Originally appeared in: HYDROCARBON PROCESSING®
May 2008, pgs 75-79.
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Ultrasonic flowmeters improve delayed coker reliability

A US refiner significantly reduced flowmeter maintenance costs and improved safety by changing to ultrasonic flowmeters for coker furnace feed flow. A second refiner chose to install ultrasonic meters from the start.

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The recent surge in building and upgrading refinery delayed coking units, particularly in the US, Canada, India and Eastern Europe, is the result of the need for refinery operators to maximize the amount of refined products they extract from crude oil. The reason for adding or upgrading delayed cokers is to convert heavy distillation bottom streams into lighter, profitable products and is driven by increased demands for cleaner fuels, the higher cost of crude oil and the need to operate refineries more efficiently.

This article discusses the use of transit-time ultrasonic flowmeters to measure vacuum distillation recycle and coker furnace feed flows at two refineries. In these processes, vacuum residue and other residue feedstocks are heated to about 930°F (500°C) in a coker furnace while being transported to the coke drum where the hot heavy tars convert to coke. When the coking process is complete, the drum is decoked. Cracked products are fractionated into gas, coker naphtha, light coker gasoil and heavy coker gasoil that are further processed in downstream units.[1]

Delayed coking. Delayed coking is the process of thermal cracking of petroleum to convert residuum or resid, the bottoms from atmospheric and vacuum distillation units, into liquid and gas products while leaving behind the remaining carbon material, petroleum coke. There are several types of coking processes; however, delayed coking is by far the most extensively used, comprising around 90% of the cokers in operation today.[2]

The name "delayed coker" is derived from the process itself. Time and temperature produce coke. In the delayed coking process, vacuum distillation bottoms enter a fractionator and are then pumped through a high-temperature multipass tube furnace typically containing four pass lines (Fig. 1). There may be two or more furnaces in the coker unit, depending on the refinery capacity. The intent is to produce coke in the coke drums, not the furnace. Any obstruction to flow in the furnace pass lines will promote plugging and contribute to unreliable coker feed flow measurement.

Case study. Management at two western US refineries made the decision to measure the feed to their coker furnaces using ultrasonic flowmeters. At a major refinery in southern California, a flowmeter is located at the inlet of each of four furnace tubes to monitor the individual flow through each pass (Fig. 2). This is a critical measurement for furnace and coker operation. If the flowrate is too low, coke will form in the furnace tubes and maintenance will be required. If coking occurs, the tubes will have to be blown out using high-pressure steam or a hydraulic ram. In the worst case the tubes could completely clog, potentially causing a dangerous situation and possibly a shutdown.

At this refinery, flow through the furnace tubes had been measured by Venturi flowmeters. By their design, Venturi meters cause a restriction to flow. Due to a long history of problems, refinery

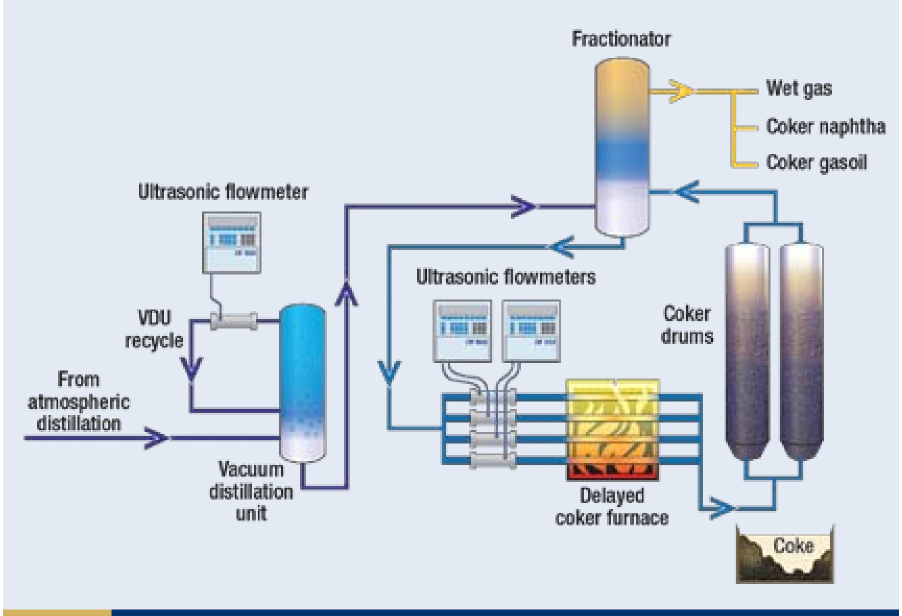

FIG. 1 A delayed coker converts resid into liquid and gas products.

personnel replaced two of the four Venturi meters with high-temperature ultrasonic flowmeters one year ago.

"Measuring hot heavy oil containing solids is problematic for other flowmeter types," said the refinery's coking optimization advisor. "The Venturi meters were problematic for years. They would sometimes read full scale. Coke particles can plug the impulse tubing of differential pressure devices and solid chunks will stop the flow. The Venturi meters would be out of operation for weeks at a time. During that period we had to estimate the flow by measuring pressure. What we needed was a meter with no restrictions whatsoever so we replaced the Venturi meters with ultrasonic meters. We're very happy with the ultrasonic meters. They've been trouble free."

"Another ultrasonic meter was installed in the vacuum distillation recycle line. This is a gravity feed line so no restriction could be tolerated. Now we have confidence in our recycle ratio and can run closer to the minimum. That optimizes yield and indicates the type of coke we are making, sponge or shot. Shot coke maximizes liquid products' yield but can cause a safety hazard because it will run out of the coker drum when opened. Another problem is hot heavy oil can auto-ignite if leaks occur when flanges are opened to clear a flowmeter obstruction. We now have a much better handle on these safety issues."

Ultrasonic meters do not cause a restriction and have no impulse lines. Since the ultrasonic meters were installed, there have been no problems with the ultrasonic flowmeters on these two furnace passes and no maintenance or calibration has been required. Previously, the Venturi meters required weekly checking.

"We don't have to do that anymore," said the Maintenance and Engineering Department instrument engineer. "Sometimes the Venturi meters would read full scale. It would take us an hour to check them and if there was a problem it could take all day to correct it. We estimate that we save $40,000 to $50,000 a year in reduced maintenance since we installed the ultrasonic meters."

If all four coker furnace lines became plugged, the refinery would have to shut down, costing millions of dollars a day until it could be brought back on line. Refinery management thought about installing a bypass system to avoid such a catastrophe but that could cause additional safety and leak risks, not to mention the expense. "That project was eliminated because the ultrasonic meters don't plug," said the Maintenance and Engineering Department instrument engineer, who plans to replace the remaining two Venturi meters with ultrasonic meters during the next maintenance cycle.

Ultrasonic meters can provide other benefits as well. "At one point during the startup, an ultrasonic meter was indicating an abnormal condition. We found that there was pump cavitation. The meter gave us good information to help diagnose the problem and come to a resolution," said the coking optimization advisor.

Fig. 3 is a graph of comparison data taken during a trial run of the ultrasonic meters. Meters FC108 and FC110 are the Venturi flowmeters. The data for these meters show spiking that occurs when coke solids plug the Venturi tubes, causing the meters to read full scale. When this occurs, the Venturi meters become inoperative.

Meters 107 and 109 are the ultrasonic meters. The data show good agreement between the ultrasonic and Venturi meters during the trial run. The ultrasonic meters exhibit more sensitivity than the Venturi meters. The ultrasonic meters did not plug with coke solids when the Venturi meters did. Overall, performance of the ultrasonic meters more than satisfied the refinery operators.

Tesoro's Golden Eagle refinery. Tesoro's Golden Eagle refinery is located in Martinez, California on 2,206 acres about 30 miles east of San Francisco. With a crude oil capacity of 166,000 bpd, the Golden Eagle refinery is the company's largest facility and the second-largest refinery in northern California. A new delayed coker unit is in the final stages of construction there. This refinery chose ultrasonic meters for coker furnace flow measurement from the start.

"We decided to use ultrasonic flowmeters to measure the flow of heavy oil through our coker furnace because they create no pressure drop," said Jim Schroeder, engineering controls superintendent at Golden Eagle. "We considered other meter types, but they all have some pressure drop that could slow the flow in the furnace and cause coking in the tubes, so we're using ultrasonic meters."

At Eagle Point, heavy oil is pushed by steam at high velocity through the coker furnace to prevent coke from forming in the furnace tubes. At this refinery there are three furnaces with two meters on each of the four furnace passes, totaling 24 meters in all. The first meter measures flow under normal conditions while the second meter is dedicated to safety shutdown in case of low flow. If heavy oil flow is interrupted, steam is injected into the furnace to prevent overheating. Steam is also used for spalling the furnace tubes every six months.

How ultrasonic flowmeters work. Transit-time ultrasonic flowmeters have a full-bore meter body with no restrictions or

FIG. 2 Ultrasonic flowmeter body in delayed coker furnace feed line.

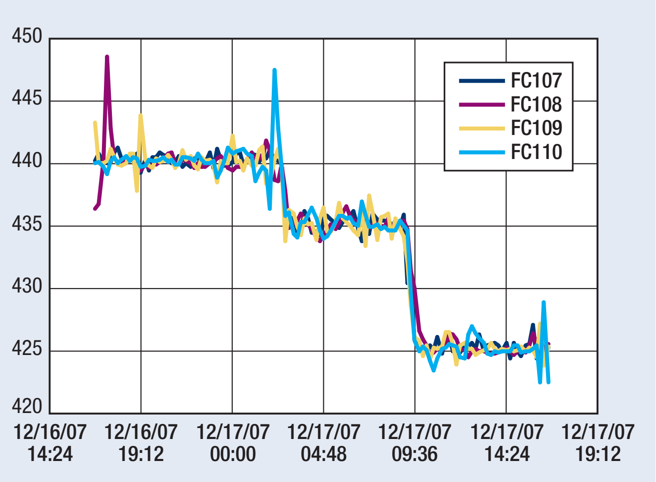

FIG. 3 Comparison of Venturi and ultrasonic meter outputs during trial run. Plugging of the Venturi meters is evident by spikes in the data.

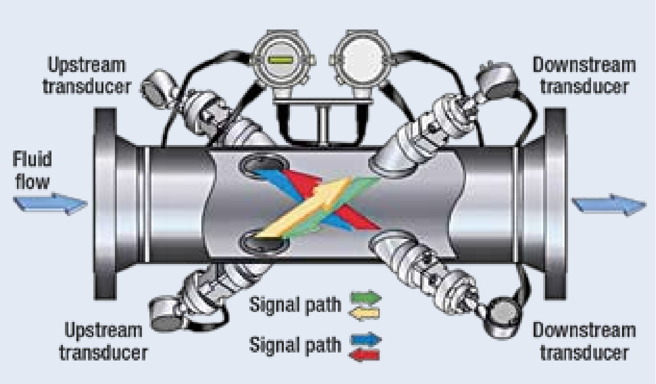

FIG. 4 Ultrasonic flowmeter cutaway view and system components.

obstructions to impede flow or cause a pressure drop (Fig. 4). Ultrasonic transducers are installed in the meter body, one upstream of the other. The transducers send and receive ultrasonic pulses through the fluid. The meter measures the difference between the upstream and downstream transit-times of these pulses, which is proportional to flow velocity. Volumetric flow is determined by the flowmeter from the velocity and the meter body cross-sectional area.

Due to the high temperatures involved in the delayed coker process, the ultrasonic transducers must be thermally protected. The temperature of the coker furnace feed is typically between 650°F and 750°F. If the transducer temperature exceeds the Curie temperature of the transducers' piezoelectric crystals, the acoustic pulse generating properties of the crystals will be lost. In the delayed coker installations described, a system consisting of buffer assemblies and ultrasonic transducers is employed. The buffer assemblies use waveguide bundles to concentrate the ultrasonic signals into the fluid. Simultaneously, the bundles act as buffers to protect the transducers from extreme temperatures. The system is rated for temperatures from –200°F to 1,100°F.

Due to the concentration of ultrasonic energy by the system buffers, the transmitted ultrasonic signals retain the energy needed to penetrate high-viscosity, high-molecular-weight residual liquids containing solids.[3] The system also allows the transducers to be replaced under flowing conditions without a unit shutdown or bypass piping. **HP**

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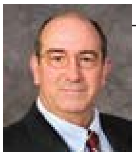

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