL vessel experience factor load

VLR vessel load ratio

4 Cargo Reconciliation

4.1 General

Each marine custody transfer should have a cargo reconciliation performed. The primary steps for marine cargo reconciliation are:

— collecting data;

— calculating the loss or gain by completing the VAR;

If a marine voyage results in a loss or gain outside established or contractual tolerances, the following additional steps are:

— investigating and documenting the reason(s) for the loss or gain;

— taking action where appropriate.

Users of this document shall conform with API MPMS Ch. 17.1 as appropriate.

4.2 Simple Voyages

A *simple voyage* is a single-grade cargo movement from one load port to one discharge port.

For a simple voyage, only one VAR form is needed, and it will cover the loading, the discharge, and a summary of the voyage.

4.3 Complex Voyages

A *complex voyage* involves the shipment of one or more grades of cargo at one or more load or discharge ports.

Complex voyages may require the use of multiple VAR forms that are analyzed collectively.

4.3.1 Collecting Information and Data

This first step consists of gathering all relevant vessel and shore measurement data. This will include the official custody transfer data, together with reports and supporting documentation from the independent inspection company. These are the main sources for measurement and calculation data.

Typical marine transfer inspection reports include shore gauging, metering, vessel gauging, time log, line fill verification, laboratory analysis, and VEF. (See relevant API *MPMS* Chapter 17.9/EI HM49, *Vessel Experience Factor* sections for a complete list of information that should be included in inspection reports.)

Any event that occurred during a loading or discharge may have been reflected in the terminal or vessel time log, and possibly in a letter of protest or notice of apparent discrepancy. This documentation should be reviewed as part of any loss investigation.

Important information that could affect measurements may need to be collected from other sources. This can include but is not limited to terminal ATG readings, remote temperature readings, product movement logs, vessel bunker reports, cargo stowage changes, trim and list condition of the vessel, and weather/sea conditions.

4.4 The Voyage Analysis Report (VAR)

4.4.1 General

The VAR provides a useful format for the organization of cargo data and provides calculations recommended in this procedure. Any shore-to-shore variances are broken down according to total calculated volume (TCV), free water (FW), gross standard volumes (GSV), sediment and water (S&W), and net standard volumes (NSV) during each stage of the voyage. As an alternative, the VAR may be performed in weight or mass.

A blank example of the VAR form is provided in Annex A. It is recognized that other forms may be used for this purpose.

The remainder of Section 4 provides instructions for completing a VAR and discusses voyage summary and reconciliation.

If more than one port or cargo is involved, complete a separate VAR form for each parcel, for each movement, and for the total shore/vessel figures (including slops and all previously loaded parcels).

The VAR is divided into six sections:

Header—General Information (vessel and cargo identification, VCF tables used, etc.).

Section I—Comparison of Shore Quantities in Custody Transfer (Load vs. Discharge Port).

Section II—Vessel/Shore Quantities at Load Port(s).

Section III—Vessel/Shore Quantities at Discharge Port(s).

Section IV—Vessel's Comparison of Loading and Discharge Port(s).

Footer—Comments and Signatures.

4.4.2 Header—General Information

The header section of the VAR includes identifying information such as vessel name and related vessel information, cargo description and quantity units, port names and dates, and the source of VCFs used to calculate shore and ship quantities at loading and discharge.

The VCF sources used should be compared and, if they are not the same, quantities should be recalculated using the discharge port VCF before completing the VAR.

4.4.3 Section I—Comparison of Shore Quantities in Custody Transfer

Section I of the VAR records the loaded cargo quantity (bill of lading) and the discharged quantity (outturn).

The reported outturn quantities from the discharge port(s) should be compared with the reported bill of lading quantities from the load port(s). The bill of lading API gravity or density should be compared with the outturn API gravity or density.

Any quantity difference is referred to as the shore-to-shore gain or loss for the shipment and is used as the primary indicator of whether a more in-depth analysis is required. The user's gain or loss experience with a particular cargo or trade route may determine if the particular shipment gain or loss is considered to be acceptable or excessive. A summary of the calculations for these shore-to-shore comparisons is shown below:

Equation 1: TCV Difference = Outturn TCV – Bill of Lading TCV

Equation 2: FW Difference = Outturn FW – Bill of Lading FW

Equation 3: GSV Difference = Outturn GSV – Bill of Lading GSV

Equation 4: S&W Difference = Outturn S&W – Bill of Lading S&W

Equation 5: NSV Difference = Outturn NSV – Bill of Lading NSV

NOTE Differences should be noted in both quantities and percentages.

4.4.4 Section II—Vessel/Shore Quantities at Load Port(s)

Section II records the vessel and shore quantities at the load port. This section will show any difference between vessel and shore quantities at the load port and will also allow the calculation of a theoretical load port shore quantity.

Compare these values by subtracting the bill of lading quantities from the corresponding vessel quantities to obtain the difference in each. For this comparison, the vessel loaded quantity is the quantity gauged (TCV) on board after loading minus any OBQ measured on board before loading.

A summary of the calculations for these vessel-to-shore at load port comparisons is shown below:

Equation 1: TCV Difference = Vessel Loaded TCV – Bill of Lading TCV

Equation 2: FW Difference = Vessel Loaded FW – Bill of Lading FW

Equation 3: GSV Difference = Vessel Loaded GSV – Bill of Lading GSV

Equation 4: TCV: VEF Adjusted Difference = Theoretical Shore TCV – Bill of Lading TCV

NOTE Differences should be noted in both quantities and percentages. It should be recognized that a total water comparison (FW + S&W) may be necessary to validate the FW difference.

4.4.5 Section III—Vessel/Shore Quantities at Discharge Port(s)

Section III records vessel and shore quantities at the discharge port. This section will show any difference between vessel and shore quantities at the discharge port and will allow the calculation of a theoretical discharge port shore quantity.

Compare these values by subtracting the outturn quantities from the corresponding vessel quantities to obtain the difference in each. For this comparison, the vessel discharge quantity is the quantity gauged (TCV) on board before discharge minus any ROB measured on board after discharge.

A summary of the calculations for these shore-to-vessel at discharge port comparisons is shown below:

Equation 1: TCV Difference = Outturn TCV – Vessel discharged TCV

Equation 2: FW Difference = Outturn FW – Vessel discharged FW

Equation 3: GSV Difference = Outturn GSV – Vessel discharged GSV

Equation 4: TCV: VEF Adjusted Difference = Outturn TCV – Theoretical outturn TCV

NOTE Differences should be noted in both quantities and percentages. It should be recognized that a total water comparison (FW + S&W) may be necessary to validate the FW difference.

4.4.6 Section IV—Comparison of Vessel Quantities at Load and Discharge Port(s)

Section IV records the reported vessel's quantity on departure at the load port and on arrival at the discharge port, and will show any change in cargo quantity during transit.

Calculate the vessel's transit quantity difference by subtracting vessel quantities at sailing port from arrival port quantities. Compare quantities for each parcel and for the total vessel.

A summary of the calculations for these vessel transit comparisons is shown below:

Equation 1: TCV Difference = Vessel arrival TCV – Vessel sailing TCV

Equation 2: FW Difference = Vessel arrival FW – Vessel sailing FW

Equation 3: GSV Difference = Vessel arrival GSV – Vessel sailing GSV

NOTE Differences should be noted in both quantities and percentages. For this comparison, no adjustments are to be made to vessel quantities for OBQ or ROB.

Calculate the OBQ and ROB difference, by subtracting the components of the ROB from the components of the OBQ.

A summary of the calculations for the OBQ, ROB, and Combined comparisons is shown below:

Equation 1: FW Difference = Total OBQ FW – Total ROB FW

Equation 2: GSV Difference = Total OBQ GSV – Total ROB GSV

Equation 3: Combined Difference = Total OBQ (FW + GSV) – Total ROB (FW + GSV)

4.4.7 Adjusted TCV Difference and S&W at Load/Discharge Ports

Calculate TCV difference adjusted by OBQ and ROB:

Adj TCV Difference = TCV – OBQ + ROB

Calculate %S&W at Load and %S&W at Discharge:

%S&W = S&W/GSV x 100

Adjusted TCV and %S&W can provide information on the potential source of loss/gain

4.4.8 Footer: Comments and Preparer's Identification

In the footer, summarize any appropriate comments that pertain to the movement, especially letters of protest (LOP) or notices of apparent discrepancy (NOAD). Enter the name, title, and company of the person preparing the VAR, and the date of preparation.

4.5 Voyage Summary and Reconciliation

A voyage should be summarized and reconciled by consolidating the reported facts from all associated VARs, together with any relevant background information, to explain the reason(s) for the voyage gain or loss.

If a gain or loss on any VAR(s) are out of tolerance, a reconciliation should be carried out, in which specific relevant factors are reviewed to evaluate each gain or loss difference identified. Whenever possible, the differences should be quantified by volume. The total of the reconciliation volumes should approximately equal the total NSV gain or loss for the movement.

All quantity calculations, measurements, or testing methods used in this reconciliation that are not based on recognized standards should be fully explained, referenced, or documented.

5 Possible Causes of Losses or Gains

5.1 General

The factors that may contribute to cargo measurement differences during a marine custody transfer movement are discussed below. When any of these factors are used or quantified in performing a voyage analysis, reasons for doing so should be supported. Their impact on the entire movement should be considered.

NOTE Marine transportation product loss/gain is defined as the difference between the net cargo quantity measured at the receiving terminal and the net cargo quantity measured at the loading terminal. This can be in volume or in weight. A loss will have a negative sign as follows in the equation below:

*Net Difference (%) = ((Outturn Net Quantity – Bill of Lading Net Quantity) / (Bill of Lading Net Quantity)) * 100*

Due to measurement uncertainties and other practical limitations discussed below, there will be differences between the quantity loaded and the quantity received. The task of loss control is to determine if a particular difference is unusual or simply to be expected under the circumstances that apply, and then, when an unusual difference is identified, to determine where any loss has occurred.

5.2 Cargo Transfer Measurement Points

When a cargo is transported by vessel from one shore terminal to another, measurements are normally made at four locations, as shown in Figure 1 for the purpose of establishing:

(a) the quantity of cargo delivered (i.e. to confirm the quantity of cargo shown on the Bill of Lading);

(b) the quantity of cargo loaded by the vessel;

(c) the quantity of cargo discharged by the vessel;

(d) the quantity of cargo received by the receiving terminal, and

(e) the difference between the quantities established under (a) to (d) above.

NOTE For a particular voyage involving more than one loading port or discharge port, measurements should be made at all such additional ports in order that a reliable comparison can be made between the quantities shown on the Bill of Lading, the cumulative outturn and ship's figures.

One of these measurement points may be defined in the contract as the point where the custody transfer measurement will be made. When a loss/gain has occurred, a comparison of these four measurement points will often show a discrepancy at one point, which will indicate where to begin further investigation.

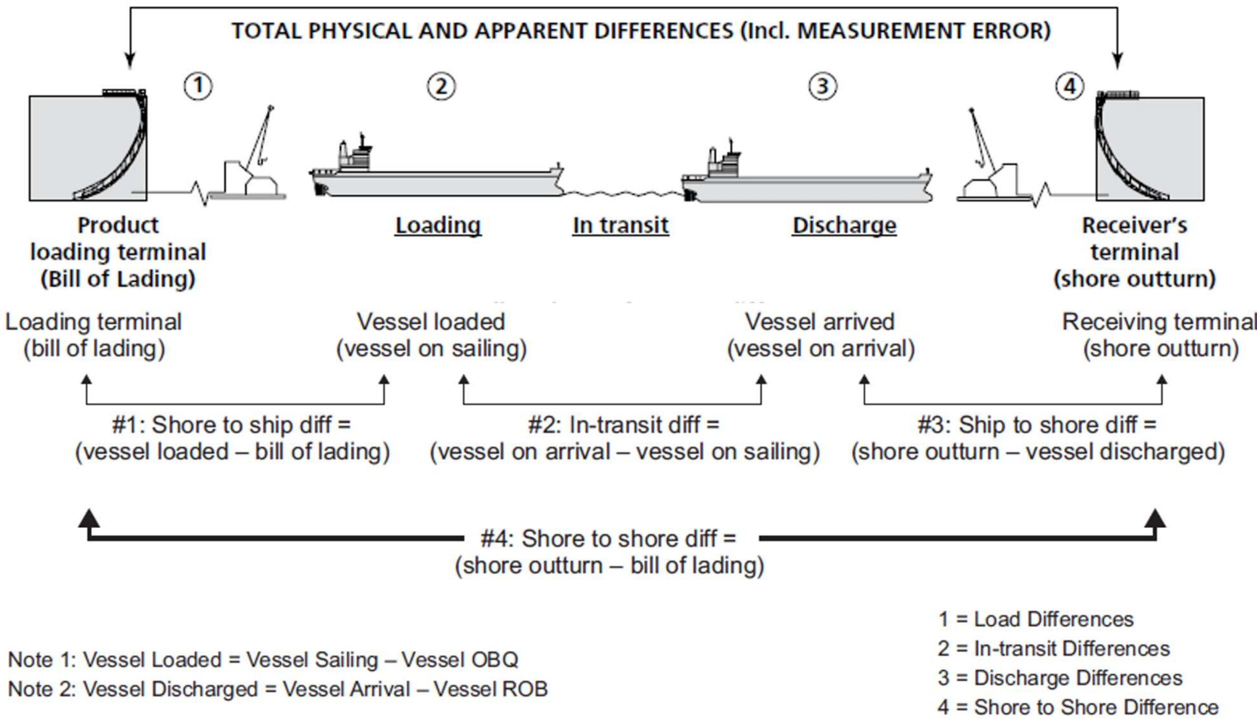

Figure 1—Four Point Reconciliation

5.3 Shore Measurements

5.3.1 Meters

Custody transfer measurement may be carried out using custody transfer meters. Some knowledge of how the various meter types operate, potential errors, and the generation of final figures will allow pertinent questions to be asked when investigating a gain or loss.

Meters could be incorrectly installed, maintained, or operated, or have errors due to wear and tear of components. Points for consideration include the following.

a) meter proving frequency (this should be in accordance with manufacturer's recommendations, company, or national legislation);

b) maintenance records;

c) control charts;

d) meter factor or K factor on the custody transfer document compared to the most recent prover report;

e) prover calibration records;

f) possible application of incorrect (out-of-limit or out-of-date) meter factors.

The terminal should provide meter factor control charts and the last prover calibration report with traceability to national/international standards. If possible, metered volumes should be compared with shore tank volumes. Custody transfer meters should be properly proven, certified, and operated to a recognized industry standard.

5.3.2 Shore Tank Measurements

5.3.2.1 General

Tank calibration tables should be requested from the facility and should comply with recognized industry standards. The date of the most recent calibration should be recorded.

When addressing suspected problems with shore tank measurements, the following issues should be considered:

a) Differences between manual and automatic tank gauge (ATG) measurements.

b) Differences between the observed reference height and the calibrated reference height on the tank capacity table.

c) Tank bottom flexing may affect measurements, especially if the tank level has changed considerably during the movement.

d) Tanks may move and deform over time, causing reference points to distort and capacity tables to become less accurate.

e) Inadequate settling time before gauging may result in inaccurate liquid measurements, particularly with regard to water determination.

f) Temperature or density (degrees API gravity/kg/m^3) stratification may have an effect on floating roof correction calculation.

g) Valve leakage.

h) Use of unslotted standpipes for measurements.

i) Tank shell thermal expansion corrections.

j) Measurements taken within the coned bottom or critical zone of a tank.

5.3.2.2 Floating Roof Tanks

If the shore tanks have floating roofs, roof position at the start or finish of the movement should not be in the critical zone. In some locations, tanks may be calibrated for both high and low leg positions, check that the correct capacity tables were used to obtain volumes.

In addition to the topics in 5.3.2.1, the following issues related to gauging a floating roof tank should be considered:

a) Sediment buildup can affect the critical zone.

b) Movement of the floating roof or gauging tape due to wind.

c) Change in tank roof orientation, i.e. tilting, sinking, turning, etc.

d) A change in the weight of the floating roof, e.g. water, snow load, product on roof.

e) Roof leg positions.

5.3.3 Line Verification

The fill condition of shorelines before and after loading and discharge should be correctly determined and documented. Slack lines can result in a discrepancy in the bill of lading or the outturn quantities. The fill condition of vessel lines after loading and discharge should also be documented to verify that there is no unmeasured cargo on the vessel. The effect of any observed differences in line fill can impact the accuracy of reported quantities and should be evaluated. Refer to API *MPMS* Chapter 17.6/HM70, *Guidelines for Determining the Fullness of Pipelines Between Marine Vessels and Shore Facilities*, for more detailed information regarding the procedure.

5.4 Vessel Measurements

5.4.1 General

Vessel measurements are a vital part of the transport chain and need to be reviewed as part of any loss or gain investigation. A difference between shore quantity and vessel quantity, adjusted by the VEF, can indicate an inaccurate shore or vessel measurement.

When addressing suspected problems with vessel measurements, the following issues should be considered.

a) Use of non-calibrated measurement equipment.

b) Weather and sea conditions.

c) Capacity tables may have been incorrect (i.e. for a different gauge point).

d) Differences between manual and automatic tank gauge (ATG) measurements.

e) Trim, list, and wedge corrections may not have been correctly applied.

f) Gauge height adjustments to allow for retrofitted equipment, such as vapor control valves and closed system fittings, may not have been correctly applied.

g) Different gauge points may have been used at load and discharge.

h) Unslotted standpipes may have been used for measurements.

i) The vessel line fill condition may have been different at load and discharge port.

j) Clingage, sludge, sediment, and unmeasured ROB and OBQ may have been present.

k) Vessel line capacities may not have been correctly accounted for; i.e., are vessel lines included in the vessel calibration tables?

l) Insufficient numbers of temperature reading may have been taken for stratified or heated cargo tanks.

5.4.2 Vessel Tank Capacity Tables

Vessel tank capacity tables should be specific to the vessel/tank and carry the date together with notes and corrections for any structural changes, particularly modifications to reference gauge point. In addition, the vessel tank capacity tables should indicate whether associated piping volume is included or excluded from the capacity table.

Calculations should be checked to verify that trim and list corrections have been applied correctly, as this can have a significant impact on the measured quantities.

5.4.3 Vessel Experience Factor

For a given vessel, the use of quantity data from many voyages provides an indication of vessel measurement differences as a numerical ratio. This ratio can also include other load and discharge factors. For each voyage, a vessel load ratio (VLR) and vessel discharge ratio (VDR) can be calculated. The mean of the qualifying VLRs or VDRs over several voyages is called the VEF (VEFL and VEFD for load and discharge, respectively). For guidance, refer to API *MPMS* Chapter 17.9/EI HM49, *Vessel Experience Factor (VEF)*.

5.4.4 Transit Differences

A comparison of the vessel's departure TCV and its arrival TCV will give an indication of transit cargo variation. The measurements that make up the TCV (GSV and FW) should be reviewed individually.

A transit difference can be attributable to:

a) material pumped from engine room bilges into slop tanks

b) heating coils leaking into cargo tanks

c) displacement into cargo tanks of other materials, which were received/discharged between the time when cargo load and discharge measurements are made, e.g., bunkers, slops, and other parcels

d) introduction of water to cargo tanks

e) measurement inaccuracy due to vessel motion and/or equipment limitations

f) vapor losses

g) cargo leakage: cargo that escapes to other cargo tanks or into voids, cofferdams, slop tanks, ballast tanks, or other non-designated areas

h) cargo diversion or cargo burned as fuel

i) transfer or decanting of free water from cargo, slop, or ballast tanks during voyage.

5.4.5 Changes in Cargo Stowage

Changes in stowage or unauthorized diversion of cargo should be investigated.

Bunker survey reports and receipts for the entire voyage should be reviewed.

5.4.6 OBQ and ROB

A difference in OBQ and ROB quantities may be expected as a result of unmeasured ROB or clingage, which may later settle to the bottom of the tanks and become measurable as OBQ for the next voyage. ROB clingage that does not settle can result in shore-to-ship cargo gains at the next load port. The implementation of enhanced cargo recovery techniques, such as crude oil washing (COW), have a marked effect on the differences in these OBQ and ROB quantities. Refer to API MPMS Chapter 17.4 *Method for Quantification of Small Quantities on Marine Vessels*, for additional guidance.

Large quantities of cargo remaining in the tanks may suggest inadequate procedures or problems with the vessel’s equipment.

If cargo heating was requested, heating records should be obtained from the vessel. These should indicate whether charter party requirements have been followed. If the cargo has not been correctly heated, wax may be deposited on the tank floor and sides, increasing measured and unmeasured ROB. Heated cargoes can suffer from high ROB if the cargo has not been discharged quickly once below the level of heating coils.

Excess ROB in one tank may indicate that stripping was too slow or that stoppages have occurred, allowing heavy cargo to begin to solidify. Time logs and any letters of protest should be reviewed. The physical characteristics of the product and the ability of the vessel to pump it are also factors affecting ROB. Problems can result from cargo vaporizing in the pumps (air lock) and loss of suction during final stripping. Trim or list may prevent the free flow of product to the suction point.

5.4.7 Crude Oil Washing (COW)

COW operations can reduce the cargo volumes retained on board after discharge (ROB). Although COW is a useful technique to improve cargo discharge, its effectiveness is dependent on many factors, including the nature of the cargo, the efficiency of equipment, the number of tanks being washed, and the ambient air and sea temperatures during discharge. An effective COW may reduce ROB. However, COW may cause additional cargo losses with volatile cargoes due to the vapor generated.

Refer to HM40, *Guidelines for the crude oil washing of ships’ tanks and the heating of crude oil being transported by sea,* for additional guidance.

5.4.8 Slops

Slops can be a source of gains/losses in cargo outturns when compared with bill of lading volumes and should be taken into consideration in the reconciliation. Slops discharged with the cargo may have been either commingled with the cargo (loaded on top) or segregated from the cargo in a separate tank.

5.4.9 Non-Nominated Tanks

Any non-nominated cargo tanks could also be a source of gains or losses due to valve leakage or line-up errors. All cargo tanks should be measured at opening and closing to ensure no change in the non-nominated cargo tanks during the voyage and during the transfer.

5.5 Water Determination

5.5.1 Free Water (FW)

When investigating possible losses, a water balance should be carried out between each measurement point. In cases where large amounts of water are found, analysis may determine the source of the water (estuary, formation water, sea water, etc.). Care should be taken that all aspects are checked as there is often confusion between fresh ballast water and formation water. Now that segregated ballast is almost universal, ballast water should not normally be found in cargo tanks.

If additional water is reflected in a larger gross measurement on the vessel after loading and then the additional water is also seen at discharge, there may not have been any product loss.

Differences in the free water (FW) quantity could be due to the following.

a) Introduction of water into the cargo from vessel pipelines, inert gas system, cargo heating system, loading/discharge lines (particularly under sea lines or floating hoses),

b) Water introduction from shorelines during the loading or discharge operations. There may be water in the shoreline between an automatic sampler or shore tank(s) and the vessel on loading which may not have been accounted for.

c) Mixing of FW with cargo as it is pumped. This will reduce the FW volume while increasing the S&W volume. However, total water should remain the same.

d) Settling out of S&W, which will increase the FW content at the discharge port, compared to the load port. However, total water should remain the same.

e) Insufficient time allowed for water to settle.

f) Different measurement methods, e.g. separate S&W and FW measurements versus total S&W of homogenized samples from an inline sampler.

g) Different methods of detecting FW, e.g. water paste versus electronic interface detector, especially for crude oils containing emulsified water.

h) FW volumes on the vessel not properly corrected for wedge or trim/list conditions. Depending on gauge point locations, a wedge of FW may not be detected under certain conditions.

i) Different sea conditions when measuring the FW on the vessel at the load port and discharge port, e.g. rough seas versus calm seas.

j) Tank bottom deformation or sediment in tanks affecting FW measurement.

k) The datum plate height above the tank bottom preventing measurement of water below the datum plate. This is a particular problem with cone bottom tanks where gauging points are typically offset to one side of the tank.

l) Shutdown or malfunction of the automatic sampler during a part of the loading or discharge or incorrect cleaning and operation.

Refer to API *MPMS* Chapter 3.1 Standard Practice for the Manual Gauging of Petroleum and Petroleum Products, Chapter 17.3, *Guidelines for Identification of the Source of Free Waters Associated with Marine Petroleum Cargo Movements*, and API MPMS Ch 17.11/EI HM52, *Measurement and Sampling of Cargoes Using Closed and Restricted Equipment* for additional information and possible explanation of the origin of excessive FW.

5.5.2 Sediment and Water (S&W)

A difference between reported S&W at load port and discharge port will give a shore-to-shore NSV gain or loss, unless this is associated with a similar change in FW.

Inconsistent S&W results can occur for any of the following reasons.

a) The non-homogeneity of product may result in samples that contain more or less water than the whole cargo.

b) The use of incorrect sampling method or procedure.

c) Inability to obtain representative samples.

d) Different methods of laboratory analysis, e.g. Karl Fischer titration, water by distillation, centrifuge, etc.

e) Settling of S&W can decrease the entrained S&W content of the vessel composite at a discharge port as compared to a load port. Likewise, mixing resulting from turbulence during pumping may increase S&W as FW becomes entrained and thus part of S&W. However, total water should remain the same.

f) Failure to follow analytical test methods.

g) Improper sample handling or mixing.

Auto sampler operation throughout the movement should be verified and evaluated against relevant standards (refer to API *MPMS* Chapter 8.2, *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products*). Manual samples obtained from shore tanks and vessels may be used for reference comparison purposes.

An automatic sampler should operate flow proportionally throughout the movement for collecting a representative sample from a cargo at loading and discharge. Manual samples, when taken through restricted or closed gauging systems, are less likely to be representative.

5.6 Additional Factors

5.6.1 Temperature

Temperature measurements are critical in standard volume calculations, and a careful review of temperature measurements is recommended as part of any reconciliation. Potential causes of temperature measurement inaccuracy include: tank stratification, use of non-slotted standpipes, use of large diameter tanks, operation of tank heaters, etc.

Temperature changes in a short period of time may indicate a measurement problem unless the product is being aggressively heated. Small differences in temperatures can result in significant volume changes.

Sensitivity varies and is greater with lighter products, but can be of the order of 0.15 % by volume for a 1 °C temperature change or 0.08 % by volume for a 1 °F temperature change.

Temperatures can be examined volumetrically, and the resulting anticipated values compared to the actual temperatures reported (see the example below in Figure 2 for the volumetric calculation).

	Volume (m3)		Temperature (degC)		(m3-degC)
Shore Opening	3,000	**X**	20	**=**	60,000
	+				+
Vessel Cargo/Transfer	7,000	**X**	35	**=**	245,000
	=				**=**
Shore Closing	10,000		÷		305,000

	30.5 *(Anticipated Temperature)*
Actual Measured Temperature	34 degC

Figure 2—Example Volumetric Anticipated Closing Temperature Calculation

In this example, the anticipated and actual measured temperature in the tank after discharge do not align. Additional temperature measurements should be performed on the shore tank to obtain a more representative measurement.

5.6.2 Evaporation Losses

Evaporation is the loss of the relatively low boiling point hydrocarbon components ("light ends") of cargoes to the atmosphere, and occurs during loading, in transit, and at discharge. Vapor pressure can be used as an indication of the relative volatility of the cargo at a given temperature. The extent of this loss is influenced by:

a) high vapor pressure of the cargo;

b) increased temperature of the cargo;

c) design and operation of the vessel's inert gas system;

d) incorrect setting of Pressure-Vacuum Vent (PVV) on the vessel;

e) gauge hatches left open;

f) excessive agitation of cargo during loading or passage, e.g. heavy weather conditions;

g) COW operations.

5.6.3 Density

A difference between shore and vessel density measurements at both load and discharge can lead to a quantity difference.

Potential causes include:

a) stratification of products;

b) long shorelines with different product;

c) poor sampling or testing.

5.6.4 Volume Correction Factors (VCF)

VCF tables should be appropriate for the commodity and the same VCF table should be used at all measurement points throughout the voyage. If the loaded quantities were calculated using VCF tables other than the VCF tables used at the discharge port, the loaded quantities should be recalculated based on the VCF tables used at the discharge port for the purposes of comparison. Any quantity difference resulting from the use of different VCF tables should be noted.

NOTE Not all countries apply current ISO, API, EI, or ASTM standards. Some continue to use the 1952 ASTM tables, GOST tables are used in some former Soviet Union countries, and ANP tables are used in Brazil.

5.6.5 Volumetric Shrinkage

Volumetric shrinkage can occur when mixing two hydrocarbons with different molecular structures. The amount of shrinkage depends on the density difference and percentage of the components. For the specific application of blending light hydrocarbons into Crude Oil there is guidance in API *MPMS* Chapter 12.3, *Calculation of Volumetric Shrinkage Resulting from Blending Light Hydrocarbons with Crude Oil*.

For further information, see EI Research Report: *Determination of shrinkage when blending petroleum product mixtures (HM 1602)*.

5.6.6 Vessel-to-Vessel Transfer (Lightering)

If weather or sea conditions during vessel-to-vessel transfers were not conducive to accurate measurement, or measurements could not be obtained, this can lead to a quantity difference.

5.7 Measurement Errors

Examples of possible errors that are not specific to a vessel or shore tank include:

a) failure to perform cargo measurement operations in accordance with industry standards;

b) the use of defective or non-standard measurement equipment;

c) the environment at the time the measurements are taken;

d) improper use of tank capacity tables (using wrong tank or compartment table);

e) the use of incorrect correction factors;

f) the use of incorrect conversion factors when converting between systems of measurement;

g) the complexity of the operation (e.g number of shore tanks and vessel compartments).

Annex A
(informative)

Guidance for Use of the Voyage Analysis Report

A.1 The Voyage Analysis Report (VAR)

The VAR form is where the essential information regarding any marine custody transfer is recorded. On complex voyages and vessel-to-vessel transfers, a separate summary VAR should also be completed. Refer to 4.4 for complete instructions regarding entries on the VAR form.

All volumes on VARs should be based on consistent units of measure and calculation procedures.

The four possible applications of the VAR form are listed below. A single VAR form may cover more than one application, and each application is indicated by checking one (or more) of the blocks at the top left corner of the form:

a) A *Loading VAR* where the following are filled in (manually or by calculation):

   1) the top section (vessel name, cargo, port, etc.) recording general information about the cargo transfer;

   2) Line 1 of Section I (bill of lading quantity);

   3) all of Section II (lines A–J).

b) A *Discharge VAR* where the following are filled in (manually or by calculation):

   1) The top section (vessel name, cargo, port, etc.) recording general information about the cargo transfer;

   2) Line 1 through Line 4 of Section 1 (bill of lading and outturn plus calculation of difference)

   3) all of Section II (lines A - J) Since the discharge port is where shore-to-shore quantity discrepancies would be found, the entire VAR form should be completed

   4) all of Section III (lines K – T)

   5) calculations in Section IV (lines U – W)

c) A *Vessel-to-Vessel (V-V) Transfer VAR* should follow the instructions for a Loading VAR except that the delivering vessel quantity delivered (adjusted by discharge VEF of the delivering vessel) is entered into Line 1, Bill of Lading, instead a shore figure.

d) A *Summary VAR* where the entire form is filled in (as applicable).

Figure A.1 below is an example of the VAR form, companies may build their own versions that meet the same intent.

☐ Loading ☐ Discharge ☐ V-V Transfer ☐ Summary				Reference No.	Voyage/Trip No.	C/P Date (M/D/Y) / /	Page No.____ Of ____
Vessel				Cargo		Type of Voyage	
Loading Port/Terminal/Berth		Arrived (M/D/Y) / /	Sailed (M/D/Y) / /	Discharge Port/Terminal/Berth		Arrived (M/D/Y) / /	Sailed (M/D/Y) / /
Quantity Unit		Supplier	Receiver	VCF Table Used			
☐ Bbls ☐ Gals ☐ M3 ☐ L				Shore Load	Shore Disc	Vessel Load	Vessel Disc
Description	API/ Density	TCV	FW	GSV	S&W	NSV	Calculation Reference
I. Comparison of Shore Quantities in Custody Transfer							
Bill of Lading 1.							-1
Outturn 2.							-2
Diff. 3.							(3) = (2) – (1)
Diff. % 4.		%		%		%	(4) = (3) / (1) × 100
Recalc. B/L 5.	(a)		Recalculate if B/L and O/T use different tables				(5) (a) Vol.Diff.
II. Vessel/Shore Quantaties at ( ) Load Port(s)							
Vessel Sailing A.					LIQUID	NON-LIQUID	(A)
OBQ (All) B.							(B)
Loaded C.							(C)=(A) – (B)
Difference D.							(D)=(C)–[(1) or (5)]
Difference % E.		%		%			(E)=(D)/[(1)or(5)]×100
Load Vessel Ratio F.							(F)=(C)/[(1) or (5)]
Load VEF G.							(G)
Theoretical Shore H.							(H)=(C) / (G)
Theoretical Shore Diff. I.							(I)=(H) – [(1) or (5)]
Theoretical Shore Diff. % J.		%					(J)=(I)/[(1) or (5)]×100
III. Vessel/Shore Quantities at ( ) Discharge Port(s)							
Vessel Arrival K.					LIQUID	NON-LIQUID	(K)
ROB (All) L.							(L)
Discharged M.							(M) = (K) – (L)
Difference N.							(N) = (2) – (M)
Difference % O.		%		%			(O) = (N) / (2) × 100
Discharge Vessel Ratio P.							(P) = (M) / (2)
Discharge VEF Q.							(Q)
Theoretical Shore R.							(R) = (M) / (Q)
Theoretical Shore Diff. S.							(S) = (2) – (R)
Theoretical Shore Diff. % T.		%					(T) = (S) / (2) × 100
IV. Vessel's Comparison of Loading and Discharge Port(s) VCF Table Must Be Consistent							
Transit Difference U.							(U) = (K) - (A)
Difference V.		%			LIQUID	NON-LIQUID	(V) = (U) / (A) x 100
OBQ/ROB Difference W.							(W) = (B) - (L)
TCV Diference (3) - OBQ (B) + ROB (L)				[S&W(1) / GSV(1)] x 100		[S&W(2) / GSV (2)] x 100	
ADJ TCV DIFF ________(Quantity)/ _________%				S&W at Load Port _______%		S&W at Discharge Port ________%	
Comments							
Prepared by		Title		Company		Date Completed (M/D/Y)	

Figure A.1 – Voyage Analysis Report

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