OPERATIONAL EXPERIENCE WITH DENSITOMETERS AND PYCNOMETERS

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Introduction

The use of densitometers is widespread over many different industries. These range from food & beverage industries to petro-chemical and pipeline transmission. This paper will cover the installation and operation of densitometers in the petroleum pipeline industry. It will also discuss pycnometers used to calibrate densitometers. In using a pycnometer, you must have the correct scales, pressure gauges and thermometers. You will learn the steps necessary to install, operate and calibrate the instrument.

Selection and mechanics of Densitometers

Today, the most prevalent type of densitometer is the vibrating tube densitometer. There are straight tube configurations and U-tube configurations. Both use the same type of physical, mechanical and mathematical concepts to determine density. Both use the change in resonant frequency with respect to the fluid passing through the device to determine the density of that fluid. Most of these are installed on a sampling or “slip-stream” line apart from the main pipeline. One of the newest types to enter the working market is the Coriolis style meter for mass measurement and density. These are predominately “in-line” devices but can also be used in the sampling type installations. Regardless of the type, the installation of the device is critical. Whether it be a vibrating tube, tuning fork or a Coriolis, the device must have a good single phase product flow and “full tube” situation at all times to develop accurate data output. With respect to densitometers installed in slip stream systems, this flow must represent the product flow of the pipeline as best possible, especially for custody determinations. Without the correct flow, the data output of these devices will not be representative of the actual flowing density of the pipeline. The selection of the type of densitometer would be based upon the criteria surrounding the pipeline and fluids being measured. This can range from simple multi-fluid interfacing detection to custody metering requirements.

Installation & Operation Densitometers

The densities of liquids being transmitted through pipelines have a rather wide range, from ethane of 0.3600 q/cc to +0.9000 g/cc for fuel & crude oils. Some of the toughest measurements are in the range of 0.3600 g/cc to 0.7000+ g/cc, which is covered by Chapters 14.6 and 14.8 of the API Standards. This paper specifically addresses the sampling or slip-stream type installation. This type or style is designed to draw a sampling stream from the main pipeline, measure that sample and return it to the pipeline or retain for lab analysis. Review of Fig. 14 in Chapter 14.6 demonstrates the flow diagrams for densitometer loops. Also, one must take into account the proving system for the densitometer when addressing the installation of the densitometer. Here the three basic components of these systems are addressed, 1) the design, 2) the operation and 3) the proof.

The Design

There are many things to consider in the design of the densitometer installation system. Some of these are whether the line is to be pig-able, is this for custody, check metering, or interface detection, slip-stream in series or parallel measurement. Most design concerns have been centered on the most popular of the systems, which is the slip stream design for custody measurement. To begin the design, the type of “sample” that is being measured must be defined. Quoting Chapter 14.8.5.6, “Sampling shall be accomplished to yield a sample that is proportional to, and representative of, the flowing stream during the measurement interval.” From Chapter 14.6.10.1 (b), “the system shall include a sample probe in the center third of the pipe for slipstream flow.” For direct measurement of density, to retrieve a good representative sample of the pipeline flow, it is imperative that the sample point be within this middle third of the pipe diameter flow. This mandates the use of some type of probe to penetrate the flow. One might ask, “why the need for this component”----“why not just take the sample from a coupling or nozzle penetration welded into the pipe”---is it not the same thing?”---and the answer to the latter is “no”. Once again quoting API, Chapters 14.6.10.1 (a) & 14.6.7.5 (a) states “The system shall be installed in a location where the fluid is homogeneous”.

The Operation

The selection of the density measuring device is up to the individual user, pipeline owner, or commercial contract agreement. Whatever the manufacturer, type or style, the selection should match the necessary data output requirements. The device should be calibrated for the density range of the product measured along with the pressure and temperature properties of the pipeline.

The Proof

The selection of a proving device is varied based upon the type of liquid(s) that are being measured and the type of densitometer system being used. For continuous flowing density or slip-stream, there are two main devices being used. They are the pycnometer or “pyc ball” and a master metering device.

The newly constructed pycnometer shall be laboratory certified prior to use.

The certification shall provide the following information:

- Certified air-filtered weight (W_a)
- Certified evacuated weight (W_0)
- Pycnometer base volume (PBV)
- Certified Coefficient of Expansion due to internal pressure of the pycnometer (E_p)
- Certified Coefficient of Expansion due to temperature of the pycnometer (E_t)

These values are to be used in the calculation associated with using pycnometer to calibrate the densitometer.

Field Verification of Pycnometer Certification

The purpose of the field verification is to ensure that there has been no shift in the certified volume of the pycnometer (PBV) or of the evacuated weight (W_0). The field test should be performed at any time there is concern about the continued accuracy of the certified values. If the field test does not agree with the certified values within .02%, the pycnometer must be recertified.

The following steps should be followed:

- Thoroughly clean the pycnometer inside and out.
- Draw a vacuum on the pycnometer and weigh it.
- Open a valve to admit air into the pycnometer and weigh it again.
- Two consecutive field tests should agree within 0.02%.
- The field tests should agree with the certified values within 0.02%.

*Note that a significant difference in elevation between the certifying laboratory and the field location will cause differences in the evacuated weight. To determine conformity with certified values, adjust the observed evacuated weight for variation in altitude.

Calibrating Pycnometer

Before a pycnometer can be installed there are calibrations that need to be completed. The accuracy of the proving is important in obtaining a successful pycnometer test. A key piece of equipment is the weigh scale. There are five pieces of equipment needed to perform an accurate pycnometer calibration of a density meter:

- Pycnometer
- Weigh Scale
- Certified test weights
- Certified Thermometer
- Certified Pressure Gauge

The weigh scale should be calibrated at the time of proving with certified apparent mass standards (test weights) to assure accuracy. Scales should be mounted on a stable and level surface. Air shields around the scale can stop the effects of current on the scale. The following shall be performed to verify pycnometers evacuated weight:

- Place evacuated pycnometer on the scale and record the scales readings.
- Verify that it does not differ more than 0.02% from the certificate.
- Once it is determined that the pycnometer is at the certified weight the pycnometer can be installed.

Installing Pycnometer

When installing the pycnometer there are a series of steps that must accurately be followed. The pycnometer may be installed in a series or parallel with the density meter. You should always allow product to enter the upstream pycnometer valve first. Gases or vapors must be vented/flared from the pycnometer and piping through the vent valve. Now that the pycnometer is fluid filled, close the bypass valve to initiate flow through the pycnometer. Next, insulate the pycnometer to speed temperature stabilization and prevent water condensation. The use of double-walled vacuum sphere pycnometer may not require this step.

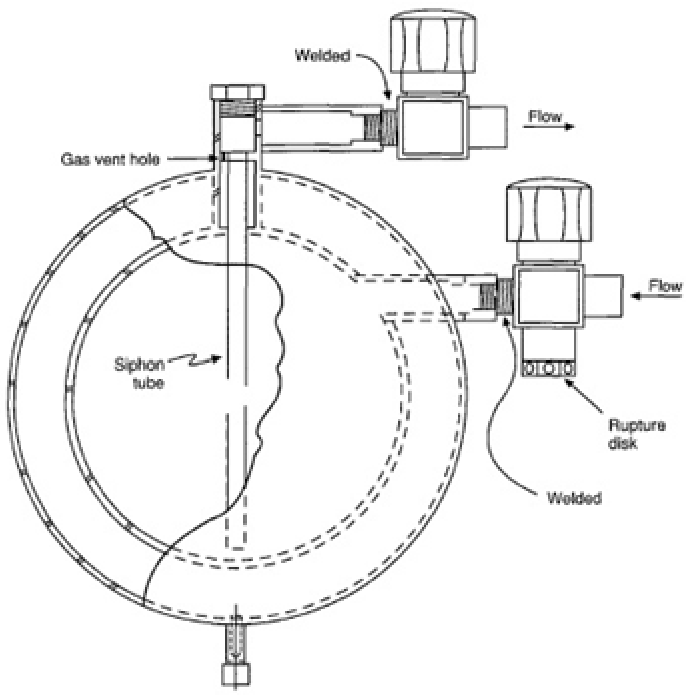

Figure 10—Double-Wall Vacuum Sphere Pycnometer

Operations

After flow is initialized through the pycnometer, the following steps must be performed to verify density, deviation and stability:

- Observe the output of the density meter for a period to verify steady conditions.
- When temperature or pressure differentiate between density meter and pycnometer are within criteria given in API MPMS Chapter 14.6.7 (generally 0.2° F and 2 lbs), record the following field data:
    1.) Observed density (density meter output)
    2.) Density meter temperature

3.) Pycnometer temperature

4.) Density meter pressure

5.) Pycnometer pressure

- Partially open pycnometer bypass valve, immediately close the inlet and outlet valves of pycnometer. Close outlet valve first.
- Remove pycnometer from sample system, check for leakage. Any leakage from pycnometer shall void test.
- If pycnometer was covered with insulation blanket, remove.
- Make sure both valve opening and outside pycnometer are washed. Blow dry with nitrogen or air. Repeat as necessary.
- This is done to make sure all moisture that may have accumulated is free from instrument.
- Repeat the above steps until you have two (2) successful consecutive provings.
- At this time calculate an average Density Meter Factor (DMF).
- For applications in which the density meter's output is adjusted, perform an additional proving run to confirm that the adjusted density meter's output does not differ from the new test's result by more than 0.05%.

Pycnometer Recertification

The pycnometer should be recertified any time that the validity of the original certification is in question. The pycnometer shall be recertified:

- Every two (2) years.
- If the pycnometer has been damaged.
- If the pycnometer has been disassembled.
- If the welded-on valve parts have been replaced.
- If the rupture disk is replaced.
- If the valve is repaired. (This is not necessary if the valve manufacturer can substantiate that there would be no change in the pycnometer volume in excess of 0.02% from valve repair.)

Master Density Meter

API Chapter 9.4 working group is testing the use of a master meter densitometer to verify and calibrate on-line densitometers. This method hopes to eliminate inaccuracies associated with the methods of handling and calibration of densitometers using pycnometers. API realizes the challenges of calibrating an on-line densitometer using a pycnometer.

Studies are ongoing with respect to the calibration performed by the manufacture and the possibility of requiring a densitometer certification similar to the requirements of certifying a meter prover.

A master meter densitometer proving method coupled with densitometer certification requirements are expected to provide an alternative to the pycnometer method. Reducing the complexity and time required of the proving at a level of performance that will greatly reduce the uncertainty.