

Choose the right metering technology for ethylene furnaces

An ethylene plant's main purpose is to convert hydrocarbon feedstock, usually natural gas liquids or naphtha, into a "cracked gas" that contains ethylene and other higher value products. Such plants exist to produce cracked gas in a pyrolysis furnace and recover valuable products within the cracked gas via separation.

There are four common flow control applications within the furnaces used to produce cracked gas. Choosing the right flowmeter technology to measure the necessary parameters in the cracked gas production process can lower cost and schedule risk for a greenfield ethylene project. Other benefits include lower cost for operation and furnace maintenance.

Normal cracking and decoking. Each furnace goes through cycles with two distinct operating stages. The first is the normal cracking operation, when, through pyrolysis, it converts a hydrocarbon feedstock into higher-value products. The second is the decoking operation to remove the coke that builds up in the furnace coils during normal operation.

To accommodate the need to periodically take a furnace offline for decoking or repair, ethylene plants typically have 6 to 12 furnaces. At any given time, one furnace is usually in decoke, one will be in "hot standby" and the remaining furnaces will be producing. The length of time it takes ethylene producers to decoke their furnaces has a direct correlation to profitability. Every day a furnace is down for decoking means lost production, resulting in millions of dollars in lost revenue.

Flow control. The furnace operator uses several flow control techniques to keep the furnace operating at optimum conditions during normal cracking operations. One is to manage the fuel gas flowrate, which allows for control of the internal furnace temperature. This is important because over-firing in the furnace increases process temperatures above the optimum. This increases the coking rate, which increases the frequency of the decoking operation, resulting in lost revenue. Over-firing is a critical concern and it must be minimized.

Another technique is to control the hydrocarbon feedstock flowrate and the dilution steam flowrate. Dilution steam is used to lower the coking rate, as well as to optimize the value of the cracked gas effluent by adjusting the reactants' partial pressures. The amount of dilution steam relative to the amount of hydrocarbon is tightly controlled primarily to optimize the cracked gas' commercial value.

FUEL GAS FLOW CONTROL

Two process measurements needed for efficient fuel gas control are gas heating value and mass flowrate.

Gas heating value. Most ethylene producers primarily use fuel gas produced from the process itself as fuel for the furnaces (FIG. 1). This plant fuel gas is supplemented by purchased natural gas as needed. It is economically desirable to use as much plant gas and as little natural gas as possible, but availability of plant fuel gas is highly variable. The composition of the fuel gas to the furnaces, therefore, varies significantly over time, which results in significant variability in the available heating value of the fuel gas.

The heating value determines how much gas is needed to maintain the required furnace temperature. The higher the heating value, the less gas is needed. The lower the heating value, the more gas is needed. The fuel gas heating value is essential to tell the controller how much fuel gas is necessary to maintain the required heat input. Once this value is known, the controller uses a flow control loop consisting of a flow control valve and a mass flowmeter to provide the furnace with the right amount of gas.

There are several technologies available today that can provide the calculated heating value of a gas. These include thermal conductivity, gas chromatography and vibrating element. The vibrating element type is recommended in this case because of its fast response, high accuracy and immunity to changes in pressure, temperature and gas compressibility. This is due to its ability to directly measure specific gravity and molecular weight. Vibrating element technology also provides the added benefits of no gas combustion, carrier gases or moving parts. Plus, it is intrinsically safe and it minimizes recalibration frequency and costs.

Mass flowrate. For this measurement approach, the biggest factor in deciding what instrument to use is the allowable permanent pressure loss across the meter element. The fuel gas system operates at relatively low pressures, and permanent pressure losses from the flow element often must be below 2

Vibrating element technology

A refiner in the US was having trouble with a density measurement used to compensate for changes in heating value in its fuel gas flow control loops. The existing technology was sensitive to changes in pressure, temperature and gas compressibility, resulting in frequent calibrations and reduced furnace efficiency. After a vibrating element technology was installed, the refiner realized improvement in furnace efficiency and a reduction in maintenance costs due to reduction in the frequency of calibrations required.

psi (0.14 bar). An accurate measurement is typically needed through a 4:1 turndown.

There are several different technologies that could provide mass flowrate measurement, but the most economical choice is a multivariable (pressure and temperature compensated to calculate mass flow) differential pressure measurement across a conditioning orifice plate. A conditioning orifice plate is recommended because the meters are often installed in complex piping arrangements. Arrangements like this have short straight pipe runs, which could affect the accuracy and repeatability of the measurement if a standard orifice plate were used. Also, to save on installation costs and avoid additional pipe penetrations for the temperature and pressure measurement that compensate for changes in density, an integrated temperature, static pressure and differential pressure transmitter solution is recommended. A configuration of this type can reduce installation costs by over 40%.

FLOW CONTROL FOR HYDROCARBON FEED AND DILUTION STEAM

Dilution steam is used to lower the coking rate and optimize the cracked-gas effluent value by making adjustments to the reactants' partial pressures (FIG. 2). The amount of dilution steam relative to the amount of hydrocarbon feed is tightly controlled primarily to optimize the cracked gas value.

Each furnace in an ethylene plant has multiple hydrocarbon feed and dilution steam flowmeters, anywhere from two to eight of each meter per furnace. The meters' output is either a mass flow calculation or direct mass-flow measurement if coriolis meters are used in the case of the hydrocarbon feed measurement. Coriolis may be preferred in this application given its superior accuracy and direct mass flow measurement, especially when the hydrocarbon feed composition varies significantly over time. If

anything but a coriolis meter is used, pressure and temperature measurements in the header dynamically compensate for changes in density, just like in the dilution steam application.

The flowmeters come in pairs to control the steam-to-hydrocarbon ratio fed to each pass in the furnace. Multiple pairs provide the ability for "pass balancing" to provide equalization of the cracking and coking rates between passes, which aids in extending the time between decoking. The turndown, permanent pressure losses, repeatability and accuracy requirements are within the limits of most flowmeter technologies, so the technology with the lowest total installed cost is most often chosen.

Most new ethylene plants require each hydrocarbon feed and dilution steam flow measurement point to have two independent flow measurements—one used for flow control and the other used for a safety loop. While the cost of the actual hardware involved would indicate that two differential pressure transmitters measuring flow across a single orifice plate would be the lowest-cost technology, this does not factor in the labor cost for installation. Every differential pressure (DP) transmitter installation takes anywhere between two and four hours more than the installation of a vortex flowmeter, which has the flow element and transmitter combined in one component. With two transmitters for each flow point in these applications, that is four to eight more labor hours when using DP technology instead of vortex. This often tips the total installed cost scale in the favor of a dual vortex meter.

For a worldscale ethylene plant, the total reduction in labor hours by using the vortex technology instead of DP could be over 1,000 hr, depending on the number of meter pairs used. There is also less schedule risk with vortex meters, because they are easier to install than traditional differential pressure meters. With less time, lower risk and equal total installed cost, a dual vortex meter could be the optimal solution for a greenfield project for both the hydrocarbon feed and dilution steam meters. It is also important to note that the upstream and downstream straight pipe length required for a vortex flowmeter is less than that of an orifice plate and DP transmitter, so no changes in piping design are required for a greenfield project or for an existing operation.

Another crucial consideration must be made for the dilution steam meters. The dilution steam is a passive ingredient in the process, or one that is not consumed. All of it is, therefore, recovered and recycled for reuse. There is a high potential for

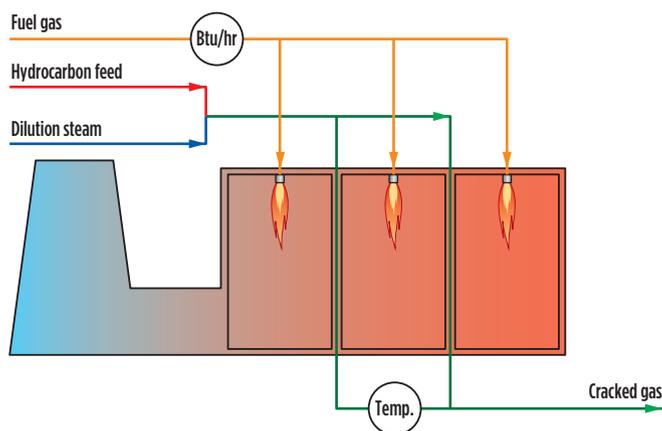


FIG. 1. Coil outlet temperature control.

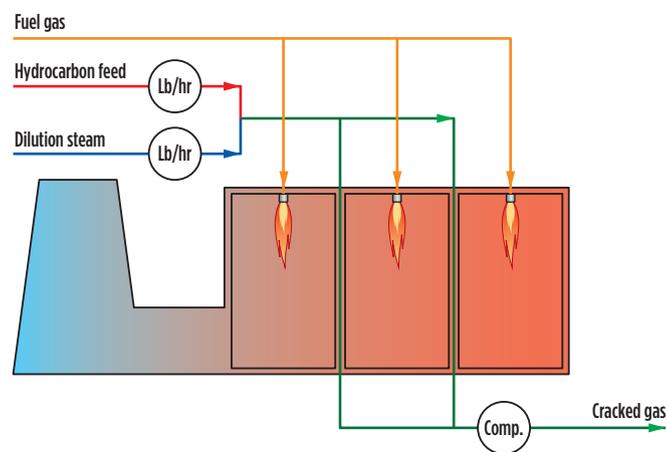


FIG. 2. Steam-to-hydrocarbon ratio control.

Gasket-less vortex meters

An ethylene producer in China saved over \$300,000/yr in maintenance costs by switching to gasket-less vortex meters in this application. Furnace efficiency at another producer in Europe was improved by 2%.

Coriolis meters

An ethylene producer on the US Gulf Coast was using rotameters for the decoking operation measurement. Not only did they not provide the needed turndown, but they were also plagued with maintenance issues. This producer chose to replace these meters with coriolis meters, ultimately saving over \$90,000 in maintenance costs and over \$380,000 in lost production per year.

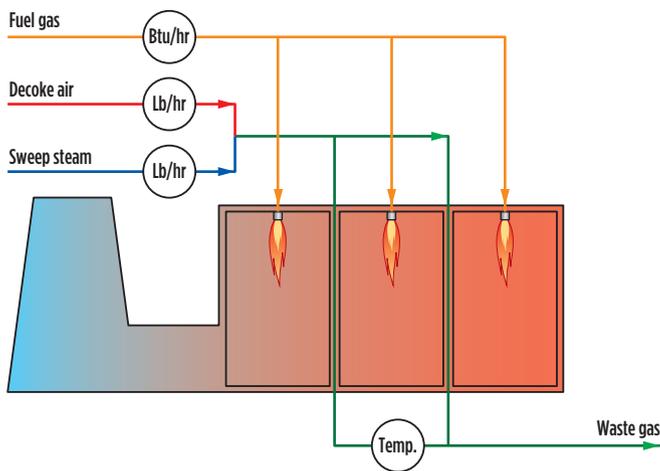


FIG. 3. Illustrated decoking process.

hydrocarbons to carry over into this recycled stream. The hydrocarbons carried over can plug up traditional DP transmitter impulse lines, which then require routine cleaning to ensure proper operation. In addition to the potential for a lower total cost of installation, a vortex meter has the added benefit of eliminating impulse lines. Not all vortex meters are made the same, however, and some have gaskets that can plug up and affect the flow measurement just like in a traditional differential pressure installation.

Ethylene producers should consider gasket-less, all-welded vortex technologies that eliminate this potential issue. Lost production due to meter failure is a common issue that can be avoided with this technology.

FLOW MEASUREMENTS IN THE DECOKING OPERATION

The final flow measurement application, decoke air, ensures that the furnace operates at optimum conditions during the decoking operation (FIG. 3). Decoke air is fed to the hydrocarbon feed lines during decoking, so the number of decoke air meters per furnace may be equal to the number of hydrocarbon feed

meters, anywhere from two to eight. The tighter the air flow control into the furnaces during the decoking, the faster and safer the decoking process becomes, which reduces the cost of lost production for an ethylene producer.

The amount of air fed to each pass in the furnace is very important, especially during the initial phases in the operation. The air is used to combust with the coke that is built up within the furnace coils. During the initial phase, too much air would overheat the tubes and damage them, which is quite costly and an unsafe prospect to an ethylene producer. Once the initial coke is combusted, the amount of air is slowly increased as the optimal decoking rate is maintained. That being the case, accuracy in measurement over a relatively large turndown of 25:1 is needed.

The pressure and temperature upstream of the decoke air flowmeter remains relatively constant, so a density assumption can be made within a volumetric flowmeter without significantly impacting the accuracy of the mass flow calculated as the output. With reasonable accuracy over a turndown of up to 30:1, a vortex meter is a good solution for this application, and it provides the lowest total installed cost. A coriolis meter, however, could be considered if a direct mass-flow measurement is desired or if there is not enough available turndown with a vortex meter.

CHOOSE WISELY

An ethylene producer can lower operational costs for an ethylene furnace by keeping accurate control over the fuel firing, maintaining the proper steam-to-hydrocarbon ratio, properly controlling the decoking rate and minimizing maintenance costs. The producer can do this all while minimizing the total installed costs of flowmetering technology when initially procured and installed. With multiple meters per unique application per furnace, and multiple furnaces per ethylene plant, a mistake in the choice of meter technology for these applications has a long-lasting and significant impact. **HP**



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