Improving Ethylene Plant Fractionation Train 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 fractionation train 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 (hot side) and the fractionation train (cold side). The fractionation train takes the effluent from the furnaces and separates it into the wide range of chemical products.

The Ethylene Plant Fractionation Train

The separation of the furnace effluent into various products is done through a series of fractionator towers that selectively separate one chemical group at a time. The effluent stream moves from one fractionator tower to the next with the remainder being sold as a pyrolysis gasoline.

While the order that the compounds are removed may vary from plant to plant, the general flow can be seen in Figure 1. After the furnace effluent has been cooled and compressed, it enters the first fractionator tower to remove the methane and lighter compounds. These light compounds leave the overhead of the demethanizer and enter a cold box where they are further separated into a hydrogen-rich tail gas and a methane-rich tail gas. Other processes needing hydrogen use the hydrogen-rich stream and the methane-rich stream is used as a fuel for burners and heaters.

The remainder of the furnace effluent leaves the bottom of the demethanizer and enters the deethanizer. The C_2s and lighter compounds exit the overhead of the deethanizer and enter a reactor to remove any acetylene that is present. Once the acetylene has been removed,

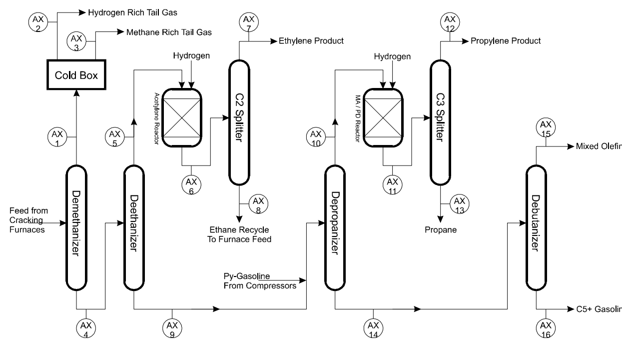

Figure 1 - Flow Diagram of a Typical Ethylene Plant Fractionation Train

the C_2s enter a C_2 splitter fractionator that separates the ethylene from the ethane. The ethylene is sold as product and the ethane is recycled back to the cracking furnaces for conversion into ethylene.

At the same time, the remainder of the furnace effluent leaves the bottom of the deethanizer and is fed into the depropanizer. Any pyrolysis gasoline created in the compression stage after the cracking furnaces is also fed to the depropanizer. At the depropanizer, the C_3 and lighter compounds are sent out the top and enter a reactor to remove any methyl acetylene (MA) and propadiene (PD) from the stream. The C_3s then enter the C_3 splitter fractionator to separate the propylene from the propane.

The last of the furnace effluent enters the final fractionator tower to separate out the C_4 olefins leaving the rest to become the pyrolysis gasoline which exits the bottom of the debutanizer.

Improving Unit Performance with Process Gas Chromatographs

With the large number of chemical separations being performed in the ethylene plant fractionation train, process gas chromatographs play an important role in maintaining efficient operation.

The first process gas chromatograph (AX #1 in Figure 1) monitors the overhead streams of the demethanizer to minimize the loss of ethylene into this stream. Two more process gas chromatographs (AX #2 and #3 in Figure 1) monitor the separation of this stream into the hydrogen-rich tail gas stream and the methane-rich tail gas.

A fourth process gas chromatograph (AX #4 in Figure 1) monitors the bottom streams of the demethanizer to minimize the light gases such as C_1 and CO_2. Any gases that get to this point ultimately end up in the final ethylene product stream as impurities so the amount needs to be controlled. This is done by controlling the C_1 to $C_2^=$ ratio.

The next series of chromatographs are used to control the purity of the ethylene product. This starts with the measurement (AX #5 in Figure 1) of the deethanizer overhead to minimize the amount of C_3 in the stream while still maximizing the recovery of the $C_2^=$. To monitor the removal of the acetylene, one or more gas chromatographs (AX #6 in Figure 1) measure the effluent from the acetylene reactors to insure that the acetylene levels will meet final ethylene product specifications. At the C_2 splitter, a gas chromatograph (AX #7 in Figure 1) monitors the ethylene product stream for impurities while another gas chromatograph (AX #8 in Figure 1) measures the bottom streams to minimize any loss of ethylene in the ethane that is being recycled.

A similar series of chromatographs are used to control the purity of the propylene product starting with the measurement (AX #9 in Figure 1) of the stream leaving the bottom of the deethanizer. Any C_2 components present would end up in the propylene product stream so they need to be controlled by maintaining the optimum C_2 to $C_3^=$ ratio. The depropanizer overhead stream is monitored (AX #10 in Figure 1) for C_4s to minimize their presence in the propylene product. To monitor the removal of MA and PD, measure at the exit of the MA/PD reactor (AX #11 in Figure 1). Finally, two gas chromatographs monitor the propylene product for purity (AX #12 in Figure 1) and the propane stream (AX #13 in Figure 1) to minimize the loss of propylene.

The final series of chromatographs monitor the final separations of the furnace effluent beginning with the measurement of the depropanizer bottom streams (AX #14 in Figure 1). This analyzer monitors the C_3 to $C_4^=$ ratio to control the C_3 impurity levels in the mixed olefins product stream. Then two more analyzers monitor the purity of the mixed olefins (AX #15 in Figure 1) and minimize the loss of C_4 olefins in the gasoline stream (AX #16 in Figure 1).

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.

Analyzer #	Stream	Components Measured	Measurement Objective
1	Demethanizer overhead	$C_2^=$	Minimize the loss of ethylene
2	H_2-rich tail gas	H_2	Determine hydrogen purity
3	Methane-rich tail gas	BTU	Calculate BTU for use as fuel gas
4	Demethanizer bottom streams	C_1, $C_2^=$	Control methane in the ethylene product stream
5	Deethanizer overhead	C_3	Control ethylene product purity
6	Acetylene reactor effluent	Acetylene	Control acetylene impurity in ethylene product
7	Ethylene product	C_1, C_2, Acetylene, CO_2	Measure impurities in ethylene product
8	C_2 splitter bottom streams	$C_2^=$	Minimize the loss of ethylene in the ethane recycle stream
9	Deethanizer bottom streams	C_2, $C_3^=$	Control ethane in the propylene product stream
10	Depropanizer overhead	nC_4	Control propylene product purity
11	MA / PD reactor effluent	MA / PD	Control MA / PD impurity in propylene product
12	Propylene product	C_2, C_3, MA / PD	Measure impurities in propylene product
13	C_3 splitter bottom streams	$C_3^=$	Minimize the loss of propylene into the propane stream
14	Depropanizer bottom streams	C_3, $C_4^=$	Control propane in the mixed olefins product stream
15	Debutanizer overhead streams	C_3, C_4, iC_5, nC_5	Measure impurities in the mixed olefins product stream
16	Debutanizer bottom streams	$C_4^=$	Minimize losses of C_4 olefins into the C_5+ gasoline stream

Figure 2 - Summary of Process Gas Chromatograph Applications in a Typical Ethylene Plant Fractionation Train

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