MICRO MOTION WHITE PAPER

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Alkylation Unit Optimization Using Coriolis Mass Flowmeters

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Abstract

In the production of Alkylate, the concentration of sulfuric acid is critical to achieve a proper reaction. The flow meters used need to have a wide turndown and provide high accuracy in order to control the process. Coriolis technology has many advantages such as providing a wide turndown, high accuracy, high repeatable flow measurement, and can provide percent concentration using the density measurement.

This paper discusses the challenges within an alkylation unit to control the process with the magnetic flow meters and what actions were taken to achieve more efficient and reliable process control.

Coriolis mass flowmeters

Coriolis meters are one of the most accurate and dependable flowmeters manufactured today. They provide both direct mass and density measurements. The typical specifications for flow measurement on the high performance models provide an accuracy of ±0.10% of flow rate. Coriolis meters can provide density sensitivity up to 0.0005 g/cc. This allows users to infer such variables as concentration and percent solids.

There are two fundamental designs or tube configurations for Coriolis meters. The traditional, dual curved tube meters provide the highest accuracy and turndown. This is mostly due to the increased Coriolis effect exhibited by the meter and will be explained further in this paper. The second design is a single straight tube meter. Every manufacturer has a unique design of the flow element, but each has the same fundamental principle of generating a Coriolis force.

The Coriolis effect was discovered by Gaspar Gustav de Coriolis in the early 1800s. In essence, this force is generated when an angular velocity comes in contact with a forward motion. The forward motion is the user's product flowing through the meter. Vibrating the flow tubes at their natural frequency generates the angular velocity. This oscillation can also be used to determine density.

To measure the Coriolis effect, the meter has a pickoff coil on each side of the flow element. The pickoff contains a coil and a magnet. As the coil moves through the magnetic field from the vibration of the tubes, voltage is produced. This voltage produces a sine wave.

By comparing the sine wave generated by the inlet and outlet pickoffs, mass flow rate can be determined. If there is no flow present, the time difference or DT between the two pickoffs will be zero as shown in Figure 1 below. However, there will be a time delay between the two pickoffs as flow begins. The higher the flow rate, the greater the DT between the two pickoff coils. This comparison, called phase shift, is directly proportional to mass flow rate.

Because Coriolis meters measure mass flow, there is no need for pressure or temperature compensation as with other volumetric technologies. Flow conditioning is also not necessary.

Operating on a similar principle as a spring and mass assembly, Coriolis meters also provide a direct density measurement. The oscillation of the tubes act as the spring and the mass is the fluid in the tube.

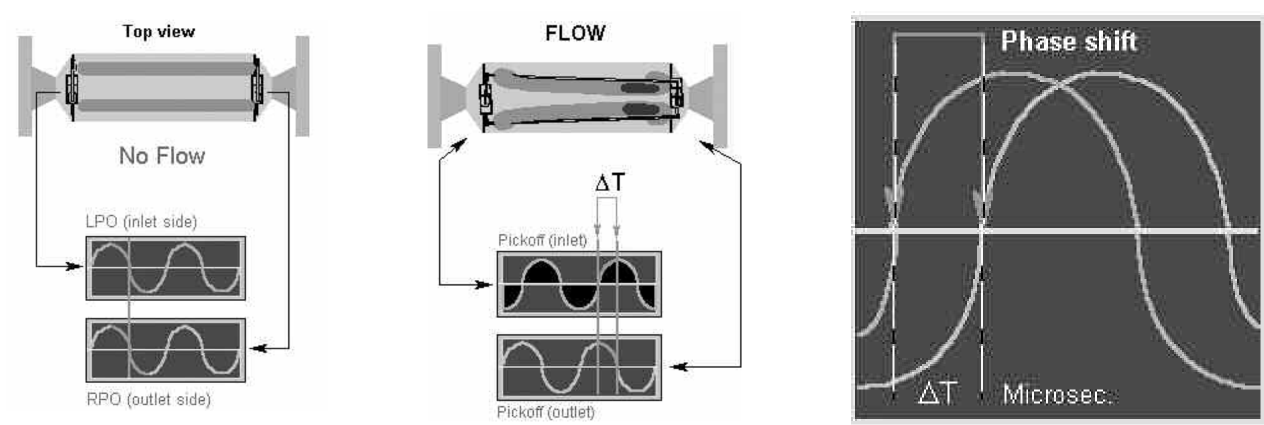

Figure 1. Time difference between two pickoffs

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Density is inversely proportional to the square root of frequency. The density of the process fluid can be derived from the frequency of oscillation of the flow sensor or the vibration of the tubes in reference to each other. In most cases, this signal is taken from the left or inlet side pickoff coil.

Because it is much easier to time tube oscillation than it is to count them, the transmitter of the flow meter will use tube period to compute the fluid density. As fluid density increases, frequency decreases. As frequency decreases, tube period increases.

Every sensor and transmitter that is manufactured must be calibrated for flow and density. Typically, two measurements are taken for density and they are usually air and water. By using air, a relatively low-density fluid, the tube period will be plotted and recorded. The same will be done with water, a relatively high-density fluid.

These tube periods are then designated as K1 and K2. The densities of these test fluids are independently measured during the calibration process. The flow transmitter that will be used with the particular sensor will be programmed with these factors that represent the calibration densities and tube periods.

In process conditions, the transmitter will then compare the tube period of the process fluid to that of the air and water. By doing so, it can do a calculation to accurately determine the density of the process fluid. Figure 2 illustrates this concept.

Background

Equistar had sulfuric acid flow measurement issues within the STRATCO® Effluent Refrigerated Sulfuric Acid Alkylation unit after it was designed and constructed. The challenge was to minimize the amount of sulfuric acid used while still maintaining an efficient acid spending strength within the reaction section of their process unit.

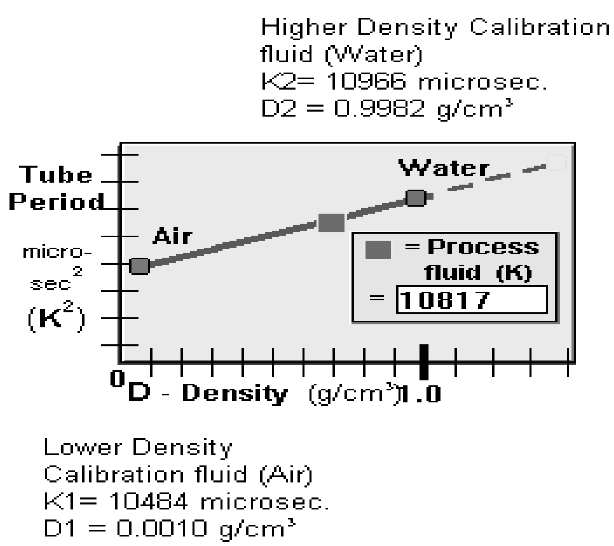

Figure 2

The unit brings in fresh acid that has a 98-wt% sulfuric acid concentration. This acid flows into the first STRATCO® Contactor™ reactor where it is used as a catalyst to produce alkylate. A second Contactor reactor is fed the spent acid from the first Contactor reactor. Finally, the acid is sent to a third and final Contactor reactor. The acid that is taken from the last Contactor reactor should have a concentration of around 90wt% if the process is being controlled efficiently. See Figure 3 for meter locations.

During the analysis of the performance of the Coriolis meters for acid flow control, another benefit of the technology was revealed. As described above, the Coriolis meter is also an effective density-measuring device, so meters were also installed to measure the density of the acid/hydrocarbon emulsion in each Contactor reactor. This on line density measurement was used to infer the percentage of acid versus hydrocarbons in the Contactor reactors, which is an important operating variable. STRATCO was granted a patent in 1998 covering this application.

Originally, magnetic flowmeters were used to control the flow of acid coming into each Contactor reactor and to measure the flow leaving the final Contactor reactor. These four meters were specified to be the same size as the line, which was 3 inches. Because pressure drop was an issue, larger meters had to be used to keep the pressure drop below 4 PSI across the entire process.

This was a challenging measurement requirement for the magnetic meters because the resulting velocity was at or below 1 ft/sec. In order for the existing meters to indicate flow, the velocities needed to be at least 1 ft/sec, with the optimum velocity for magnetic flow meters at 30 ft/sec. Given this, the control room rarely received meaningful flow rates from the meters. An additional problem with acid is that at higher velocities, acid becomes erosive. This required the process engineers and operators to make difficult assumptions of how much acid was flowing through the unit at any given time.

An onsite laboratory performed an analysis a few times a day to determine the concentration of acid leaving the unit. If the acid concentration dropped below 90%, the unit was not producing acceptable final product and in addition ran the risk of acid runaway. Therefore, they had to use more acid than they wanted to ensure the final product would meet specification. In most cases, the lab reported the acid concentration was above 94-wt%. This meant the unit was using much more acid than necessary just to ensure the process needs were being met.

Solution

STRATCO sought a measurement technology that had enough turndown to handle the low flow, while keeping the pressure drop below 4 PSI.

Four 3" Micro Motion® Coriolis meters were installed in place of the magnetic meters. The cost of the Coriolis meters was

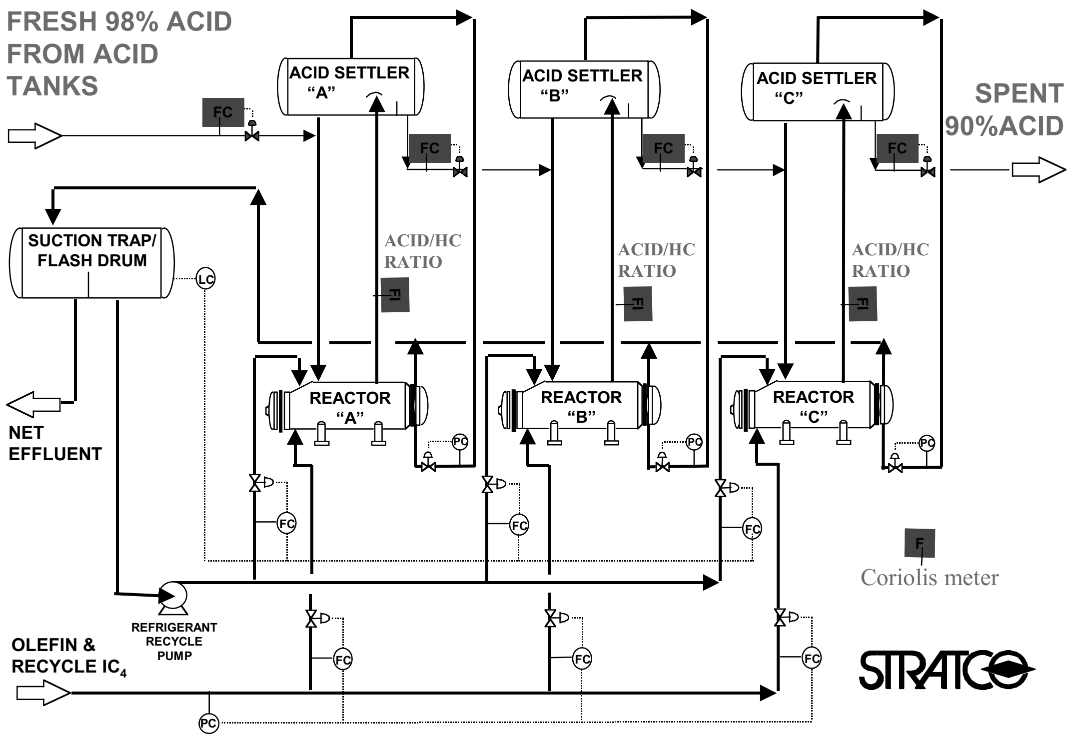

Figure 3. Coriolis meter locations

about four times that of the magnetic type. However, Straco saw that the Coriolis meters could save money by using less acid and giving the operating department better control of the unit operations.

Once installed, the technology proved itself. The pressure drop was below 4 PSI and the meters were able to accurately measure the flow rate between each Contactor reactor. By doing so, the control room could optimize the flow rates to ensure that the acid concentration stayed between a range of 89-wt% and 91-wt%.

Added benefits of using Coriolis meters were also found. Rather than using the lab to test the acid concentration, the Coriolis meters could output density real-time. Based on the acid density, operators could maintain the desired acid strengths for an efficient process. Coriolis meters measure both mass and density directly. The mass and density measurements were sent to the DCS and the operators controlled the process based on both measurements.

Acid strength measurement

There are also significant process benefits resulting from the installation of the Coriolis meters to measure both acid strength and Contactor reactor acid/hydrocarbon ratio.

Running at the proper acid strength in an alkylation unit is very important for the efficient, reliable, economical and safe operation. Typical refineries without acid Coriolis meters sample the acid up to three times per day. There is up to an eight hour lag time between this analyzed acid strength and what the unit acid strength really is. Here are some of the positive aspects of knowing what the acid purity is real time, not eight hours later:

- **Product quality -** The Contactor reactors produce better quality alkylate with less side reactions when the acid purity is within normal limits. Operators can use the real time acid strength to make the operational adjustments necessary to maintain the proper acid purity. Consistent higher quality alkylate is worth more to the refinery as a gasoline blending feedstock.
- **Side reactions -** Side reactions that occur due to inadequate acid purity produce hydrocarbons that can overload the existing effluent treating system. If this happens corrosion can occur in some of the equipment and piping. This results in unit downtime (loss of production).
- **Acid strength too high -** This is the original reason the Micro Motion meters were installed. The alkylation unit will produce excellent quality alkylate with recommended acid strengths, but at a significantly lower cost of acid usage. Economics usually do not favor higher than required acid strengths.
- **Acid runaway -** The plant has experienced acid runaways in the past that have been very costly. The acid runaway occurs when the acid strength drops below approximately 86 to 87 wt %. Often times the operator does not realize that he is experiencing an acid runaway due to the potential 8 hour lag time previously mentioned. An acid runaway not caught in time will probably result in significant loss of production, significant corrosion, and a potential safety hazard if not treated properly. Knowing the acid strength real-time gives an operator one more tool to recognize whether he is in an

acid runaway condition. When caught early it can significantly reduce the downtime to as little as a few hours with no corrosion.

The use of a Coriolis meter to measure the acid/hydrocarbon ratio is of tremendous benefit to the operation of the alkylation unit and a very valuable tool for the operator. Operating at the proper ratio produces better quality alkylate and minimizes corrosion and potential downtime. Currently, the majority of Contactor reactors use a "ratio glass" to manually measure this ratio. STRATCO realized the benefits of utilizing a Coriolis meter in this service a number of years ago. However, at this time Equistar is one of the few locations to upgrade to this improved technology. If the ratio glasses are not maintained properly, they become plugged and inoperable. Often times this ratio is not measured often enough and the results are not consistent from operator to operator, leading to incorrect unit adjustments.

The plant now uses these acid/hydrocarbon meters to routinely adjust the unit and depends on them for monitoring and more efficient operation of the alkylation unit.

Conclusion

Due to the increased turndown and accuracy of Coriolis meters, the plant was able to optimize their process.

Operationally, the acid strength and acid/hydrocarbon ratio meters have enabled Equistar to operate at maximum capacity with confidence that the alkylation unit is operating as efficiently and safely as possible. These meters have also given the operators valuable tools which will allow them to not only make routine changes but maybe more importantly to make the right decisions during unit upsets and potential acid runaways.

The cost savings on acid alone paid for the entire project in around 6-8 months. In this case the savings per year are based on the increased acid utilization. By consuming the acid to 90wt% concentration versus 94wt%, the plant has effectively increased its acid utilization by 50%.

About the authors

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