ACCURATE BS&W TESTING IMPORTANT FOR CRUDE-OIL CUSTODY TRANSFER

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Monitoring crude-oil sediment and water content at the field production site is essential in accurate crude-oil custody transfer operations.

This is accomplished by manual methods, or on-line devices like capacitance, density, or energy-absorption analyzers.

For custody-transfer purposes, sediment and water is determined by a test which follows one of the API manuals of petroleum measurement standards (MPMS).

Typically, this test is conducted in the field by the field centrifuge method which, if performed properly, yields very accurate results. Laboratory tests can be performed, but sample handling becomes even more critical.

MONITORING BS&W

The quantity of sediment and water in crude oil must be established accurately as part of the custody-transfer process. Purchasers pay only for the crude oil received and want to minimize the quantity of sediment and water they must handle.
Consequently, monitoring the sediment and water content is performed at the production site to prevent excessive amounts entering the pipeline system.

How much a pipeline is willing to accept into its system depends on geographic location, market competitiveness, and its ability to handle the sediment and water in the system. Each pipeline publishes the quantity it will accept.

Most pipelines require that a lease automatic custody transfer (LACT) unit be equipped with a basic sediment and water (bs&w) monitor, typically in a vertical rise of pipe. Most of the bs&w monitors in use are capacitance devices and generally detect only the amount of water present (Fig. 1).

The capacitance probe works by measuring the capacitance of the fluid-filled probe and comparing the value obtained to those values obtained with the probe filled with either all water or all oil. The capacitance output from the process fluid-filled probe will be proportional to the water content.

This technique assumes that the dielectric strengths of the oil and the water will remain relatively constant.

This type probe can be affected by the amount of water, the emulsion characteristics, temperature, variation in properties of either the hydrocarbon or the water, presence of free gas, and paraffin deposition. The analyzer should be calibrated at the factory by the manufacturer with oil and water similar in composition to what the device will encounter in the field.

The analyzer is installed in vertical pipe to provide the best mixing which, if the water content is less than 3%, will ensure that an oil-continuous emulsion will exist (essential for this type of device). The analyzer should be calibrated at normal operating temperatures because dielectric constant is a function of temperature.

Table 1 shows the dielectric constant of water at various temperatures. Table 2 shows the dielectric constants of example hydrocarbons. Fig. 2 demonstrates the change in dielectric constant as a function of salinity. These changes require that the analyzers be zeroed and spanned in the field periodically to render optimum performance.

Free gas in the stream typically results in under measurement of the water cut, so care should be taken to reduce or eliminate any free gas in the system.
Similarly, the buildup of paraffin in the probe causes erroneous readings. This buildup can be minimized by chemical treatments, heat tracing, or frequent cleaning with a solvent. Care should be taken to avoid damage to the probe’s coating during cleaning to avoid errors.

Other types of analyzers to monitor water cut are becoming more popular. One, the density-type, works because the densities of oil and water are generally very different. Thus, measuring the density of the emulsion can yield the percentage water.

The vibrating element, differential pressure, nuclear, and Coriolis meters are density monitors. These devices are affected by temperature, free gas, variation in the densities between the oil and water, vibration, and paraffin deposition.

Because temperature affects fluid density, these units must either have temperature compensation or be installed on a steady-temperature stream. The effect of free gas and paraffin on these devices is similar to the effect on the capacitance devices.

Vibration effects should be minimized or eliminated, especially on the vibrating element devices and Coriolis meters.

These units do not work well on heavy crudes for which the densities of the crude and water are similar.

Another type of unit in use is the energy absorption water-content monitor. This device measures the electromagnetic energy-absorption rate. The difference in the energy-absorption rates between water and hydrocarbons is utilized to determine the water content.

These devices are not affected by variations in fluid densities and are less affected than the other devices by paraffin deposition.

These monitors should be installed in vertical pipe with downward flow so that an oil-continuous emulsion occurs.

Free gas has significant impact on these devices and thus must be eliminated from the stream. This is accomplished by proper separator design or use of an air eliminator.

Variations in temperature of the stream affect these devices and dictate recalibration whenever large variations occur. Field calibration should be performed periodically to obtain optimum performance. The frequency with which this is required is a function of the field conditions.
FIELD TESTING

While monitoring of sediment and water sets up a "go/no go" decision on whether the pipeline will handle a particular quantity of crude, the sediment and water testing is used for the determination of the custody-transfer quantity for which the producer will be paid.

Typically, this measurement is performed at the production facility, utilizing API Manual of Petroleum Measurement Standards (MPMS), Chapter 10, Section 4, Determination of Sediment and Water in Crude Oil by the Centrifuge Method (Field Procedure)-1986.

API-MPMS Ch. 10, Sec. 4 requires the centrifuge tubes (Fig. 3) used be either 6 or Bin. cones. The standard specifies allowable tube dimensions and tolerances.

Here is the field procedure:

1. Fill two centrifuge tubes to the 50 ml or 100 part mark with the homogeneous sample to be tested. Read the top of the meniscus.

2. Fill the two tubes with 50 ml of solvent which brings the total contents of the tubes to the 100 ml or 200 part mark. The acceptable solvents are Stoddard, kerosine, toluene, and xylene. Note that toluene and xylene should be water-saturated at test temperature.

3. Invert the tubes 10 times to mix the sample and solvent. This should be done below eye level for safety, and safety glasses are recommended.

4. Place the tubes in the preheater and heat to 140 F. 5 F.

5. Invert the tubes again 10 times to mix.

6. Place the tubes on opposite sides of the centrifuge to balance the load and close the lid.

7. Centrifuge for a minimum of 5 min.

8. When the centrifuge comes to a rest, test the temperature of the tube contents without disturbing the oil-water interface.
9. If the temperature of the sample is 125 F. or greater, read and record the combined sediment and water content at the bottom of each tube. If the temperature is less than 125 F., the tubes must be reheated and the test repeated without further agitation until two consecutive consistent readings are obtained.

10. If an emulsion is visible, add a solvent containing a demulsifier to the sample and retest. (This is covered in the appendix of the Standard.)

11. Compare the readings from the two tubes. If the results vary by more than one subdivision on the centrifuge tube, the sample was not homogeneous. Thus, the test should be repeated with two fresh samples.

If the procedure is followed closely, the results obtained will be reliable and accurate. In order for the correct results to be obtained, special attention should be given to the obtaining of a representative sample.

Sampling is covered in API-MPMS, Chapter 8, Sections 1 and 2. Fig. 4 shows tank locations for taking samples.

SAMPLE SIZE; READING

If the centrifuge tube is filled with any proportion other than 50:50 sample/solvent, the results cannot be read directly from the centrifuge tube. The following equation must be used to adjust for the incorrect mixture:

\[
\text{Sediment and water, } \% = \left( \frac{S}{V} \right) \times 100
\]

where:

\[ S = \text{Volume of sediment and water found, ml} \]

\[ V = \text{Volume of oil tested, ml} \]
This is why the procedure recommends that the sample be placed in the centrifuge tube initially. If this is done, adjustments to the quantity can be made by either adding or removing sample until the 50 ml mark is achieved.

The proper reading is at the top of the meniscus. If tubes marked with 100 ml at the top are utilized, the actual sediment and water is the sum of the readings from the two tubes.

If tubes marked with 200 parts are used, the correct sediment and water result is the average of the two readings.

SOLVENTS

Solvents can be hazardous and consequently should be handled with caution. Avoid breathing the vapors. Use only in well-ventilated locations. Rubber gloves should be used to avoid repeated or prolonged contact with the skin.

Handling precautions recommended by the manufacturer should be followed. These solvents are either flammable or combustible and thus necessary precautions should be observed.

Stoddard solvents are most commonly used in the field since they are readily available and require no water saturation. Asphaltenic and paraffinic crudes require the use of either toluene or xylene to obtain the correct results.

Both of these solvents, however, must be water saturated at test temperature (140°F.) and maintained at this temperature until used. The proper technique for water saturation is covered in Appendix of API-MPMS, Chapter 10, Section 4.

One vendor has started packaging water-saturated toluene in glass vials which are easy to use in the field and minimize any exposure to the toluene. The same vendor has a device available to heat the glass vials to 140°F. prior to use.

LABORATORY TESTING

Sometimes samples are transported to a laboratory for the determination of sediment and water for custody-transfer purposes. In a lab environment, the actual tests performed can be more accurate; however, proper sample handling becomes critical.

During transportation to the lab, the sample may stratify or separate into layers. Before the analysis is performed, the sample must be brought back to its original state by mixing.
How often the sample is transferred affects how representative is the actual field fluid. Without a representative sample, it is impossible to obtain the correct results.

Representative samples can be analyzed for water content by use of API MPMS, Chapter 10, Section 3, "Determination of Water & Sediment in Crude Oil by the Centrifuge Method" (Laboratory Procedure). This method is very similar to the field centrifuge method, except that only 8-in. centrifuge tubes and water-saturated toluene are permitted.

The water content may also be determined by API MPMS, Chapter 10, Section 9, "Determination of Water in Crude Oils by Coulometric Karl Fischer Titration." This methodology provides accurate results in the 0.02-5.0% water in crude oils. Mercaptan and sulfide in the crude interfere with this test.

The methodology in API MPMS, Chapter 10, Section 9, requires that an aliquot be injected into the titration vessel of a Karl Fischer apparatus. Iodine for the Karl Fischer reaction is coulometrically generated at the anode.

Excess iodine is detected by an electrometric end-point detector and the process terminated when all the water has been titrated. One mole of iodine reacts with one mole of water. Therefore, the quantity of water is proportional to the total integrated current according to Faraday's Law.

Mixing is critical to this methodology because the largest aliquot injected is only 1 g. In the higher water-content ranges (0.5-5.0%), only 0.25 g aliquots are recommended. Thus the ability to get a representative sample is critical. The quality of the reagents and solvents used in this test is also important.

LABORATORY PROCEDURE

1. Add fresh solvents to the anode and cathode compartments of the titration vessel and bring the solvent to end-point conditions.

2. Mix the sample so that a representative aliquot can be obtained.

3. Starting with a clean, dry syringe (high quality of suitable capacity), withdraw at least three portions of the sample and discard to waste.
4. Withdraw the aliquot to be tested into the syringe.

5. Clean the needle with a paper tissue.

6. Weigh the syringe and contents to the nearest 0.1 mg.

7. Insert the needle through the inlet port septum, start the titration and, with the tip of the needle just below the liquid surface, inject the sample.

8. Withdraw the syringe.

9. Weigh the syringe to the nearest 0.1 mg.

10. After the end-point is reached, record the titrated water registered on the instrument display.

The calculation is as follows:

Water, mass % = W1/(10,000 X W2)

where:

W1 = Mass of water titrated, mg

W2 = Mass of sample used, g

Water, vol % = AR

and:

A = Water, mass %

R = Relative density of crude oil
Additionally, the appendix covers a methodology which utilizes volumetric determination of sample size. Results of round-robin testing indicate that the volumetric methodology can be just as accurate as the methodology described here previously.

The volumetric methodology can be performed in a laboratory environment or in the field. This technique requires high-quality syringes. Ten ml graduated for readings to 0.01 ml is preferred, but the resolution must be at least 0.01 ml.

The presence of gas bubbles in the syringe is a source of uncertainty. Any gas bubbles should therefore be removed before the test is performed. The procedure is the same as just described, but instead of weighing the sample, note the sample volume.

The calculation is as follows:

\[
\text{Water, volume \%} = \frac{V_1}{(10,000 \times V_2)}
\]

where:

\[V_1 = \text{Volume of water titrated, ml}\]
\[V_2 = \text{Volume of sample, ml}\]

"Water by Distillation" is covered in API MPMS, Chapter 10, Section 2. It is considered the most accurate methodology available.

However, this technique is very time consuming and thus is rarely performed for normal custody transfers of crude oil.

All of these laboratory methods, except the centrifuge method, test only for the water content. Thus a second test method must be performed to determine the sediment content.

Occasionally, the Coulometric Karl Fischer methodology is utilized to obtain the water content, and the sediment content is obtained by centrifuge. Generally, if laboratory tests are performed to obtain the water content, the sediment content is obtained by either sediment-by-extraction or sediment-by-filtration.
Sediment-by-extraction is covered in API MPMS, Chapter 10, Section 1. Sediment-by-filtration has not yet been finalized as an API standard. Both of these techniques are strictly laboratory techniques and are not covered here because they are relatively time consuming.

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