Improving Ethylene Plant Cracking Furnace Performance with Process Gas Chromatographs

Process gas chromatographs have been used since the 1950s to provide real-time compositional data to process control systems. Today, there are tens of thousands of process gas chromatographs in use throughout the process industry making the gas chromatograph the analytical workhorse for on-line compositional measurements. One example of how process gas chromatographs are used for improving process operations can be found in the ethylene plant cracking furnace in a refinery.

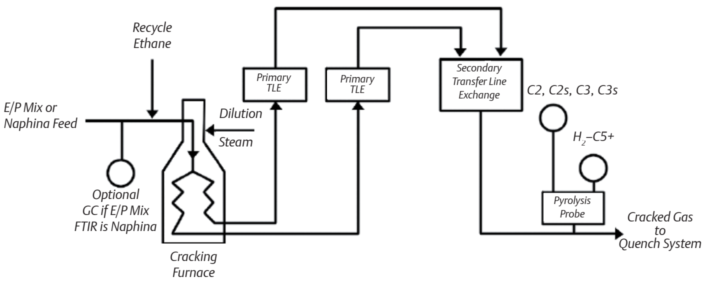
One of the most common building blocks of the petrochemical industry is ethylene with millions of tons produced every year throughout the world. Ethylene is used to make such common chemicals such as polyethylene, polystyrene, and alpha-olefins. A typical ethylene plant also makes a number of other important building-block chemicals such as propylene, butadiene and an aromatics-rich pyrolysis gasoline.

The typical ethylene plant is divided into two basic sections: the cracking furnaces and the fractionation train. The furnaces can go by a number of names: "naphtha cracking furnaces," "pyrolysis furnaces," "naphtha pyrolysis furnaces," "naphtha steam cracker," etc.

The Ethylene Plant Cracking Furnace

As the name implies, the cracking furnace in an ethylene plant takes the feedstock and cracks the molecules in the presence of a catalyst at high temperatures. Typically 12–15 furnaces are used in a single ethylene plant. Most feed streams are naphtha-type stream in plants outside of the United States. In the U.S., the feed stream is predominantly a mixture of ethane and propane (E/P mix). As shown in Figure 1, the feed is mixed with steam and cracked at 850 °C in the furnace coils. The furnace effluent gas is cooled in transfer line exchangers (TLEs) where the heat removed from the cracked gas is used to generate high-pressure steam.

Figure 1 - Flow Diagram of a Typical Cracking Furnace in an Ethylene Plant



After the transfer line exchanges, the sample is cooled even more with oil-quenching and water-quenching systems. The cooled furnace effluent is compressed to an optimum pressure for separating into the various chemical components in the fractionation section where product recovery occurs. The stream is also run through a caustic wash system to remove H_2S and CO_2 between compression stages.

Improving Cracking Furnace Performance with Process Gas Chromatographs

Advanced control of the cracking furnace is critical to the ethylene plant's entire efficiency. "Over-cracking" of the feed stream can lead to premature furnace shutdowns due to excessive coke formation on the catalyst. Yet, "undercracking" of the feed is a direct reduction in overall production. Process gas chromatographs provide the data the plant's control system needs to find the right balance for cracking severity.

The primary analysis point for this measurement is the exit from the transfer line exchangers. It is common to use two analyzers at this sample point (AX #1 and #2 in Figure 1). Before either analyzer can extract a sample, a specialized sample probe called a "pyrolysis" or "reflux" probe must first condition it. This probe strips out the tars and other contaminants created in the furnace from the sample before it is sent to the analyzers.

The first analyzer measures the conditioned sample for only C2s and C3s and occasionally C1, to provide fast feedback to the plant control system on the cracking severity.Because of the need for fast analysis update time, a separate process gas chromatograph is dedicated to each furnace. There may even be provisions made in the sample system design to have one analyzer back-up another in case of analyzer failure since the data is so critical for efficient operation of the furnaces.

A second, more thorough analysis is done on the furnace effluent, in parallel to the first. This complete analysis of the furnace effluent is used by the plant control system to update the furnace cracking control model. Since time is not nearly as important for the updated results, a number of furnaces may be measured by the same gas chromatograph.

For plants using an ethane/propane mix as feed, a process gas chromatograph (AX #3 in Figure 1) is often used to monitor variations in feed composition. For plants using naphtha as feed, a process gas chroma-tograph is too slow to be helpful. In those cases, other analyzers such as process Fourier Transform Near Infrared analyzers have been used. A summary of these applications can be seen in Figure 2.

The Emerson Solution

Emerson has a long history of providing process gas chromatographs for the ethylene industry. Emerson's process gas chromatographs have set the standard for on-line process measurement by supplying analyzers that are both robust and capable of handling the analytical requirements.

Table 1 - Summary of Process Gas Chromatograph Applications in a Typical Ethylene Plant Cracking Furnace

Analyzer #	Stream	Components Measured	Measurement Objective
1	Furnace effluent (one per furnace)	C1, C2, C2=, C3, C3=	Used to calculate conversion severity
2	Furnace effluent (shared between furnaces)	H_2–C5+	Provide mass balance information to furnace control model updating
3	Furnace feed (if E/P mix)	C1, C2, C2=, C3, C3=, C4+	Compensate for variations in product feed composition

www.RosemountAnalytical.com
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Emerson Process Management
Rosemount Analytical
Gas Chromatograph Center of Excellence
10241 West Little York, Suite 200
Houston, TX 77040 USA
Toll Free 866 422 3683
T +1 713 396 8880 (North America)
T +1 713 396 8759 (Latin America)
F +1 713 466 8175
gc.csc@emerson.com

42-PGC-AN-CHEMICAL-EPCF-GAS-EN