FUNDAMENTALS OF PYCNOMETERS AND DENSITOMETERS

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Introduction

This paper will discuss the role of the pycnometer in density meter calibrations. The primary objective will be to provide the necessary steps required to properly install, operate, and maintain the densitometer and pycnometer (pyc). Common issues encountered with pycnometers as well as densitometers are also discussed.

Densitometer Operation/Installation

Several different types of densitometers are available today. The most common used in the industry rely on vibration to calculate fluid density. Whether a tuning fork, straight tube, or Coriolis design, each of these use the same basic principle of vibration. These types of density meters all vibrate at a resonant frequency, as product is introduced into the system that frequency is altered. The system senses the change in vibration making the necessary calculations and transmits the measured density.

Typically densitometers are installed using a slip-stream method which involves placing the densitometer on a sampling line parallel to the main line. Usually this is a smaller diameter pipe as compared to the main line piping. This method relies on a means to generate differential pressure to flow through the densitometer. Sometimes the process will not allow necessary back pressure to generate sufficient flow through the density meter. This normally results in an inaccurate density indication because the measured product is no longer representative of the main line product. Though not exactly a prevalent problem, the potential still exists and should be monitored. Low flow rates through the density meter normally lengthen the time it takes to equalize fluid temperatures to the main line enough to perform a pycnometer proving.

Coriolis meters can provide an alternative solution to slip streaming. Their larger sizes can match the main line size. This allows density measurement of the full stream, along with volume and/or mass flow measurement. The added benefit is that 100% of the product is being measured by one device. In most cases the only deterrent of this type of configuration might be the cost of a larger Coriolis meter versus that of the smaller densitometer. Ultimately, the deciding factors come down to product type, pipeline configuration, and contractual agreement.

Pycnometer Design/Characteristics

There are several different types of pycnometers. High pressure pycnometers are normally used in the hydrocarbon industry. Though some do offer advantages over others, most can be utilized effectively. In reality almost anything can be used as a pycnometer as long as you can accurately determine its base volume and certified weight/mass.

For this paper, the focus will be on the most common design, the double wall vacuum insulated sphere type pycnometer. This design is popular for its efficiency in reaching and sustaining stable density conditions. This is due in part to the double wall design. Within the layer separating the inner and outer walls, a vacuum is drawn. This acts as an insulator for the small fluid containment area within the center. A siphon tube inside runs nearly the length of the pycnometer's product chamber. This causes a slight swirl effect and helps homogenize the product for more stability as well as transferring gases or vapors up and out of the pyc.

All of these features help to stabilize fluid conditions to more accurately conduct a density meter proving, but the pycnometer is still vulnerable to ambient conditions around the pycnometer. Test results are influenced by environmental conditions, pipeline processes, or even system configuration. Arguably the most negative influence on the test is the presence of moisture/condenation on the outside of the pycnometer. Condensation has mass and excess mass will skew the results. Unless measures can be taken to eliminate this risk, it is a good practice to avoid testing during rainy or extremely humid conditions. Other examples of environmental concerns would include extreme temperatures, both hot and cold. Typically the further apart the product temperature and ambient temperature are, the more difficulty you will have in attaining stable temperatures. This can usually be avoided by completely insulating the system and choosing the most efficient piping configuration, though not always the most convenient.

Often times the configuration of the pycnometer/densitometer loop can produce challenges itself. Simply put, efforts should be made to keep the length of the loop as short as possible. By doing this, the distance between the main line, densitometer and pycnometer is reduced. The shorter distances should allow for conditions to stabilize much more quickly and also be sustained. The loop should also be configured in such a way that temperatures and pressures can be verified across each point in the system.

Finally, pipeline process can also affect densitometer calibrations. Most commonly they are:

- Unstable product conditions
- Erratic flow rates
- Varying fluid temperature
- Unstable fluid density

Certification/Verification of the Pycnometer

Before a “pyc” can be used in the field to conduct a calibration, it must first be certified. This process is done within a laboratory setting and carried out with strict adherence to API standards. There are five key factors that make up a “pyc” certification and they must be present on the associated report. They are:

- The air-filled weight (Wa) which represents the weight of the “pyc” with the fluid chamber full of air.
- The evacuated weight (Wo) which represents the weight while the fluid chamber is under vacuum.
- The pycnometer base volume (PBV), or the determined volume of the fluid chamber.
- The coefficient for expansion due to temperature (Et).
- The coefficient for pressure expansion (Ep).

Verifying a pycnometer’s empty weights takes place in the field before starting a proving. This procedure is necessary because it must be assured that the weight of the pycnometer has not shifted from the certified values. The field values must agree with the certified values by +/- 0.02% or the pycnometer must be cleaned and verified. If it cannot be verified within +/- .02%, it must be recertified.

The basic steps to conduct pycnometer field verification are:

- Clean the pyc thoroughly inside and out.
- Ensure that it is completely dry as well.
- Level and verify/calibrate the weight scale using certified traceable test weights.
- Draw a vacuum on the pycnometer and record the weight.
- You can also verify Pycnometer by air filled weight, open valves to allow air to fill the pycnometer and record weight.
- Either weight must be within +/- .02% of certified weight.

It is important to note that the correction for changes in elevation must be accounted for when testing. The greater the elevation difference between verification and certification sites, the more error will be introduced between field and reference values. This can cause a pycnometer to fail verification.

Pycnometer Installation/Operation

When installing the pycnometer ensure that connections are made with a secure fit and proper seal. Allow flow to slowly enter the upstream valve first, to fill the pyc. Open the vent valve to allow any gases/vapors to escape and not enter the pyc. Ensure the pyc is filled completely with process fluid and no gases. Next, close the bypass valve to initiate flow through the pyc.

Steps to perform a density meter proving are highlighted throughout **API MPMS 14.6**. Allow sufficient time for the density in the loop and the pyc to stabilize. Verify process conditions are stable. Once the temperatures for the pycnometer and densitometer are agreeable to within 0.2 degrees F and pressure differential to within 1 psi, as outlined in **API MPMS 14.6**, data collection can begin. Collect and record the following data:

- Densitometer Temperature
- Densitometer Pressure
- Pycnometer Temperature
- Pycnometer Pressure
- Ambient Air Temperature
- Uncorrected Observed Density for the indicating instrument (uncorrected by the current DMF)

After all information is collected, carefully, safely, and quickly remove the pycnometer. First close the outlet valve of the pyc. Open the bypass partially before closing the inlet valve. This will usually help maintain temperature stability. Once both valves are closed, isolate the pyc from the system and vent/flare residual product from the connections. Remove the pyc. Be sure that the weigh scale is calibrated, level, and has stabilized to ambient conditions. Next, make sure that pyc is still free of debris or moisture. If necessary wash the outside and blow dry with air or nitrogen. Record the weight of the fluid filled pyc. Repeat these steps until two consecutive density meter factors (DMF) repeat within 0.05%. Average the two repeatable DMFs together to calculate a final density meter factor (DMF). **API MPMS 14.6.13.8** specifies that for meters in which the density output is adjusted, an additional proving run must be performed to confirm that the adjusted output does not differ from the new tests result by more than 0.05%.

Recertification of the Pycnometer

There are several instances that require the pycnometer to be recertified. The pyc is required to be recertified every 2 years in accordance with **API MPMS 14.6.9.5**.

This standard also states that the following occurrences mandate recertification:

- Damage to the vessel
- Disassembly of the vessel
- The rupture disc has been replaced
- The valve parts have been replaced

Note that if the valve manufacturer can present substantial proof that the certified volume and weight of the pyc would not change by more than +/- 0.02%, then it is not necessary to recertify the pyc after a valve change.

Conclusion

The process of calibrating a density meter through the use of a pycnometer can be quite tedious. It is a careful process that requires close attention to detail as well as very stable conditions. This testing does prove to be extremely accurate and effective if the steps and provisions outlined in this paper are explicitly applied and adhered to.