MEASUREMENT OF PETROLEUM ON BOARD MARINE VESSELS

Juri Koern
Shell Distribution North America
777 Walker Street
Houston, Texas 77002

INTRODUCTION

The process that calculates the volume of liquid petroleum loaded onto, or received from, a ship or barge is known as Custody Transfer Measurement. It is important to note that the custody transfer measurement is not determined by a single measurement. A series of measurements are taken, tests are performed and calculations are made before, during and after the transfer takes place in order to reach a Custody Transfer Measurement. The transferred volume is usually determined by calculating the difference between the volume measured before and after the transfer.

After gauging, sampling and temperature readings are taken ashore, on the vessel(s) or by a combination of the two, volume quantities may be calculated. Shore volumes are the quantities measured on shore. The quantities measured on the vessel are ship, barge or vessel volumes.

Custody transfer volumes are determined by the shore measurement figures unless there is an active shore tank. If there are active shore tanks, then the vessel volumes with a Vessel Experience Factor (VEF) will be applied to the custody transfer quantities. It is important to be able to compare vessel volumes with the shore volumes in order to view any gains/losses on the voyage. The capacity tables generated for a vessel are usually based on the architectural drawings; therefore, shore measurements are more accurate. The VEF is a comparison between vessel and shore volumes that corrects for calculation errors in the vessel's capacity tables. A VEF ratio generated from the ship/shore comparison will be applied to the vessel volumes to give a more accurate volume for the vessel.

Cargo Reconciliation and Analysis is essential in determining custody transfer volumes. Cargo Reconciliation and Analysis may identify any discrepancies between shore/vessel, vessel sailing/ vessel arrival (intransit) and vessel/ shore volumes. A gain/ loss can occur at any stage of the voyage.

Apparent loss/gain is commonly referred to as paper loss. Physical losses are most often caused by leaks, evaporation, Remaining on Board (ROB) and diversion of cargo.

API Manual of Petroleum Measurement Standards (MPMS) Chapter 17

The American Petroleum Institute "Manual of Petroleum Measurement Standards" are guidelines for measuring the volumes on board a vessel and ashore. Chapter 17 standards are used in obtaining accurate measurements on board marine vessels. There are (12) sections in the MPMS Chapter 17 series:

Section 1 - Guidelines for Marine Cargo Inspection
Section 2 - Measurement of Cargoes On Board Tank Vessels
Section 3 - Guidelines for Identification of the Source of Free Waters Associated with Marine Petroleum Cargo Movements
Section 4 - Method of Quantification of Small Volumes on Marine Vessels (OBQ/ROB)
Section 5 - Guidelines for Cargo Analysis and Reconciliation
Section 6 - Guidelines for Determining the Fullness of Pipelines between Vessels and Shore Tanks
Section 7 - Developing Barge Control Factors
Section 8 - Pre-Loading Inspection of Cargo Tanks
Section 9 - Vessel Experience Factors (VEF's)
Section 10 - Measurement of Refrigerated and/or Pressurized Cargoes on Board Marine Gas Carriers
Section 11 - Measurement and sampling of cargoes on board tank vessels using closed and restricted equipment
Section 12 - Procedure for Bulk Liquid Chemical Cargo Inspection by Cargo Inspectors

Gauging

Manually gauging a tank using the innage/ullage methods measures the level in the tank. Innage gauge measures the level of liquid in the tank whereas an ullage gauge measures the empty space in the tank above the liquid level. The gauges are recorded for each tank then compared to a calibration table to obtain the total observed volume (TOV).

The volumes on the calibration tables are based off of a designated gauge point on the vessel or shore tanks, the gauging needs to be taken from the correct gauge location. If the correct reference point is not used, the volumes recorded will not be accurate.

The liquid level measurements of the product and any free water and/or solids at the bottom of the tank are required to determine custody transfer volumes. Heavy products such as crude oil usually contain free water and sediments. Some of the water and sediments will settle to the bottom of the tank. The water that separates from the product and the sediment is called free water. Any impurities in the form of sand and mud not part of the product or free water is called sediment. The free water and sediment are deducted from the TOV to obtain the net standard volume (NSV).

Vessel tanks may be gauged through a closed/restricted (pressure control valve/ standpipe) or manual (open gauge hatch/ standpipe) system. Manual gauges are recommended for liquid level measurements and sampling when possible.

Section 1 - Guidelines for Marine Cargo Inspection states that measurements taken through non-slotted standpipes may be inaccurate as a result of plugging at the base of the pipe, capillary action, or pressure differentials. Additional measurements may be needed from other locations when this condition exists.

Section 2 - Measurement of Cargoes On Board Tank Vessels states "A closed measurement system is designed to allow cargo measurements to be taken with no vapors escaping to the atmosphere. A restricted measurement system is designed to allow measurements to be taken with minimum vapors being allowed into the

atmosphere. The two basic categories of closed or restricted system measurement equipment used on marine tank vessels are “portable manual” and ‘fixed automatic’”

On vessels fitted with closed gauging systems, comparison gauges shall be taken whenever the vessel is gauged using the open gauge method. Any necessary calibration to the closed gauging system(s) should then be made using the results of the open gauging as the guide.

Temperature

Taking temperature readings is a very important aspect of the inspection process. The most commonly used devise is the portable electronic thermometer (PET) to take the temperature readings. While some facilities may still use the cup-case thermometer for shore tank readings, this method is currently being phased out within the industry due to the mercury contained in the thermometer. The temperatures reading need to be verified on the PET and the closed/restricted equipment daily or before each use in the field. Verification is confirmed by checking it against a certified ASTM glass stem thermometer in liquid in a cold, warm or hot bath. If the readings differ by more than 0.2 deg. F, the PET should be re-standardized before it is used for custody transfer. An error in temperature determination of 1 deg. F can result in a five barrel error for every 10,000 barrels measured. Temperatures taken should be clearly designated as being degrees Fahrenheit or Celsius as appropriate.

The API MPMS Chapter 7 suggests that for a thermometer in motion and immersed in a liquid of API gravity less than 20, the portable electronic thermometer will be submerged about five minutes versus 45 minutes for the cup case thermometer.

Volume of Ship's Pipelines

A marine tank vessel has a maze of piping above and below decks. This piping system can hold large quantities of oil which may or may not be accounted for in the vessel's capacity tables. Each individual ship should have a diagram on which the location of loading and discharging piping is clearly indicated. The diagram should show the diameter and line volume when full, and/or provide sufficient information to calculate such volume. Knowledge of the pipelines used during the cargo handling operation should make it possible to determine which pipes could contain oil at any phase of the cargo operation. Before loading and after discharging the vessel, the lines should be empty. After completing the load/discharge, the vessel lines should be purged with nitrogen or air so that the product will be pushed into a compartment where it can be measured.

Vessel Capacity Tables

Unlike shore tanks, a vessel's cargo tanks are not customarily "strapped" to determine the total tank capacity. Instead, the volumes of these tanks are usually determined by mathematical means using the vessel's architectural drawings. The tank dimensions are taken from the vessel's drawings in order to calculate the liquid volumes for the vertical linear measurements, i.e. gauge readings.

Section 2 - Measurement of Cargoes On Board Tank Vessels states that capacity tables need to show the volume corresponding to each measured innage or ullage. Measurements should be taken in the same units used in the tables.

These tables may be calculated and presented in the innage or ullage format and the appropriate gauging procedure must be used accordingly. On ships, the ullage format is used for full tank amounts and the innage format is used with special tables such as the wedge tables. On most barges, the tables are presented in the innage format.

In addition to the quantities per level measurement, vessel calibration tables usually contain corrections to be applied to the volume for the vessel's trim and list in the water. These are needed because the calibration table volumes are calculated as if the vessel is on an even keel at the time of static measurement while in fact the vessel may not be totally level at the time of measurement. Make certain that the capacity tables are current. If there were any structural modifications made to the compartments, this will affect the volumes.

Many ships and some barges have had additional tables developed to be used when low liquid levels are in the vessel's tanks. These special tables are needed because the internal tank structures and conditions of the vessel's trim and list make the use of the "drawing method" to develop the calibration tables inadequate to accurately determine small quantities of liquid in the tanks. These special tables are called "wedge" tables and are used much like the calibration tables. Because of the inherent differences in ship/shore tank calibration methodology, the shore tank volumes are generally considered more accurate than the vessel tank volumes under the same conditions of measurement. It is essential for vessel owners to invest in the wedge tables so the inspectors can get an accurate volume. This would eliminate the need to calculate the wedge manually.

Trim And List Of Vessel

Vessel calibration tables are calculated as if the vessel was on an even keel at the time of measurement. If the vessel is not on an even keel, the volumes may be determined by using the draft mark readings and clinometers along with the trim and list tables in order to make the appropriate adjustments. Therefore careful readings of the draft and clinometers must be taken before every measurement operation on a vessel.

Further, when the marine tank vessel is out of trim, ROB/OBQ or free water under oil may not be measurable at the usual gauge points. While it should be found in the general direction of the trim or list, it may be trapped in segregated areas of the tank (i.e., behind beams and stringers). In these circumstances, more extensive methods of liquid determination may have to be employed if safety and operational conditions permit. In all such circumstances, the cargo documentation should show the list and trim of the vessel as well as any other pertinent facts.

Free Water

After a liquid level measurement of the product, a water finding paste should be put onto the bob and lowered to the bottom of the tank to get a "water cut". Once the bob is retrieved from the tank, there will be a color variation on the paste to indicate the presence of water. The process of free water measurement is usually referred to as

"taking water cuts" because the water "cuts" the water indicating paste on the innage bob or bar at the level of the oil/water interface.

The accurate measurement of free water on vessels may be very difficult when the vessel is not on an even keel. If the vessel is not on even keel, additional water cuts should be taken at locations in the direction of the trim or list of the vessel.

Small Quantity (OBQ/ROB) Measurements

To determine the volume of OBQ(On board Quantity)/ROB(Remaining On Board), gauged liquid levels should be trim/list corrected if the material is in contact with all bulkheads. When the material 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.

Section 4 - Method of Quantification of Small Volumes on Marine Vessels (OBQ/ROB) states when the marine tank vessel is out of trim, some OBQ and ROB Quantities may not be measurable at the usual gauge points. In these circumstances, more extensive methods of volume determination may be necessary with additional measurements taken at more than one location in each tank, if possible.

The measurement of OBQ and ROB volumes may be done by the innage or ullage method. Liquid material is usually measured by innage gauge, while solid material is measured by ullage gauge. ROB measurements should be taken after lines and hoses have been drained into a single small compartment so more accurate measurement may be achieved.

Sampling

Vessel samples are required for custody transfer quantity and quality assessment or for use as a backup/retain sample. Though very similar to static shore sampling, vessel sampling is usually more difficult to perform because of the greater number of tanks involved and the larger number of obstructions found in the vessel's tanks. Also, because vessels may have inert gas systems, sampling may have to be done through a vapor/pressure lock standpipe which is a slow, tedious process. Accordingly, vessel sampling may, in some cases, have to be performed during or after the measurement of the vessel's tanks.

Static sampling is the process of obtaining a sample of the material in a tank or container to use for testing or other purposes. A representative sample is a small portion extracted from the total volume of material that contains the same proportions of the various flowing constituents as the total volume of liquid being transferred. Static samples may be used as for custody transfer that can be determined by the API Gravity / Relative Density for volume calculations, for quality testing, or as a backup to verify automatic sampling.

When sampling is completed, each sample needs to be labeled with the following information:

- applicable ticket number or other identification
- date and time sample was obtained
- tank number

- name of vessel
- crude oil or product sampled
- type of sample i.e., opening middle sample of 3 samples; closing lower sample of 2 samples
- test requirements i.e., gravity test
- name of sample taker

Vessel Experience Factors (VEF's)

To more accurately determine the volumes on board the vessel and to be able to have a better ship/shore volume comparison, the Vessel Experience Factor (VEF) was developed. It takes five qualifying voyages to generate a VEF. This factor is a ship/shore volume comparison ratio developed over a number of voyages. It is applied to vessel volumes in order to determine more accurately the volume on board the vessel.

Section 9 - Vessel Experience Factors states that the VEF is a compilation of the history of the Total Calculated Volume (TCV) vessel measurements, adjusted for OBQ or ROB, compared with the TCV shore measurements. Separate VEFs should be developed for loadings and discharges. The information used to calculate a VEF should preferably be based on documents that follow accepted industry standards and practices, such as inspection company reports.

Conclusion

Vessel measurements are an important part of determining the final custody transfer quantities. If the vessel is not on even keel, check the draft marks and/or clinometers. Use trim and list tables to correct the volumes. Ballast and void tanks need to be observed for any leakage from the compartments. Some other factors to take into consideration when measuring the liquid level measurements are:

- Inadequate pre-unloading conference during the key meeting.
- Use of the wrong tape/bob combination
- Inappropriate measurements using the innage or outage methods
- Improper sampling of sediment and water
- Taking of temperatures in all the compartments
- Accurately accounting for the heels of the product
- The use of the same equipment at load and discharge
- Calibrate equipment before inspection