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Fundamentals of Liquid Measurement II

Class 2170

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INTRODUCTION

Measurements of liquid petroleum can be performed with the liquid in a static or dynamic state. Custody measurements are made in both states. Static measurements of petroleum liquids are made with the liquid in a tank. This paper will discuss the steps required to calibrate, gauge and sample tanks. These are the steps necessary to measure liquid petroleum in a static state.

CALI BRATION OF STORAGE TANKS

Calibration is defined as the process of accurately determining the capacity or partial capacities of a tank and expressing this capacity as a volume for a given linear increment or height of liquid.

Storage tanks may be calibrated by several methods. However, all current methods require at least one manual measurement of the circumference of the tank. This is done by strapping a tape around the outside of the tank. Tank strapping is the term generally used to describe the procedure of physically measuring a tank to provide the dimensions necessary for the computation of volumes and the generation of a capacity table for the tank. The capacity table indicates the volume contained in a tank at any given depth or increment.

The most commonly used method of tank calibration is the Optical Reference Line Method (API MPMS 2.2B). This method requires a reference circumference to be measured by the base method (API MPMS 2.2A).

Description of the Tank Strapping Method

The standards for tank calibration (tank strapping) are in the API Manual of Petroleum Measurement Standards (MPMS), Chapter 2. Typical equipment used for tank calibration is listed below.

Strapping tape

Step over

Spring Balance for Measuring Tape Tension

Tape Positioners and Cords

Steel Rule

“Littlejohn” Grips

Spirit Level

Thickness Gauge

Gauge Tape and Bob

Cup Case Thermometer

Sampling Equipment

Bottom Survey Equipment

Ladders, Bosun Chairs, Staging, etc.

The tank must be filled at least once with a liquid having a density equal or greater than the liquid to be stored in the tank.. The hydrotest done before a tank can be put into service meets this requirement.

Circumference Measurements

The internal tank diameter is determined by measuring the external tank circumference and determining the steel plate and paint thickness. The external tank circumference is determined by laying the working tape around the tank. The working tape must be verified against a master tape that has been certified by an appropriate facility (NIST in USA). The NIST calibrates the master tape to a specified length at a given temperature and tension. The temperature is normally 68ºF. The tape may be adjusted to the petroleum industry standard temperature of 60ºF by using the thermal coefficient of expansion shown on the calibration report for the tape. The master tape should never be used to take measurements of the tank. Standard tapes are usually 100', 200', 500', and 1000' in length. Tapes are ¼" to ½" in width. Tapes are graduated at the ends in 0.01' increments and are read to the nearest 0.005'.

Two strappings per course are required. The position of the strapping for each course depends on the design and construction of the tank. Each circumferential measurement can be made in one continuous measurement or in sections. The tape is laid flat on the tank, parallel to the horizontal tank seam. The tape is then brought to the specified tension by using "littlejohn" grips and a spring balance. Positioning the tape is done by either laying it on the tank and "sawing" it back and forth several times or by using "tape positioners".

A check measurement must be made to assure the first measurement is correct. Release the tension on the tape and ten apply the tension again. The two measurements must agree within 0.060" to be good. This must be done at two locations for each course of the tank.

Measurements must be taken to determine the tank shell plate thickness and the thickness of the paint. The plate thickness for welded tanks is usually determined from construction drawings. Paint thickness is usually determined using a non-destructive thickness test method. The tank shell height and gauge height must also be measured.

Tank Tilt

Measurements of the tanks should be made to determine if the tank is tilted from the vertical. This is normally done by hanging a plumb bob from the top of the tank at various locations. Tanks with a tilt of less than one part in seventy do not need to be corrected for tilt (correction less than 0.01%).

Deadwood

Deadwood is anything that takes space or adds space to the inside capacity of the tank. Deadwood includes pipes, heaters, mixers, ladders, manways, sumps, floating roof legs, etc. The size and location of all deadwood must be determined. It should be measured to the nearest ¼". It is necessary to enter the tank to make these measurements.

Bottom Survey

A bottom survey is done to determine the slope of the bottom of floor of the tank. This is done to determine the capacity of the bottom of the tank. As with the determination of deadwood this requires entry into the tank. Measurements are made to compare the difference in height of the datum plate and the floor. This is done at multiple positions. The measurements are made at fixed intervals around the tank.

The best method to determine bottom capacity is to do a liquid calibration. Metered quantities of water are put in the tank. The water height is measured and recorded with the corresponding metered volume.

Floating Roof Measurements

Tanks with a floating roof require an adjustment to volume due to the displacement of the roof when it is floating. An accurate determination of the roof weight is required. The weight of the roof is normally provided by the tank builder.

The lowest point of the floating roof above the datum plate must be determined. This point establishes the point at which the roof will begin to displace liquid. From this height to the liquid height where the roof is completely floating is known as the "critical zone". The volume displaced by the roof in this area cannot be accurately determined. The "critical zone" should be determined and noted on the capacity table.

Optical Distance Ranging Method

The optical distance ranging method determines the tank circumference by measuring the distance from aan optical reference line to the tank at determined stations around the tank. The minimum number of stations is determined from MPMS 2.2B according to the tank diameter. An even number of stations must be used. These measurements are made using an optical device mounted on a tripod or other supporting device and a magnetic trolley with a horizontal calibrated scale.

The ORLM may be done internally or externally. MPMS describes the number and locations of measurements that are required. The measurement of the distance to the reference line is then used to determine the tank circumference for each course of the tank.

Tank Capacity Calculations

A rough calculation of the tank capacity of a cylindrical tank can be computed using the following formula;

$V=D^2 \times 0.14 \times H$

Where:

V = Volume of Liquid in Barrels

D = Inside Diameter in Feet

H = Height of Liquid in Feet

MEASUREMENT OF OIL IN STORAGE TANKS

Gauging and Liquid Level Measurements

Gauging is the act of measuring the height of liquid in a tank, the density or gravity, the temperature, the level of tank bottom impurities, and sampling for impurities in the liquid. The main purpose of tank gauging is to determine the volume of the liquid in the tank.

Typical equipment used for tank gauging is listed below.

1. Steel tape with reel - Tape is normally ½" wide, graduated in feet and inches (eighths or sixteenths) or feet and hundredths, and fitted with a swivel snap.
2. Brass plumb bob - Plumb bob is pointed. Standard bob is six inches long but a longer bob is sometimes used for special conditions.
3. Thermometer - Cup case type thermometer that has a replaceable etched stem mercury in glass thermometer is most common type. A thermometer with the range or 0ºF to 105ºF and graduated in 1ºF increments. A thermometer graduated in ½ºF may also be used, or a portable electronic tank thermometer (PET) may be used.
4. Thermohydrometer - A hydrometer combined with a thermometer is used to determine the density or gravity of the liquid. The hydrometer should be graduated in 0.1degree increments and the thermometer should be graduated in 2ºF increments. The hydrometer should have a range suitable for the gravity of the oil being tested.
5. Hydrometer cylinder - A brass, glass or plastic cylinder with an inside diameter at least one inch greater than the diameter of the thermohydrometer should be used to float the thermohydrometer for reading. The cylinder must be of sufficient depth so that when the hydrometer is immersed is more than one inch from the bottom of the cylinder.
6. Oil sampler - Any acceptable type such as a Tulsa Thief, equipped with brass trip rod, brass, plastic or glass thief can, or bottle sinker can be used.
7. Cord - Cotton cord for the thermometer, long enough to permit taking temperatures at the lowest depth of the tallest tank to be gauged.

8. Gauging manual - Company issued Gauging or Measurement Manual.
9. Sample cans - Cans or bottles suitable for storing and/or transporting samples of liquid in the tank.

Care of Equipment

All equipment used in gauging should be kept clean and in good working order. The ½" steel gauge tape should never be repaired. A kinked tape must be replaced. The gauge reel should be kept clean. When the markings on the tape become illegible, the tape must be replaced.

The six inch brass plumb bob should be pointed. Plumb bobs that ate worn and blunted should be replaced. If the six inch bob is not heavy enough to penetrate settled S&W a larger bob should be used. The bob should be removed from the tape at the end of each use to prevent wear and kinking of the tape.

Special care should be given to handling the thermometer. Thermometers with separation of the mercury column should not be used. Thermometers should be checked before each use.

The thermohydrometer should be clean before each use and should be cleaned after each use. The thermometer should be checked for mercury separation and the gravity scale should be checked to assure it has not moved.

Description of Gauging

1. The tank should be gauged with a steel tape graduated in 1/8 inch or 1/100 foot increments and fitted with a brass or non-sparking plumb bob graduated in the same increments.
2. The "innage" method is the normally used for opening and closing gauges. Some conditions may require the use of the "outage" method of gauging. An example is if the tank has a layer of solid or semi-solid material that prevents the plumb bob from reaching the bottom of the tank.

   The "innage" gauge is determined by immersing the tape in the oil until the plumb bob touches the bottom of the tank or the datum plate and then reading the height to which the wet oil cuts or marks the tape.

   The "outage" gauge is obtained by measuring the distance from a gauging reference point to the oil level and subtracting the distance from the over-all depth of the reference point to the datum plate. An "outage" gauge may also be obtained using and "outage" tape. The zero point of the "outage" tape is at the to of the "outage" plumb bob. The "outage" plumb bob is marked opposite a regular bob. A six inch bob has the six inch mark at the tip and zero mark at the top of the bob.
3. Tanks of less than 1,000 barrels capacity are gauged and reported to the nearest ¼ inch.
4. Tanks of 1,00 barrels and larger incapacity are gauged and reported to the nearest 1/8 inch 0or 1/100 foot.
5. The following precautions and procedures are recommended for good gauging:

(a) The liquid surface should be quiet before gauging

(b) Two or more gauges should be taken for each tank gauging until two consecutive gauges agree.

(c) Applying a gauging paste to the tape is necessary if it is difficult to read the liquid cut on the tape. Never use chalk, talcum powder or other material that allows the liquid to creep up the tape.

(d) Always lower and remove the steel tape keeping it in contact with the tank gauge hatch. This grounds the tape to the tank and prevents a static discharge.

(e) Lower the gauge line into the tank slowly especially when the plumb bob nears the bottom. The plumb bob should touch the bottom of the tank or datum plate lightly and should not tilt or deviate from the vertical position.

(f) Use the same gauging method and procedure for opening and closing gauges. Use the same equipment and gauge at the same point.

Procedure for Gauging Floating Roof Tanks

Gauging of tanks with floating roofs is best done from a gauging platform. If gauging must be done from the deck of the floating roof be sure to follow all company procedures for gauging and for confined space entry.

Gauging of tanks with floating roofs is normally done using the “innage” method of gauging. The presence of water, snow, or ice on the roof can cause an error in gauging. These materials change the weight of the roof. They should be removed before gauging the tank if possible. If it is not possible to remove the water, snow or ice then an estimation of the average amount should be made and recorded. The estimated weight of the material should be determined

(a)

The roof must be fully landed or fully floating at the time of gauging the tank. Friction from the roof binding or dragging due to various conditions can cause a variation in the roof displacement. Settled S&W material can change the roof displacement zone and change the “critical zone” for the tank.

Tank Measurement Uncertainties

Tank gauging can accurately measure the volume o liquid in a tank. However there are several things that contribute to inaccurate tank volumes. API MPMS 3.1A discusses these in detail.

1. Tank table error
2. Shell expansion and deflection
3. Bottom movement
4. Still pipe movement
5. Un-slotted still pipe
6. Datum plate movement
7. Incrustation

Tank Sampling

Accurate measurement involves the determination of quality as well as quantity. Actually some quality measurements are used for quantity determination. Samples of the liquid are used for S&W, gravity and other tests to determine both the quantity and the quality. Therefore, obtaining a representative sample is an important part of good tank measurement.

Samples must be representative of the liquid to be tested. That portion of the sample used for testing should be thoroughly representative of the total sample. Proper mixing and handling procedures are important. The API MPMS Chapter 8 has procedures for taking a sample and for mixing and handling the sample.

Samples can be obtained by several different methods:

1. Bottom Closure type thief (Tulsa Thief)
2. Bottle type sampler
3. Line sampling
   (a) Manual
   (b) Automatic
4. Tank taps

Observed Gravity and Temperature

After obtaining a sample the tests for quality are performed. The determination of gravity is the most common test performed.

Place the thief or the hydrometer cylinder in a vertical position. Select a clean thermohydrometer of the proper range. Immerse the thermohydrometer in the liquid. Lower it into the liquid to a point slightly below that to which it will naturally sink and release it. Allow the thermohydrometer to remain in the liquid for at least three minutes or longer to accurately determine the test temperature. The thermohydrometer must be floating freely and not touching the wall of the container. With your eyes on a level with the liquid surface, read the observed gravity on the upper scale at the nearest tenth of a degree point to which the liquid rises along the stem above the main surface of the liquid. This rise of liquid above the main level is called the meniscus and for crude or other opaque liquids the reading should be taken at the top of the meniscus. Subtract 0.1 degree to correct for the meniscus. For products and other clear liquids the reading should be taken at the bottom of the meniscus where the main level would cross the stem and no correction is needed.

Keep the thermohydrometer immersed in the liquid. Read the observed temperature to the nearest degree. The thermometer is graduated in two degree increments but may be read to the nearest degree. It is important to read the temperature immediately after reading the observed gravity.

Corrected or API Gravity

Relative density of a liquid is the ratio of the weight of a given volume of liquid to the weight of the same volume of water at the same temperature. The weight of a gallon of water at 60ºF is 8.328 pounds. Dividing the weight of a gallon of oil at 60ºF by 8.238 will give the relative density of the oil.

When relative density is known, the following formula is used to determine the API gravity:

APIº = (141.5 / RelDen@ 60/60F) - 131.5

Measurement of Free Water

The most common method used to determine free water and sediment in a tank is to use a water finding paste on the plumb bob and gauge line. A thin coat of paste should be applied to the bob and tape at the level at which the water is expected. This teat can be made when obtaining the innage gauge by allowing the coated bob and gauge line to remain in the gauging position for a sufficient time to obtain a good water cut.

When measuring water in tanks containing heavy viscous liquid, apply a film of thin lubricating oil over the water finding paste to facilitate reading the water cut. Allow the gauge line and bob to remain in the gauging position for at least 60 seconds. When gauging tanks containing black oils, it may be necessary to wash the surface of the tape with light oil or solvent to permit reading the water cut. For some oils, particularly some crude oils, the depth of water will be indicated by a color change or the complete removal of the paste over a definite area.

Another method of determining the quantity of water and sediment is to use a bottom sampler or bottom closing thief. The thief is equipped with a trap door that can be closed by a gentle tap on the tank bottom. A column of the water and sediment is trapped in the thief and retrieved to the top of the tank. The contents of the thief are slowly poured over a glass or a gloved hand until discoloration or pure water appears. The thief is then turned upright and the remaining content level is measured. This measurement is recorded as the quantity of water and sediment.

Tank Temperature Determination

Temperature is one of the most important qualities of the liquid to me measured. Therefore, a thermometer or electronic temperature probe is one of the most important instruments used in oil measurement. More oil is lost with a thermometer than with a gauge tape. An error of four degrees in temperature is equivalent to an error of ±1/4 inch in a tank of any diameter for every 10 feet of liquid.

The temperature of the liquid in the tank should be made independent of any temperature determined in the gravity test. The temperature read on the thermohydrometer is only used for correcting the observed gravity.

Special care should be taken when measuring temperature especially during times of inclement weather and high or low ambient temperatures. The API MPMS Chapter 7, Temperature, gives immersion times for cup case and electronic thermometers. The cup case thermometer (woodback) is still commonly used for taking the temperature of oil in a tank, although electronic temperature measurement is often used. The required immersion time for electronic thermometer is much less than that required for the cup case thermometer.

One procedure for taking a tank temperature is as follows:

1. Immediately after the gauge has been taken, suspend the thermometer in the liquid. When the proper depth for suspension has been reached, the thermometer should be raised and lowered many times to assist in a rapid stabilization of temperature. The point of suspension should be as far away from the tank shell as possible. Generally this is about 12 inches.
2. If using a PET, raise and lower the probe 1 foot (0.3 meter) until the temperature stabilizes.
3. Withdraw the cupcase thermometer from the tank and keep the cup in the gauge tube. Read the temperature as quickly as possible to the nearest degree. DO NOT EMPTY THE OIL FROM THE CUP BEFORE READING THE TEMPERATURE. If using a PET record the temperature.
4. Take three temperatures at appropriate levels if the tank level is more than 10 feet or the tank is larger than 5000 barrels.
5. Record the ambient temperature as determined in a shady area or a local on-site weather station.

Conclusion

Static or tank measurements are accurate and may be used for both custody measurement and inventory measurement. However if the proper equipment and procedures are not used the error in measurement may be large.

Note: This paper is patterned and has excerpts from original papers written by Michael J. Yeandle and Bob Dix.