Analytical Products and Solutions

Petrochemical Industry Ethylene Plant

Process Gas Chromatograph Application Note

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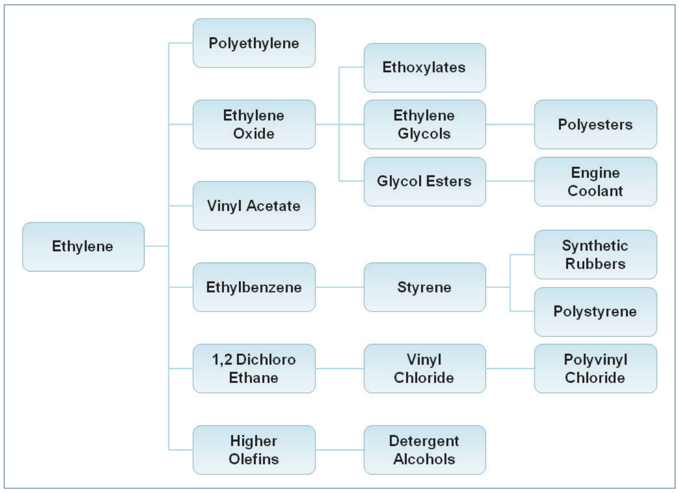
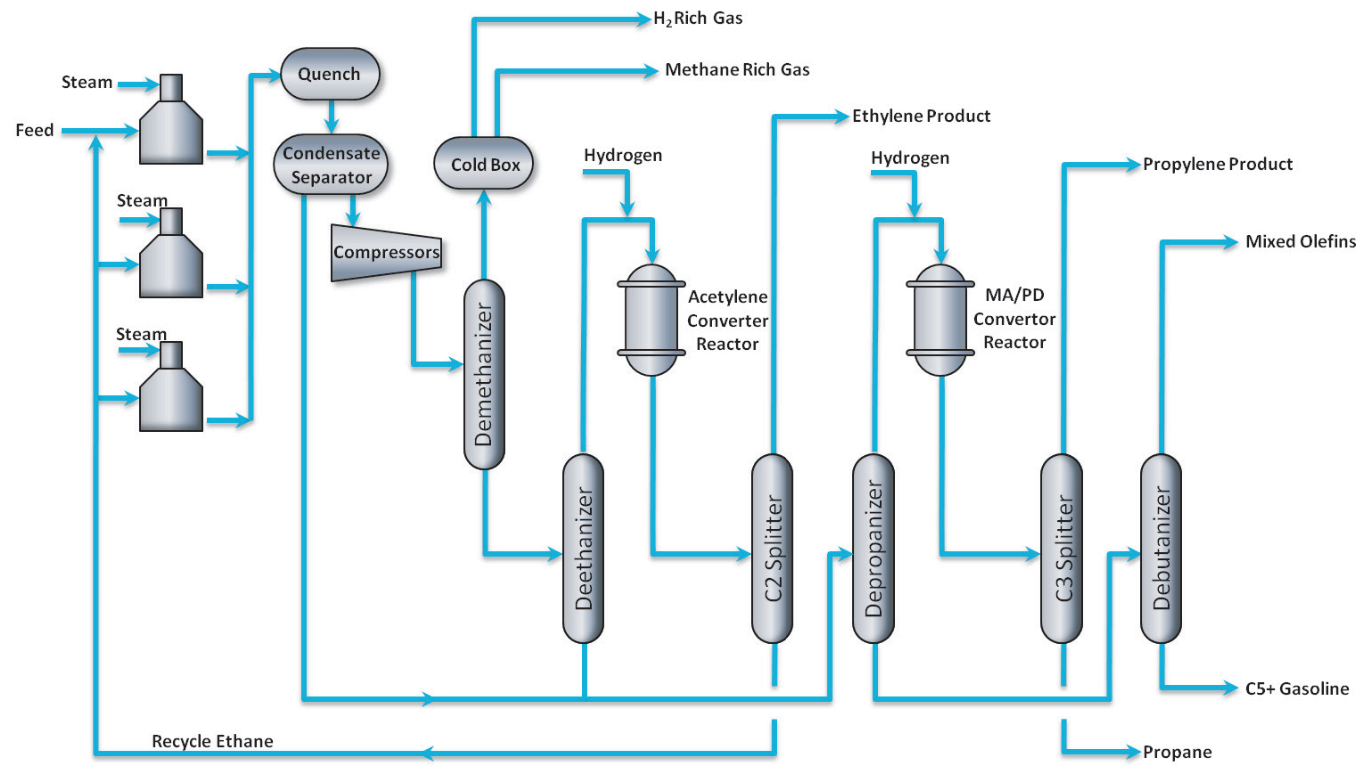
The Ethylene Plant provides the base feedstock for the manufacture of a number of critical products used throughout the petrochemical industry. Compounds ranging from polyester fibers to engine coolant are all based on ethylene. However, the primary product of an ethylene plant is polymer grade (99.999% pure) ethylene that is used in the production of polyethylene. An ethylene plant is also a major producer of polymer grade propylene as well as other light hydrocarbon olefins. These products are used in the manufacturing of a wide range of derivative products such as polyester fibers, synthetic rubbers and detergent alcohols (see graph below).



Most ethylene plants use naphtha as the feedstock (supplied by a refinery). But in some regions, most notably the United States, an Ethane/Propane (E/P) mix is the feedstock to the plant. In either case, the basic process for production of ethylene and other olefins is the same. First, the feed is "cracked" in pyrolysis furnaces to form olefins as well as other products; this stage is usually called the "hot side" of the plant. The cracked gas is then purified via fractionation to form the desired product streams; the "cold side" of the plant.

Ethylene Plant



Furnace Analysis (Hot Side)

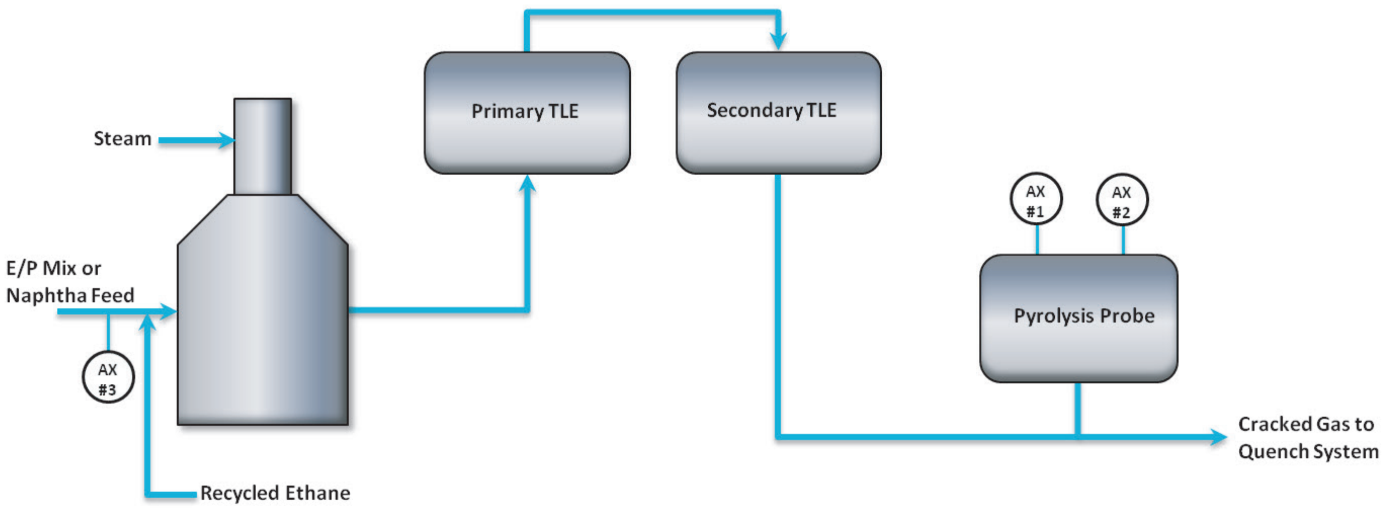
The first section of the Ethylene Plant is the pyrolysis furnaces that crack the feedstock into ethylene and other light hydrocarbons and is often referred to as the “Hot Side” of the plant. The first step is the hydrocarbons feedstock is preheated and cracked in the presence of steam in tubular SRT (Short Residence Time) pyrolysis furnaces. The cracked hydrocarbon products exit the furnace at 1400 – 1600°F and are rapidly quenched in the transfer line exchangers (TLE) that generate high pressure steam for use in other parts of the plant. Many modern pyrolysis/quench furnaces are often designed to handle the full range of gaseous and liquid feedstock from light ethane to heavy naphtha. The number of cracking furnaces will vary from plant to plant depending on the plant’s production capacity.

Typical GC measurements

The typical furnace analysis (hot side) of an ethylene plant has three measurements by a process gas chromatograph:

1. Furnace Effluent Stream (I) – this analyzer is used to measure ethane, ethylene, propane and propylene in the stream as fast as possible for quick compositional feedback to the advanced control system. The data allows the plant to adjust the cracking furnace’s operation for maximum efficiency.
2. Furnace Effluent Stream (II) – this analyzer measures the same sample point as GC#1 and is used to give a full composition analysis for mass balance calculations. This analyzer is often configured for sampling multiple furnaces on a single GC because update time is not as critical.
3. E/P Feed to the Furnace – for ethylene plants using Ethane/Propane mix as the feed, this analyzer provides feed-forward data for advanced furnace control in order to maximize cracking furnace efficiency. For ethylene plants using naphtha a the feed to the cracking furnaces, a process FT-NIR is often used instead of a GC.

Cracking Furnaces (Hot Side)



Analyzer No.	Stream	Components Measured	Measurement Objective
1	Furnace effluent stream (to Pyrolysis Probe)	C_2, $C_2^=$, C_3, $C_3^=$	Short and fast analysis to provide quick feedback on cracking severity within the cracking furnace
2	Furnace effluent stream (to Pyrolysis Probe)	H_2 - C_5+	Longer, complete analysis for mass balance feedback to the control system
3	E/P feed to the furnace	C_2, C_3	For cracking furnaces that use E/P mix as the feedstock. Provides feed forward data needed for advanced furnace control.

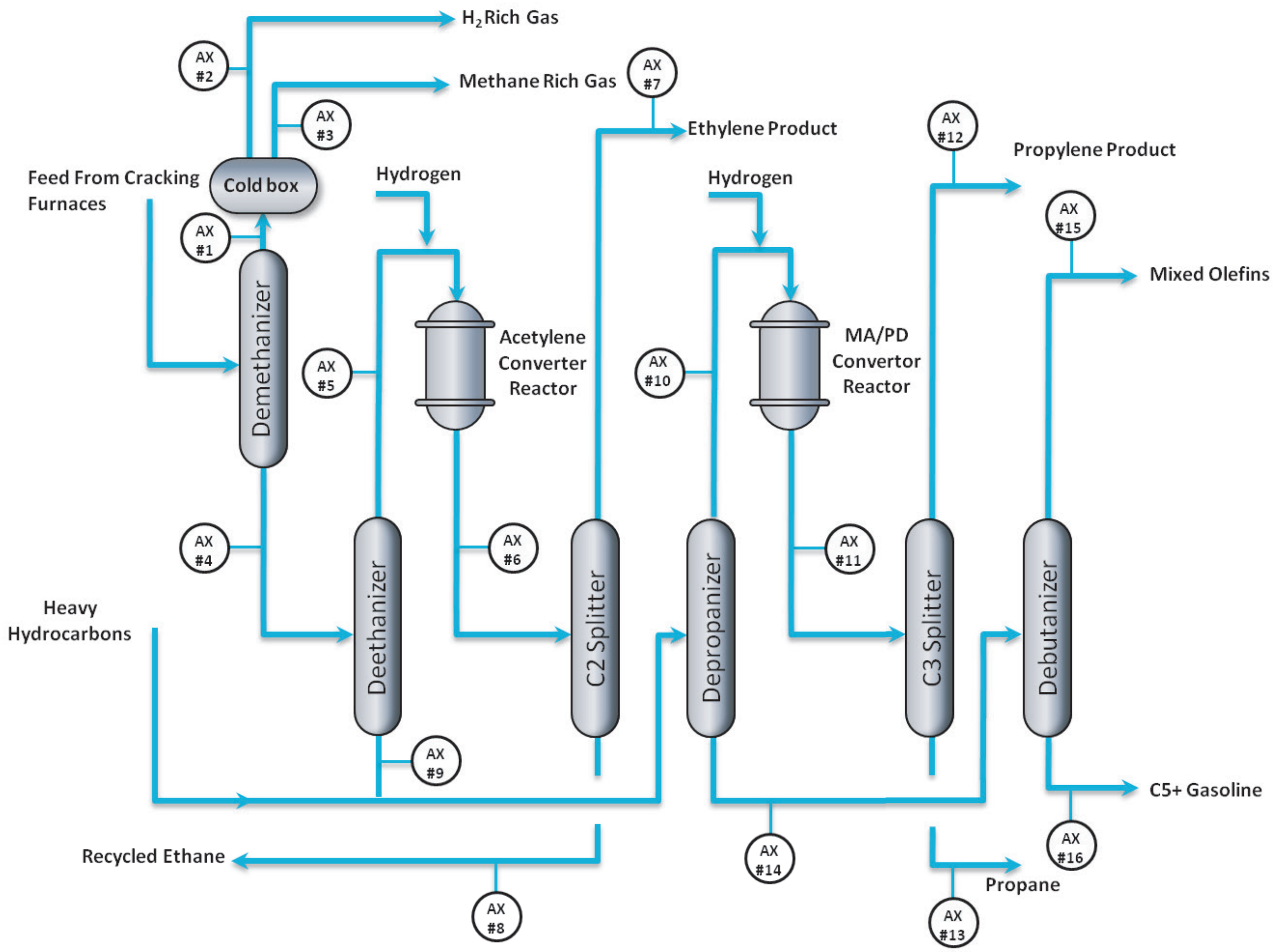
Fractionator Tower Analysis (Cold Side)
After the cracked gas is quenched, the heavy hydrocarbons are separated from the light hydrocarbons. The light hydrocarbons are compressed, and the heavy hydrocarbons are sent to a fractionator further along in the process. The streams are dried and sent to a series of fractionators that purify the cracked gases into the various plant products. Though there are varying plant designs, the first fractionator is often the demethanizer. This separates the lightest gases, such as hydrogen and methane, out through the overhead and into the cold box unit for use in other areas of the plant. The bottoms stream of the demethanizer flows to the deethanizer where ethane, ethylene, and acetylene are split from heavier hydrocarbons. The mixture is hydrogenated in an Acetylene Convertor Reactor to reduce the acetylene levels to meet the final ethylene product specifications. The effluent from the reactor is fractionated in the C_2 Splitter. Ethane leaves the bottom of the ethylene fractionator and is recycled back to the feed of the cracking furnaces. The final ethylene product stream leaves the overhead of the C_2 Splitter.

The deethanizer bottoms and the heavy hydrocarbons from the compression system are depropanized. Polymer-grade propylene can be produced by further purification of the depropanizer overhead; the MA/PD convertor removes the methylacetylene and propadiene from the C_3's. The C_3's are then split into the propylene product and propane. The depropanizer bottoms are separated into mixed C_5+ and mixed olefins for sales or use in other process plants.

Typical GC measurements
The typical fractionator tower analysis (cold side) of an ethylene plant has a number of process gas chromatograph measurement locations for optimum plant operation:

1. **Demethanizner Overhead** – measures ethylene to minimize the losses of ethylene in the overhead stream
2. **Hydrogen Rich Tail Gas** – verifies the quality of the hydrogen product stream.
3. **Methane Rich Tail Gas** – determines impurities in the methane stream to ensure the appropriate amount of methane is exiting.
4. **Demethanizer Bottoms** – measures the ratio of methane to ethylene in the bottoms stream to ensure that the methane levels will not exceed the allowed amounts in the final ethylene product stream.
5. **Deethanizer Overhead** – measures ethane, ethylene, and acetylene for feed-forward control to the Acetylene Converter Reactors.
6. **Acetylene Reactor Effluent** – monitors the conversion of acetylene into ethylene. This measurement is important because acetylene is a poison to polymer production, and the amount that exits the reactors will ultimately be found in the ethylene product stream.
7. **Ethylene Product Stream** – verifies the ethylene product stream meets its purity specifications
8. **Ethane Recycle Stream** – measurement is to minimize the amount of ethylene lost in the bottoms stream
9. **Deethanizer Bottoms** – measures the bottoms stream to ensure that the ethane to propylene ratio will not exceed the allowed amount of ethane in the final propylene product stream.
10. **Depropanizer Overhead** – the purpose of this analyzer is to measure butane in order to minimize the butane impurities in the final propylene product stream.
11. **MA/PD Reactor Effluent** – monitors the conversion rate of the MA and PD.
12. **Propylene Product Stream** – measures ethane, propane, MA, and PD to verify the propylene product stream meets specifications for impurities.
13. **C_3 Splitter Bottoms (Propane)** – determines the relative amount of propylene in the propane stream to minimize the loss of propylene with the Propane product.
14. **Depropanizer Bottoms** – measures the propane to butane ratio with the goal of minimizing propane impurity in the Mixed Olefins stream.
15. **Mixed Olefin Stream** – verifies the Mixed Olefins product stream meets its specifications for impurities.
16. **C_5+ Gasoline Stream** – measures butane to ensure that is the maximum level of C_4 olefins are flowing into the Mixed Olefins overhead stream and not into the C_5+ stream.

Fractionation Section (Cold Side)



Fractionation Section (Cold Side)

Analyzer No.	Stream	Components Measured	Measurement Objective
1	Demethanizer Overhead	$C_2^{=}$	Maximize $C_2^{=}$ recovery
2	Hydrogen Rich Tail Gas	Impurities in Hydrogen	Verify quality of Hydrogen product stream
3	Methane Rich Tail Gas	Impurities in C_1	Verify quality of C_1 product stream
4	Demethanizer Bottoms	C_1, $C_2^{=}$	Minimize C_1 impurity in the final Ethylene Product stream
5	Deethanizer Overhead	C_2, $C_2^{=}$	Feedforward control of Acetylene Convertor Reactor
6	Acetylene Reactor Effluent (or Mid Bed)	Acetylene	Monitor conversion rate of Acetylene into $C_2^{=}$
7	Ethylene Product Stream	C_1, C_2, Acetylene, CO_2	Verify Ethylene Product stream meets specifications for impurities
8	Ethane Recycle Stream	$C_2^{=}$	Minimize loss of $C_2^{=}$ in the recycle stream
9	Deethanizer Bottoms	C_2, $C_3^{=}$	Minimize C_2 impurity in the final Propylene Product stream
10	Depropanizer Overhead	nC_4	Minimize C_4 impurities in the final Propylene Product stream
11	MA/PD Reactor Effluent	MA, PD	Monitor conversion rate of the MA and PD in the reactor
12	Propylene Product Stream	C_2, C_3, MA, PD	Verify Propylene Product stream meets specifications for impurities
13	C_3 Splitter Bottoms	$C_3^{=}$	Minimize loss of the $C_3^{=}$ in the Propane stream
14	Depropanizer Bottoms	C_3, C_4	Minimize C_3 impurity in the final Mixed Olefins stream
15	Mixed Olefins Stream	C_3, iC_5, nC_5, C_4's	Verify Mixed Olefins product stream meets specifications for impurities
16	C_5+ Gasoline Stream	nC_4	Maximize recovery of C_4 olefins

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