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Installation and Operation of Densitometers
Class # 2205.1

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Introduction

The use of Densitometers is wide spread over many different industries. These range from food & beverage industries to petro-chemical & pipeline transmission. This paper will be covering installation and operation of densitometers with regards to the petroleum pipeline industry. In this area, the densitometer is used to determine various specifics of the transmitted product in the pipeline. They are used to monitor flowing density of non-custody transfers, fluid mix interfaces, custody transfers, and other applications.

This paper will mostly cover the recommended installation and operation of densitometers for custody transfer applications. We will review the standards for density measurement found in API Standards Chapter 14.8 and 14.6.

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, mechanics 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 meters 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 is a vibrating tube, tuning fork, or a Coriolis, the device must have a good single phase product flow and a "full tube" situation at all times to determine accurate density.

With respect to densitometers installed in slip stream systems, this flow must accurately represent the product flow of the pipeline, especially for custody determinations. Without the correct flow, the density 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, 0.3600 g/cc (ethane) to the high 0.9000's g/cc for fuel & crude oils. Some of the toughest measurement is in the range of 0.3600 g/cc to 0.7000 g/cc which is covered by Chapters 14.8 & 14.6 of the API Standards.

Discussion will concentrate specifically with 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. We can see in Fig. 14 of Chapter 14.6 flow diagrams for densitometer loops. Also, we must take into account for the proving system for the densitometer when addressing the installation of the densitometer. Today, we will address three basic components of these systems, 1) The design, 2) The operation, & 3) The proof.

1) 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 installed systems, which is the slip stream design for custody measurement.

During the design phase, we must address the type of "sample" that is being measured. 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 measuring 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 1/3rd of the pipe diameter flow. This mandates the use of some type of probe to penetrate the flow. 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?” ---- 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.

Fluid dynamics of the flow are constantly changing in the pipe. Flow profiles, fluid mixes, and boundary layers dictate that the best homogeneous representative sample of the product can be found within the center 1/3rd of the flow profile. The layer next to the pipe wall is the worst due to the inherent flow characteristics of the boundary layer. There are many designs and types of probes; it is up to the user to determine the correct type for their system and fluid types.

The sampling loop should be designed to not only hold the densitometer, but also all the necessary components that are needed to monitor the sampling properties. Chapter 14.6.7.5 provides initial criteria to follow in the design of the sampling system. Following these we find that thermal, pressure, and flow characteristics in the loop should be the same as in the pipeline flow. Also, the loop should be such that adequate flow is provided to the densitometer for accurate measurement and is comparable to the physical properties of the pipeline fluid.

To accomplish this, the loop should be located as close to the volumetric measuring device as possible without bypassing the flow meter and as physically close to the pipe outer wall as possible. Loops that have many feet of tube or pipe carrying the sample fluid are going to experience pressure and temperature differentials that will not give a good representative output of the flowing density. Size of the tubing or pipe used in the loop should be taken into account to allow for the least amount of losses in both kinetic (flow) and potential (thermal) energies.

If the loop constricts flow, then the densitometer is “starved” and density output can be erratic and not representative. If the loop is massive, then thermodynamics of the loop need to be addressed. The more mass that the loop system has, the larger the heat-sink it becomes and the slower the response to line-fluid changes. A balance between size, (diameter) wall thickness and length is sought to minimize the effects of outside sources on the sample product flow. Also, the loop should be such that adequate flow is provided to the densitometer for accurate measurement and is comparable to the physical properties of the pipeline fluid. To assure adequate flow, the design must take into account the mechanics of fluid dynamics.

The flow through the sampling system is created by a pressure differential between the inlet of the loop and the outlet. This can be accomplished using the velocity flow of the pipeline, the installation of an orifice type device, or a pump. Chapter 14.6.10 follows up with a more in depth design criteria. Chapter 14.6 Fig.'s 8.13 thru 16 provide a selection of flow diagrams that should be utilized to model your actual system. Once the type and shape of the loop is created, the selection of the necessary connections is to be determined.

The different connection needed on the loop is determined by the criteria presented for sampling system. For slip stream, temperature, pressure and flow monitoring is needed. The connections for the densitometer and the selected type of proving device are to be located such that the properties of the fluid sample are correctly monitored. Safety connections that allow for the release of product during testing and proving to a flare or containment system should also considered.

2) <u>The Operation</u>

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 density 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. For all devices, maintenance monitoring is a necessity. Pipeline flows can contain a range of contaminants or trash inherent to the processes. Various types of filtering and screening as available and should be utilized for metering and measurement sections of the pipeline. Even with these sets implemented, the densitometer will need to be inspected and cleaned. Contaminates and scale effect the operation and calibration of the devices.

Other than these few basic steps, most densitometers used in dynamic measurement have very few parts that need maintaining. In review, the operation of the loop needs to be within the same physical parameters as the pipeline, yet maintain the correct flow to the densitometer. Insulation of the loop from outside influences is highly recommended. This will assure that the thermal properties of the sampling are maintained. The addition of a flow meter in the loop will give the user an actual flow reading through the densitometer.

3) <u>The Proof</u>

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. Use of either must assure that the properties of the loop are stabile. Deferential in pressure and temperature within the sample loop will produce a density that is not indicative of the correct density measurement.

During the proof, especially when using a pycnometer, the flow through the loop could be changed significantly due to the restriction of the pyc ball. During this time, necessary steps should have been taken in the design to assure that the flow can be maintained and that velocity through the proving device is regulated to prevent fluid dynamic changes. Too high of velocity or pressure differentials will cause density changes in the test fluid and even undetected flashing in the low density fluids. There can also be noted temperature drops across the pycnometer are indicative of problematic flows and can cause measurement errors.

<u>Conclusion</u>

In review, it can be determined that the design and installation will greatly affect the performance of the densitometer of choice. Likewise, the same design can determine the accuracy of the proving and the resulting DCF for the densitometer. Care and good judgment along with practical & sound engineering should be used when determining the installation and operation of densitometer.