Liquid Bulk / Quantity Measurements and other challenges

Prepared by Jorge Pecci, SafeWaters UM

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Introduction:

Quantity of crude oil or petroleum product(s) loaded, assessed by measurements done ashore at the terminal and afterwards shippers enter these figures in the bill of lading. On the other hand ship’s figures ascertained on board by way of measurement of ship’s tanks and concomitant calculations done by especially appointed surveyor together with responsible for cargo operations ship’s officer, normally Chief Mate. These figures obtained ashore and on board of tanker, as a rule, differ from each other. There are many factors contributing to these discrepancies such as superseded tables used by the terminal in the calculation of Bill of Lading quantities, inaccurate vessel experience factor, Cargo Custody transfer practices and the competency of Cargo Inspectors and crew. These discrepancies product of errors in calculation eventually evolve in what is normally called in insurance “paper loss”.

When ship’s measurements show less cargo than stated in bill of lading the charterers are facing potential liabilities for cargo shortage at the discharge port. Therefore they usually specifically provide in their voyage instructions for actions required from the owners and the master of the vessel in such circumstances.

These instructions, normally subject to tolerable margin, because small discrepancy is practically inevitable, but sometimes not. Master’s should not sign the bill of lading until he first communicates with the charterers/owners.

Usually, communication between all the parties concerned, i.e. the shippers, the charterers, the brokers and the owners takes time, sometimes many hours, especially if loading has been completed on weekend or after office hours. The owners can avoid liability for delays related to such communication and disputes over the ship/bill of lading discrepancies if they show that the master acted reasonably and he did not cause or contribute to the delay by any unreasonable act or omission on his part. On the other hand courts and arbitrators have always been quick to support the owners who take a stand to insert an accurate figure in the face of a shipper who is demanding a questionable figure.

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Single Point Mooring (SPM) Loading Operation

<table>
<thead>
<tr>
<th>Class</th>
<th>Length</th>
<th>Beam</th>
<th>Draft</th>
<th>Typical Min DWT</th>
<th>Typical Max DWT</th>
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</thead>
<tbody>
<tr>
<td>Seawaymax</td>
<td>226 m (741 ft)</td>
<td>24 m (79 ft)</td>
<td>7.92 m (26.0 ft)</td>
<td>10,000 t</td>
<td>60,000 t</td>
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<td>Panamax</td>
<td>228.6 (750 ft)</td>
<td>32.3 m (106 ft)</td>
<td>12.6 m (41 ft)</td>
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<td>80,000 t</td>
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<tr>
<td>Aframax</td>
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<td>44.2 m (145 ft)</td>
<td>11.6 m (38 ft)</td>
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<td>Suezmax</td>
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<td>16 m (52 ft)</td>
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<td>120,000 t</td>
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<tr>
<td>VLCC (Malaccamax)</td>
<td>330 m (1,080 ft)</td>
<td>60 m (200 ft)</td>
<td>20 m (66 ft)</td>
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<td>315,000 t</td>
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<tr>
<td>ULCC</td>
<td></td>
<td></td>
<td></td>
<td>320,000 t</td>
<td>550,000 t</td>
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</tbody>
</table>
Petroleum Measurement Standards - Marine Measurement

In order to be able to understand how quantities are measured today on board a tanker it is critical to recognize some basic vocabulary/definitions.

**Observed Reference Height** is the distance actually measured from the tank bottom or datum plate to the established reference point.

**Reference Height** is the distance from the tank bottom to the established reference point or mark.

**Reference Point** is the point from which the reference height is determined and from which the ullages / innages are taken.

**Sediment and Water** (S&W) is the non-hydrocarbon solid material and water in suspension in petroleum liquid. Sediment and water is measured by the techniques described in MPMS Chapters 10.1 ~ 10.8 of Appendix A.

**Slops** are oil, oil/water/sediment, and emulsions contained in the slop tanks or designated cargo tanks. The mixture usually results from tank stripping, tank washing, or dirty ballast phase separation.

**Stop Gauge** is a pre-transfer determination of a specific volume of cargo represented by a specific tank level, which, when reached, results in cargo completion of the transfer. This determination may be done by either shore or vessel personnel.
Tank Washing is divided into two types of activities:

Water Washing involves the use of high-pressure water stream to dislodge clingage and sediment from the bulkheads, bottom and internal tank structures of a vessel.

Crude Oil Washing (COW) involves the use of a high-pressure stream of the crude oil cargo to dislodge or dissolve the clingage and sediment from the bulkheads, bottom and internal tank structures of a vessel during the discharge operation.

It must be noted that regulatory agencies (including most ship / facility internal documented procedures require the tanks to be inerted during tank cleaning.

Total Calculated Volume (TCV) (Go to Volumes)

Total Observed Volume (TOV) (Go to Volumes)

Trim is the condition of a vessel with reference to its longitudinal position in the water. It is the difference between the forward and aft drafts and expressed "by the head" if the forward draft is deeper than the aft draft or "by the stern".

Trim Correction is the correction applied to the observed gauge or observed volume when a vessel is not on an even keel (equal forward and aft drafts), provided that the liquid is in contact with all bulkheads in the tank. Correction for trim may be made by referencing trim tables for each individual tank or by mathematical calculation.

Ullage Gauge (Outage) is the measured distance from the cargo liquid surface to the reference point.

Vessel Experience Factor (VEF) is a compilation of the history of the total calculated volume (TCV) vessel measurements, adjusted for on-board quantity (OBQ) or remaining on board (ROB), compared with the TCV shore measurements. Separate VEFs should be developed for loadings and discharges. The information used to calculate VEF should preferably be based on documents that follow accepted industry standards and practices, such as inspection company reports.

It may be noted that for the purpose of calculating a load or discharge vessel ratio, the TCV on board the vessel includes all petroleum liquids, sediment and water, free water and slops found after loading (TCV sailing volume) or before discharge (TCV arrival volumes). However, if in the completion of the Sequential Voyage Log, a TCV ratio (vessel - shore) appears to be in gross error, the ratio may be deleted with the agreement of both parties. If all qualified voyages are based on load/discharge data from the same terminal, the applicability of those VEF data to the loads/discharges at other terminals should be evaluated.

Vessel Load Ration (VLR) is the total calculated volume (TCV) by the vessel measurement upon sailing, less on-board quantity (OBQ), divided by the TCV by shore measurement at loading -

\[ VLR = \frac{\text{TCV on sailing} - \text{OBQ}}{\text{TCV received from shore at loading}} \]
Vessel Discharge Ratio (VDR) is the total calculated volume (TCV) by the vessel measurement on arrival, less remaining on-board (ROB), divided by the TCV by shore measurement at discharge:

\[ VDR = \frac{\text{TCV on arrival} - \text{ROB}}{\text{TCV received from shore at discharge}} \]

**Volume Correction Factor (VCF)** is the numerical value determined by laboratory analysis or by standardized computer arithmetic that when multiplied by the Gross Observed Volume at tank temperature results in the volume of the product at its standard temperature (15°C or 60°F). The factors applicable for bands of API (relative density) and temperature are available in standard tables booklets or may be computed using a standardized format. If the VCF is below 1 it is shown accurate to 5 places of decimal otherwise it is shown in 4 places of decimal.

**Using an Innage Tape and Bob**

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

*Traditional Tape and Bob*
Modern measurement tapes

Alternative Innage Procedure
An ullage gauge may be converted to an innage gauge by subtracting the ullage from the reference height shown on the capacity tables.

Open Free-Water Measurement
The use of water-indicating paste in conjunction with innage or ullage procedures provides a measurement of the free water in a vessel's tanks. The recommended procedure for free-water gauging is by the innage method. If the level of the water being measured is high enough to show a cut on or above the tape clip, a larger gauge bar should be used. However, if measurement conditions dictate, it may be necessary to utilize the ullage method or other methods as agreed upon by all the parties.
Vessel tanks should be gauged for free water using water-indicating paste or other equipment agreed upon by the parties involved. Measurements should be taken independently of any other innage or ullage measurements and should be properly recorded. Free water should be measured at both the loading and the discharging port.

**Using an Innage Tape and Bob to Measure Free Water**

Apply the water-finding paste on the bob or bar sufficiently high to measure the anticipated level of water.

After grounding, the innage tape and bob should be lowered into the tank until the bob is a short distance from the bottom, as determined by the tape reading at the reference point.

The tape should then be unwound slowly until the tip of the bob just touches the bottom or datum plate. If the tape is lowered too far, the bob will tilt and an incorrect gauge will be obtained.

Once the bob touches bottom, keep it there long enough for the paste to react to the water. Withdraw the tape and read and record the highest, clearly defined water cut (see notes 4 and 6).

Repeat steps a through e until two identical readings are obtained.

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

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

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

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

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

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

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

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

**Open OBQ / ROB Measurement**

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

When a vessel is out of trim, some OBQ and ROB quantities may not be measurable at the proper gauge points. In these circumstances, more extensive methods of volume determination may be necessary, and additional measurements will usually be required.

Safety and operational considerations must always be factors in determining what actions can be taken, but in all situations, existing conditions and the specific actions taken to measure ROB and OBQ must be noted in the report.

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

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

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

**Open Temperature Measurement Equipment**
All temperature equipment must be safe for use with the material whose temperature is to be obtained. The preferred method of obtaining temperatures of the liquid in a vessel's tanks is to use a portable electronic thermometer (PET). Alternately, a mercury-in-glass thermometer with etched glass face may be used. Thermometers used for custody transfer should be properly calibrated and their accuracy verifiable and traceable

**Thermometers**

**Field Verification of Temperature Equipment**
All thermometers used for custody transfer measurements should be verified for accuracy before initial use, and at least once a year thereafter. In addition, before each use or once per day (whichever is less frequent) the thermometer should be spot-checked.

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

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

Modern equipment for measurement: (includes thermometer and interface measuring see video)

https://www.youtube.com/watch?v=FGs9NQ7DniU

Open Temperature Measurement Procedures

Manual temperature measurement is the determination of the temperature of a liquid in a vessel's tank, using the appropriate devices. The primary considerations of accurately determining temperature are

- the size and location of cargo tanks,
- whether or not heat has been applied to the cargo,
- the atmospheric and seawater temperatures, and
- the degree of temperature stratification within the cargo. Temperatures should be taken and should be clearly designated as degrees Fahrenheit or Celsius, as appropriate.

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

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

The immersion time required for the thermometer reading to reach equilibrium will vary depending on the type of liquid and equipment.
Portable Electronic Thermometers (PETs)

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

- Attach an electrical ground between the thermometer and the tank before the hatch is opened.
- Check the ground to ensure that it is securely attached to the thermometer.
- Set the temperature range selector as appropriate.
- Lower the sensing probe to the predetermined level.
- Raise and lower the probe 1 foot (0.3 metre) above and below the predetermined level to allow rapid stabilization.
- After stabilization, read and record individual temperatures to the nearest 0.1°F or 0.1°C.
- Determine the average tank temperature to a tenth of a degree.
- Round off and report the average tank temperature in accordance with the most recent edition of API MPMS round off and report average tank temperature to 1°F or 0.5°C [round 0.5°F up]. Temperatures may be reported in units less than whole degrees by mutual agreement.
- If the probe is allowed to remain stationary, contact with a convection current of colder oil will cause low readings. With a moving probe, however, the thermometer may be considered stabilized if the readout varies by no more than 0.2°F (0.1°C) for 30 seconds.
- Mercury Thermometers In addition to the steps described earlier, the following procedure is recommended for measuring temperatures with a mercury thermometer.
- Lower the thermometer assembly through the gauge hatch to the required level.
• Repeatedly raise and lower the thermometer 1 foot (0.3 meter) above and below the required level so that the equilibrium temperature will be reached more rapidly.
• Withdraw the thermometer after the required immersion time.
• Round off and report the average tank temperature
• Report the temperature to the nearest 1°F or 0.5°C.

Repeat items a through e for every tank to be 'temperated'

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Arctic Oil transshipment

Closed and Restricted Measurement

A closed measurement system is designed to allow cargo measurements to be taken with no vapours escaping to the atmosphere. A restricted measurement system is designed to allow measurements to be taken with minimum vapours being allowed into the atmosphere. The two
basic categories of dosed or restricted system measurement equipment used on marine tank vessels are "portable manual" and "fixed automatic."

Manual equipment can be used to obtain levels of liquid cargo and free water, cargo temperatures, and samples; whereas automatic systems are primarily used to obtain the levels and temperatures of liquid cargo only. While either type of equipment can be used for custody transfer measurements, it must be understood that not all automatic equipment was designed and installed on vessels for that purpose.

Some systems were designed to be used for shipboard operational purposes only (i.e., for determination of proper trim and stability and cargo loading/discharging). Accordingly, both parties should be aware of the limitations of any shipboard measurement system and agree on the method of measurement to be used to determine the "official" custody transfer volumes.

**Manual Closed and Restricted Systems:**

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

**Manual Closed and Restricted Equipment**

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

**Vapor Control Valve**

![Vapor Control Valve Image]

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

Vapor control valves come in varying diameters from 1 in. (25.4 mm) to 4 in. (101.6 mm). The valve sizes and types are specified by the manufacturer and the vessel owner. However, if the VCV is too narrow, it will not allow adequate sampling to be conducted.

The location and size of the VCV is critical to the ability to be able to measure tank contents and to take sufficient samples. In order to be able to measure small quantities in a tank when the vessel is not on an even keel, a VCV must be located as close as possible to the bulkhead that is in the direction of the vessel's normal operating trim and list when the vessel is in an OBQ/ROB condition. In placing the VCV, care must be given to assure its location will not cause the measurement equipment to touch the tank bulkhead when in use.

It may be noted that since many vessels have been retrofitted with vapor control valves that are not in the exact location as the existing "open" gauge points, tank capacity tables should be adjusted to take in consideration any new gauge location for PMU equipment. Also, the vapor control valve locations should be placed in accordance with MPMS Chapter 2.8B. If the tables have not been adjusted for these location changes, some corrective action may have to be taken to obtain correct measurements. Such corrective action must take into consideration the use of adapters that allow the use of different manufacturers’ portable measurement units with varying vapor control configurations.
Liquid Bulk Cargo Loading and Discharging Procedures (From the vessel perspective)

The following procedures are recommended to ensure that a proper record is made of the loading, carriage and discharge:

1. The ship should compile and retain a report on the condition of the vessel's tanks prior to loading, including a record of the ullages in slop tanks. Once the ship's officers are satisfied about the cleanliness of the tanks, cargo interests and/or representatives of the terminal should be invited to inspect the tanks and confirm their acceptability in writing prior to the commencement of loading.

2. A loading/discharge programme should be planned in advance and agreed with cargo interests and the terminal staff. This should cover the order in which tanks are to be loaded/discharged, tank/pump/pipe work allocation and loading/discharge rates in order to minimise the stress on the vessel and the risk of cross-contamination of different grades of cargo.

3. An efficient system of communication should be established between the vessel and the terminal and the start-up/shut-down procedures for cargo operations agreed. A close watch should be maintained on weather conditions in order that cargo operations can be shut down in good time, and, if necessary, so that the vessel can depart from the terminal prior to the onset of adverse weather. A comprehensive ship/shore checklist will ensure that these details are given the appropriate attention and will provide evidence if needed that this is the case. For further information check the Steamship/Videotel training programme 'The Ship/Shore Interface' on this section of this website under Onboard Safety Training.

4. The sea valves and their seals should be checked in the presence of cargo/terminal representatives prior to loading and checked and sealed again after departure.

5. All operations undertaken during loading and discharge should be logged by the ship including details of all valve positions, changes in valve usage, pumping rates, manifold pressures and vessel’s draught and trim.

6. Ullage and temperature measurement of all the vessel's cargo tanks should be carried out in the presence of the terminal and cargo representatives upon completion of loading and immediately prior to discharge. The results should be carefully recorded and countersigned by cargo interests.

7. A calculation of the loaded quantity should be made, based upon the vessel's ullage and temperature figures, and the result compared with the shore figure to ensure that any difference falls within the vessel's experience factor. If it does not, a Note of Protest should be issued by the Master and an acknowledgement obtained from the shippers and/or charterers. Bills of lading should wherever possible be endorsed to show that the volume and weight
measurements are not provided, ascertained or warranted by the carrier. If there is an unusual discrepancy between the shipper's figure and that disclosed by the vessel's loading ullages, every effort should be made to have the latter inserted in the bill of lading. At the very least, a Note of Protest should be drawn up by the Master to be attached to the bill of lading or passed to the shipper and any named consignee or notify party. Often in these circumstances the shipper will be reluctant to agree any reservation regarding his loading figure.

8. Samples should be taken from the top, middle and bottom of each of the vessel's cargo tanks in the presence of a representative of the terminal and cargo interests. Similar samples should be drawn prior to discharge. It is also useful whenever possible to obtain samples of cargo immediately prior to loading, including samples from a point as near to the ship's manifold as possible. All samples should be sealed, labelled and stored for possible future reference. This can obviously lead to a storage problem, particularly since the samples should be retained for at least 12 months. However, such evidence is essential for the defense of any contamination claims that might arise. Often samples are taken at the commencement of loading after a small quantity has been pumped, in order to check if any contamination is revealed. If contamination is present, the cause of this must be fully checked and eliminated before the Master allows loading to continue. In case of doubt the Master or Member should contact either the P&I Club.

9. When loading crude oil cargoes, dips should be taken of all the vessel's cargo tanks upon completion of loading to check for the presence of free water. If any free water is found, a Note of Protest should be issued and an acknowledgement obtained from the shippers/charterers. As an additional precaution, further dips should be taken on the following day, by which time the majority any water in suspension in the cargo will have separated out.

10. Samples should be taken from the vessel's bunker tanks upon completion of loading and prior to discharge.

11. During the voyage daily checks should be made of the cargo tank ullages and temperatures, and the results should be recorded. Constant checks should also be made on the inert gas pressures, and any marked drop in pressure in individual tanks investigated. Records should also be kept of the loading or discharge of any ballast or of any internal cargo transfers.

12. On completion of discharge all tanks, including empty ballast tanks, should be dipped and, where possible, visually inspected in the presence of a representative of the terminal or cargo interests, to ensure that no cargo remains on board. The terminal or cargo interests' representative should be requested to sign a dry tank certificate and only after this has been signed should shore hoses be disconnected. Using these procedures will establish a written record of the voyage which will be invaluable in reconstructing events when a claim is made.
Shortage Claims

Many shortage claims are based on incorrect calculations. With a standard operating procedure and full records it should be possible in cases involving routine voyages to show that all the cargo loaded was discharged, and that the carrier is not responsible for differences between the shore loading and discharge figures.

Claims for shortage are often based on a comparison of shore tank figures, but in most countries the carrier’s liability only commences at the point where the cargo passes through the vessel's permanent manifold connections, and terminates when the cargo passes out through the manifold connections at the port of discharge.

A comparison between the ship’s figures at loading and discharge, and not the terminals’ figures, is necessary to determine if any loss has occurred onboard the vessel. To verify the quantities actually received on board and discharged from the vessel the following documents are usually required:

- A dry tank certificate reporting on the condition of the vessel's tanks prior to loading.
- A record of the quantity of material already in the slop tanks.
- An ullage report prepared on completion of loading.
- A statement of the vessel's draught on departure from the loading port. This may be contained in the ullage report, as in the example above.
- A statement of the vessel's draught on arrival at the port of discharge, which again may be contained in the ullage report.
- An ullage report prepared prior to the start of discharge operations.
- A dry tank certificate issued on completion of discharge, which should preferably have been signed by the consignees. The original bill of lading and charter party. Evidence of the cargo value, such as the commercial invoice with many liquid cargoes, unpumpable residues will remain on board. Whilst it is important that the quantity of such residues should be checked, clear evidence to the effect that the residues are indeed unpumpable is essential if claims are to be avoided. Investigations may therefore be necessary to prove that the vessel's valves, lines and pumps are all in good order.
- A dry tank certificate confirming that all pumpable cargo has been discharged and any quantity remaining on board (ROB) is unpumpable, will normally be conclusive evidence, particularly if signed by a representative of the consignees. In many countries, courts will accept that the carrier is not liable for shortages of up to 0.5% of the quantity laden. It is generally acknowledged that ship owners should have the benefit of a percentage allowance, since the measurement of bulk liquids is not an exact science, and unavoidable loss will often occur during a voyage. To keep measurement inaccuracies to a minimum, standard procedures should be adopted by the ship's crew when measuring cargo and calibrating equipment. If the routine documentation described above indicates a shortage which exceeds the usual allowance for the type of cargo and vessel in question, then additional investigations may be necessary, for example:
  - A survey of the vessel's tanks to verify there was no leakage of cargo during the voyage.
  - A check upon inter-tank transfers during the voyage. Accurate records should be maintained of all such transfers.
  - A review of weather conditions during the voyage. Prolonged rolling and pitching during heavy weather can increase the rate of evaporation of cargo, and may result in the release of cargo from full tanks.
  - A review of bunker records and a survey of cargo lines in order to rebut any allegation that cargo has been diverted from cargo tanks.
Example of Loadicator screen available in most tankers today

Contamination Claims

The most important evidence in the handling of contamination claims is that represented by cargo samples. Much of the documentation and evidence required for shortage claims is also necessary to contest contamination claims. In addition, the following documentation should be obtained:

- The vessel’s maintenance records, including details of previous cargoes, surveys and cleaning operations.
- A record of all cargo operations carried out on board the vessel during the relevant voyage, including pumping operations and inter-tank transfers.
This cargo pump aboard a VLCC can move 5,000 cubic meters of product per hour

Coriolis Flow Meter/ The Mass Flow Meter:

New Technology apply to quantity measurement (at present only for bunkering)

There are lot of discussions going on for adopting the mass flow metering system known as the Coriolis flow meters (based on the Coriolis Principle – named after Gustave Coriolis, a French mathematician) in the bunkering industry to improve upon existing measurement technologies and to prevent fuel-pilferage.

Thousands of vessels stem bunkers around the world every day and every now and then we come across news about bunker theft either by the supply vessel (bunker tanker or barge).
What is the Coriolis Principle?

In order to understand how the Coriolis flow meter work, we first need to understand the Coriolis Principle.

The Coriolis flow meters work on a basic principle of Coriolis Effect or ‘Force’ – which is essentially a veering or deflection of a moving object when viewed from a rotating reference frame. In the Northern Hemisphere a moving object will appear to deflect to the right (facing the direction of motion) and vice versa in the Southern Hemisphere. Note that Coriolis force is actually not a force but since the objects tend to veer to the left or right of its path, it is assumed that a force has acted upon it to cause this deflection because of the Earth’s movement underneath it.

Mass flow meters are based on this principle and a simplified explanation is as follows:

Imagine a jet of water e.g. from a pressure hose pointed straight ahead – the jet of water will move in a straight line but when viewed from a rotating reference the jet will appear to be veering to the right or left depending on the hemisphere. If the same jet of water was now enclosed in a measuring tube rotating around a fixed point with its axis perpendicular to the direction of flow of water; the measuring tube would appear to twist/deform due to the change in angular velocity from the Coriolis Effect. However, it’s not practical to make the tube rotate so instead, the tube is oscillated electromagnetically causing it to vibrate achieving the same effect as if the tube was rotating. This
twisting/deformation of the tube results in a phase difference (time lag) which is registered by use of special sensors and thus form the basis of the mass flow measuring in the system.

Watch video on how this device works:
https://www.youtube.com/watch?v=XIIViaNiTIw

The mass flow meters come in different varieties – such as straight tube type, twin tube type, bent tube type – with each having its own advantages and disadvantages; however, discussion on these types is beyond the scope of this article.

Volumetric Flow Meters vs. Coriolis Flow Meters:

The question we all face today is whether the Coriolis meters could be an alternative solution to existing volumetric flow meters (also called positive displacement meters) and manual measurements (where a bunker surveyor would measure the quantity of fuel transferred using the ‘dip’ method and look-up tables).
The issues primarily faced today are:

1) Experience of the surveyor / ship crew to carry out accurate calculations – there are many factors that can contribute to errors like incorrect temperature, density etc. and these errors can be compounded quickly giving rise to large errors in the final quantity of mass delivered. In other words, the final results will only be as good as the surveyor who performed the calculations. Whereas the Coriolis mass flow meters measures the mass directly taking into account various temperature and pressure change automatically and thus eliminating any guess work and need for any look-up tables, trim corrections etc.

2) Faulty Moving Parts of Volumetric Type Meters – Existing flow meters i.e. volumetric type meters have moving parts which can be degraded / clogged over time and thus giving inaccurate readings. Whereas the mass flow meters have no moving parts and thus does not require much maintenance. This inherent advantage is shared among all mass flow meters currently available from several manufacturers’.

3) Gauge Glasses of Flow Measurement Systems Can be Tampered With: Existing flow measurement systems will have a separate temperature and pressure gauges where these could easily be tampered with or gauges not being accurate like non-aqueous liquid filled gauges with glycerine and silicone oils often seen with broken sight glass. The whole purpose of a liquid filled gauge is for the liquid to absorb vibrations, thus providing a dampening effect to enable accurate readings and also to reduce wear and tear by lubricating all moving parts – in other words this affects the integrity and reliability of the gauge readings over time. On the other hand, mass flow meters have another inherent advantage of measuring temperature, pressure, temperature and density simultaneously via built-in sensors and displayed on an LCD display.

4) Inability Of Volumetric Meters to Detect Entrained Air in the System: Amongst other things, one major flaw in volumetric meters is and will always remain – is its inability to detect entrained air in the system which may be introduced inadvertently like during tank stripping, changing tanks, leaking valves to an empty tank; turbulence during high loading rates or deliberately leaving a valve open to an empty tank or blowing compressed air into the system through the delivery hose. This malpractice is known as ‘cappuccino bunkers’.

The cappuccino or aerated bunkers (often with froth and bubbles) when sounded will give the impression that the fuel is delivered as ordered. In fact after sometime when the entrapped air in suspension settles out of the fuel oil the fuel level drops and a short fall is discovered. In other words the existing flow meters in use today will only measure the volume of throughput and not the actual mass of fuel being delivered. As a result when air introduced into the system, which is essentially ‘small air bubbles’ – the flow meter will register it as volume and when this volume converted to mass (because fuel is always sold by weight but delivered by volume) will result in a substantial loss, especially in large bunker deliveries this could be considerable, with huge financial implications.

Prepared by Jorge Pecci, SafeWaters UM
Whereas in the case of Coriolis mass meters manufacturers’ have been claiming that these are much better in handling the ‘cappuccino’ bunkers but not all Coriolis meters have the ability to deal with entrained air which can still pose a challenge. Manufacturers’ have various varieties of mass flow meters available today however, what is not clear is how these meters would cope with the presence of entrained air or two-phase flow (gas + fuel oil) because any flow meter’s (whether volumetric or mass) basic function is to measure what goes through it and if a mixture of air and fuel is present then how it’s going to differentiate the two?

Further, the entrained air is also likely to produce a lot of additional noise and since the Coriolis meters flow measurement is based on signal processing then this will tend to interfere with the readings and thus further reduce the accuracy of flow measurement.

In short, even if the manufacturers claim to have solved the entrained air problem; we believe this issue is here to stay. Because even though Coriolis mass flow meters will outperform any other volumetric meter type on the market, it would be extremely difficult for the manufacturers to claim 100% accuracy and reliability of the measurement in the presence of entrained air.

5) Traditional Methods of Surveying Can Give Less Quantity Tolerance Level: Lot of manufacturers’ of mass flow meters claim a quantity tolerance level of less than 0.5% and some stating tolerance levels to be as low as 0.1%. Considering a stem of 2000 tons of bunker; 0.5% would mean a loss of 10 tons (in a large fleet this can easily be compounded to a huge loss \(-10 \text{ t} \times \$600 = \$6000\) per vessel) whereas comparing this to traditional method of surveying can give errors of less than 0.1% or better (this is from own experience) most of the time.

6) Vibrations Can Affect Coriolis Meters: Coriolis meters would also need to be compensated against external vibrations and be corrosion resistant. Because flow rates are measured by vibrating tubes; therefore the readings could be affected by external forces or vibrations transmitted through pipelines and also due to the operating environment where pitting, cracking, coating erosion is common place; corrosion resistant meters would need to be considered like stainless steel, titanium etc. Again some of the manufacturers’ claim to have solved this issue but will this hold up to the harsh marine environment and constant vibrations that is felt on a vessel during cargo operations etc.

Conclusion:

In conclusion Coriolis meters will definitely reduce the amount of bunker quantity disputes as these meters are less prone to tampering and can be used as an anti-pilferage tool in deterring cappuccino bunkers and at the same time increase the transparency during a stem operation. The present method of manually gauging the tanks and calculations are of course not only more prone to error but also time consuming especially in an event of a dispute but when diligently carried out the quantity tolerance can be less than 0.1% most of the time.

As technology advances and mass flow meters are more perfected (quantity tolerance-wise) vessel operators and bunker suppliers will see tangible benefits in form of high level of transparency,
efficiency and faster turnaround times for the vessel. Because everyone in this industry is well aware that in case of a major dispute a success of a claim will largely depend on the nature and the quality of evidence gathered at the time the supply is made. Without detailed contemporaneous written evidence, the party affected is likely to lose the claim or it could be many years before the dispute is settled!

To achieve global acceptability manufacturers’ may need to provide and install these meters at own cost on vessels and barges in order to conduct trials and document results. Some manufacturers’ are already engaged in trials with ship operators and suppliers but more needs to be done in order to win the confidence and trust of the end users.

Unless the use of mass flow meters is mandated disputes could still arise. For example, a vessel is fitted with a mass flow meter but the barge is not and in case of a short delivery (caused other than the cappuccino effect or other dubious practices); the barge could still stand ground that the full ordered quantity was delivered! What would you do in a situation like this? Therefore until such time, the use of mass flow meter should complement the existing method of manual surveying. Lastly, even though often the buyers (ship operators) may be tempted to buy bunkers from those offering the lowest price per ton; they should continue to use only the most trusted and reliable bunker suppliers.

- International Maritime Organization (September 1999). "IMO and the safety of bulk carriers" (PDF). Focus on IMO. Retrieved 2007-04-09.


• **International Association of Classification Societies (2007).** "21: Evaluation of Scantlings of Hatch Covers and Hatch Coamings of Cargo Holds of Bulk Carriers, Ore Carriers and Combination Carriers (Rev. 4)". Requirements Concerning Strength of Ships (PDF). Unified Requirements. International Association of Classification Societies. pp. 21–1.


• [Law and Sea](http://www.lawandsea.net/COG/COG_Bill_of_Lading2.html)