ETHYLENE INDUSTRY SOLUTIONS

Real-time analysis of ethylene production processes to optimize yield while maximizing uptime and maintaining safety and environmental compliance.

Analyzer solutions to reduce natural gas process downtime, ensure safe operation, and meet stringent product quality requirements.
Ethylene is the most produced organic compound globally and is an important building block for the petrochemical and chemical industry with over 150 million tons of ethylene produced yearly. The main commercial production of ethylene is by thermo/steam cracking of different hydrocarbon feed stocks, which is typically divided into a few main steps: cracking, quenching, compression and drying, and separation.

Ethylene plants can use a wide range of hydrocarbon feed stocks. One of the most common types is naphtha, a mixture of hydrocarbons that has a boiling range of 30°C to 200°C (86°F to 392°F). In some regions, including the United States and the Middle East, ethane and propane are the most commonly used feed stocks in ethylene production. The rapidly growing production of shale gas has resulted in the construction of more than 20 new and expanded ethylene plants. Most of the ethylene produced is used in the production of polyethylene and ethylene oxide which is a feed stock for many more complex hydrocarbons and polymers. Process analytics ensures process control via online monitoring of the various process streams in olefin production.

Process control through compositional analysis by online analyzers results in maximized yields and ensures product quality.

AMETEK, Inc.

AMETEK Process Instruments is a worldwide manufacturer of process analyzers and instrumentation. We focus our experience on designing new, innovative analyzers that help our customers achieve higher levels of productivity and quality. By seeking out ways to overcome the limitations of current methods of process monitoring, control and quality assurance, we have created some of the most capable, unique technologies in the world.

A business unit of the Process and Analytical Instruments division of AMETEK Inc., we are part of a global corporation with a growth plan founded on four key strategies: Operational Excellence, Strategic Acquisitions, Global & Market Expansion and New Products.

Find the right solution for your ethylene plant
ETHYLENE PLANT OVERVIEW

AT1: Hydrocarbon Feed Stock
AT2: Recycle Gas
AT3: Furnace Fuel
AT4: Cracker Furnace Combustion Control
AT5: Stack Gas
AT6: Furnace Decoking
AT7: Steam Boiler Combustion Control
AT8: Boiler Flue Gas
AT9: Effluent Gas
AT10: Outlet of Compression Tower
AT11: Refrigeration Off Gas
AT12: Drying Outlet
AT13: Demethanizer Off Gas
AT14: Demethanizer Bottom Gas
AT15: Deethanizer Bottom Gas
AT16 & AT17: Hydrogenator Inlet and Outlet
AT18: C2 Fractionator Bottom Gas
AT19: Depropanizer Bottom Gas
AT20 & AT21: Hydrogenator Inlet and Outlet
AT22: C3 Fractionator Bottom Gas
AT23: Propylene Product
AT24: Debutanizer Overhead Gas

Processes not pictured in diagram:
AT25 – Thermal Oxidizer
AT26 – Flare
AT27 – Tank Head Space Monitoring
AT28 – Ambient Air Monitoring

Find the right solution for your ethylene plant

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The first section of the ethylene plant is the pyrolysis furnace that “cracks” the feedstock into ethylene and other light hydrocarbons. The hydrocarbon feed stock is preheated and cracked in the presence of steam in tubular pyrolysis furnaces. The residence time in the cracking furnace (~871°C/~1600°F) is generally only a few seconds. The furnace temperature and residence time determine the distribution of hydrocarbon products.

The next step is the fractionation to separate the desired products. The diagram opposite refers to the main process units in a typical ethylene production plant. The analyzers and analytes measured are referenced using “AT” numbers. The analyte concentrations range from high percent to low parts per million (ppm) levels.

Analysis of feed stock and effluent gas are paramount to process optimization. AMETEK mass spectrometers provide real-time analysis. Severity and conversion ratios will be calculated in seconds rather than minutes using a gas chromatograph. Better analysis and/or the measurement of multiple analytes at the same time.

**AT1: HYDROCARBON FEED STOCK**
**AT2: RECYCLE GAS**
**MEASURES:** C1-C4, C5+
**PRODUCTS:** StreamPro, ProMaxion, ProLine

Analysis of feed stock and effluent gas are paramount to process optimization. AMETEK mass spectrometers provide real-time analysis. Severity and conversion ratios will be calculated in seconds rather than minutes using a gas chromatograph. Better control reduces the amount of decocking needed, therefore reducing maintenance and increasing production of ethylene.

**AT3: FURNACE FUEL**
**MEASURES:** C1-C8, C2=, N2, H2, CO, CO2
**PRODUCTS:** ProMaxion, FlarePro

Refinery fuel or natural gas is used to heat the cracking furnace. Analyzing the major components of the fuel provides an estimate of the heat content expressed as BTU (British Thermal Unit).

**AT4: CRACKER FURNACE COMBUSTION CONTROL**
**MEASURES:** O2, Combustibles (CO+H2), Methane/Hydrocarbons (CH4+)
**PRODUCTS:** 5100HD, WDG-V

Within the cracker furnace, burners are used to generate the heat required for the cracking process. At the burner, fuel is combusted in the presence of air. Optimal combustion is typically at a setpoint of 1-2% excess oxygen (O2). A flue gas analyzer is used to monitor the excess O2 levels, and additional measurements can be made to detect incomplete combustion by measuring combustibles (CO+H2) and to detect flame-out during start-up by measuring methane and hydrocarbons. The hydrocarbon measurement can also serve to detect potential process leaks from the tubes.

**PRODUCT SOLUTIONS**

- **StreamPro**
  - Reliable, compact process mass spectrometer providing real-time gas analysis of components in multiple sample streams for processes.

- **ProMaxion**
  - Cost-effective, high-performance online gas analysis for weatherproof or hazardous area locations.

- **ProLine**
  - Designed for multi-port, multi-component process analysis, this versatile mass spectrometer uses our proven quadropole mass filter, in combination with a contaminant-resistant enclosed ion source.

- **5100HD**
  - Uses tunable diode laser absorption spectroscopy (TDLAS) technology, and can be configured with one or two absorption cells, providing dual-stream analysis and/or the measurement of multiple analytes at the same time.

- **WDG-V**
  - Designed for safety and serviceability, providing accurate measurements of oxygen (O2), combustibles (CO+H2), and methane (CH4) for process control and safety in combustion applications.

- **FlarePro**
  - Quadrupole process mass spectrometer that provides fast, accurate component and BTU content measurements, even when confronted with wildly changing flare gas streams.
In the United States, Environmental Protection Agency (EPA) regulations require continuous emissions monitoring of stack gas for sulfur dioxide (SO₂) and oxides of nitrogen (NOx). Moisture is usually measured so that the emissions can be reported on a wet and dry basis.

In ethylene production, a hydrocarbon feed stream mixed with steam enters a tubular reactor where, under controlled conditions, the feed stock is cracked at 800 to 850°C (1472 to 1562°F) into steam and hydrocarbons. To maximize conversion, the feed stock is cracked at 800 to 850°C (1472 to 1562°F) into steam and hydrocarbons. The effluent coming off the reactor results in various products, including the one of interest. A knowledge of the fuel leaks during start-up.

Effluent Gas
Analysis of the furnace effluent gas provides valuable information on process control for the plant. The ratio of the types of products produced depends on the tubular furnace's temperature and pressure. The effluent coming off the reactor results in various products, including the one of interest. A knowledge of the effluent gas composition determines product yield, helps to regulate fuel consumption. Mass spectrometry allows for simultaneous, real-time, multi-component analysis of the effluent gas stream to maximize overall plant efficiency.

AT7: STEAM BOILER
MEASURES: O₂, Combustibles (CO+H₂)
Methane/Hydrocarbons (CH₄+)
PRODUCTS: WDG-V

A boiler is used to generate steam, which can be added to the feed to decrease coking and lower hydrocarbon pressure to increase olefin yield. A flue gas analyzer is used to measure oxygen (O₂) and control the burner of the boiler. The flue gas analyzer can also measure combustibles (CO+H₂) to optimize combustion, and it can measure methane/hydrocarbons to detect potential flame-outs or fuel leaks during start-up.

AT8: BOILER FLUE GAS
MEASURES: NOₓ, CO, O₂
PRODUCTS: 9900, 914

Continuous emissions monitoring of carbon monoxide (CO), NOₓ, and O₂ in the flue gas is performed to meet emission regulation requirements.

AT9: EFFLUENT GAS
MEASURES: C₁-C₄, C₂+, C₃+, C₅+, H₂, CO
PRODUCTS: ProMaxion, StreamPro, ProLine, 5100

Analysis of the furnace effluent gas provides valuable information on process control for the plant. The ratio of the types of products produced depends on the tubular furnace's temperature and pressure. The effluent coming off the reactor results in various products, including the one of interest. A knowledge of the effluent gas composition determines product yield, helps to regulate fuel consumption. Mass spectrometry allows for simultaneous, real-time, multi-component analysis of the effluent gas stream to maximize overall plant efficiency.
Following the cracking process, the gas is quenched and compressed to remove any remaining heavy hydrocarbons, hydrogen sulfide ($H_2S$) and carbon dioxide ($CO_2$). The required quench stages are determined by the feed stock.

After water quenching, the gas is compressed to separate the hydrocarbons from the quench water. Then, a caustic solution is used to remove the acid gases $H_2S$ and $CO_2$. The cracked gas undergoes further cooling and drying before separation begins.

**AT10: OUTLET OF COMPRESSION TOWER**

**MEASURES:** $H_2S$, $CO_2$, $CO$

**PRODUCTS:** 5100HD

The cracked hydrocarbons are rapidly quenched in several stages. The quench stages are determined by the feed stock. After the water quench step, the gases pass through a series of compressors where the hydrocarbons are separated from the quench water. Next, the gases are scrubbed of hydrogen sulfide ($H_2S$) and carbon dioxide ($CO_2$) using a caustic solution. The acid gases are stripped from the caustic solution and incinerated or sent to a sulfur recovery unit if high sulfur is present in the feed stock. $H_2S$, $CO_2$, and $CO$ in the cracked gas after caustic scrubber are analyzed using a 5100 TDLAS analyzer for process control.

**AT11: REFRIGERATION OFF GAS**

**MEASURES:** C1-C8, C2=C, CO, $CO_2$, N2, O2, H2, H2O

**PRODUCTS:** ProMaxion, StreamPro, ProLine, 3050-DO

Following the removal of the acid gases the cracked gas is cooled so that the $H_2$ produced in the cracking reaction can be removed. This hydrogen rich stream can be used as a fuel or sent to a gas plant for purification.

**AT12: DRYING OUTLET**

**MEASURES:** CO, Ethylene

**PRODUCTS:** ProMaxion, StreamPro, ProLine, 5100HD

Prior to entering the demethanizer the treated feedstock is analyzed for the amount of $CO$ and $C2=\,$ as a process control factor.

**PRODUCT SOLUTIONS**

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Cost-effective, high-performance online gas analysis for weatherproof or hazardous area locations.

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- **5100HD**
  - Uses tunable diode laser absorption spectroscopy (TDLAS) technology, and can be configured with one or two absorption cells, providing dual stream analysis and/or the measurement of multiple analytes at the same time.
  - **Drying Outlet**
  - **Refrigeration Off Gas**

- **3050-DO**
  - Proven, accurate quartz crystal microbalance (QCM) technology with built-in verification provides operators with increased measurement confidence.
  - **Drying Outlet**
  - **Refrigeration Off Gas**

Find the right solution for your ethylene plant
The bottom gas of the cracking furnace is comprised of ethylene and heavier compounds including propane, propylene and contaminants. Methane rich hydrogen (AT17) and is recycled to the cracking furnace. The bottom gas, which is primarily ethane, also contains low levels of ethylene and moisture (AT17) and is recycled to the cracking furnace.

After the removal of the hydrogen, the cracked gas passes into a demethanizer where the bulk of the methane is removed from the higher molecular weight compounds. The demethanizer overhead includes methane with some impurities such as hydrogen, CO, and trace amounts of ethylene. The methane rich stream is blended with natural gas and used to heat the cracking furnace.

The demethanizer bottom gas consists of ethylene and heavier components and is typically sent to the deethanizer.

In the deethanizer, C2 hydrocarbons are separated and sent to acetylene hydrogenation reactors. Acetylene is a significant byproduct in the cracking process. Deethanizer overhead gas includes acetylene, ethane, and ethylene. The bottom gas consists of C3 and heavier hydrocarbons.

Ethylene and ethane are separated using a C2 fractionating column. The bottom gas, which is primarily ethane, also contains low levels of ethylene and moisture (AT17) and is recycled to the cracking furnace.

If significant propane is contained in the feed stock, the bottom gas from the deethanizer will contain higher molecular weight compounds including propane, propylene and contaminants methyl acetylene (MA) and propadiene (PD). The depropanizer separates the C3 components from the C3+ components. Several components are analyzed in the bottom gas of depropanizer for process control purposes.

The fractionated products from C3 fractionator are sent into the propylene product, which is analyzed for process control purposes.

The depropanizer bottom gas is further processed in the debutanizer unit to separate the C4 product from light gasoline.
**SEPARATION AND HYDROGENATION STAGES**

**PROCESSES NOT PICTURED IN DIAGRAM:**

AT25: THERMAL OXIDIZER

**MEASURES:** $O_2$, Combustibles (CO+H₂), Methane/Hydrocarbons (CH₄+);

**PRODUCTS:** WDG-V

For air pollution control, a thermal oxidizer is used to treat the waste gases and unwanted byproducts of the process. Thermal oxidizers typically use direct flame incineration of the waste streams and burner management systems are used for combustion control. A flue gas analyzer is used to measure oxygen to ensure proper operating setpoints. The flue gas analyzer can also measure combustibles (CO+H₂) to optimize combustion, and it can measure methane/hydrocarbons to detect potential flame outs or fuel leaks during start-up.

AT26: FLARE

**MEASURES:** C₁-C₆, BTU, Speciation, HC/Steam Ratio, Wobbe Index, Calorific Value

**PRODUCTS:** FlarePro

Determining the heating values (HC/Steam Ratio) of vent gas is important because sufficient combustible material must be continuously present to achieve high combustion efficiencies. To assist chemical plants in making that determination, AMETEK Process Instruments has developed the Dycor FlarePro quadrupole process mass spectrometer. The FlarePro provides fast and accurate BTU content measurement, even when confronted with widely changing flare gas streams. Field testing has shown that the FlarePro mass spectrometer offers more detailed and relevant data faster than gas chromatography and provides BTU numbers that are equivalent to those provided by a calorimeter, but with greater specificity.

AT27: TANK HEAD SPACE MONITORING

**MEASURES:** $O_2$

**PRODUCTS:** 5100HD

There are many organic vapor streams where it is critical to monitor the oxygen concentration to minimize the risk of explosion. For example, the tank head space contains volatile compound levels exceeding the Upper Explosive Limits (UEL) and therefore nitrogen blanketing is carried out to generate a non-combustible atmosphere with acceptably low levels of oxygen. To increase safety and minimize the use of nitrogen simultaneously, the nitrogen blanketing gas is controlled as a function of oxygen concentration in the headspace to ensure the oxygen concentration is below the lower explosive limit (LEL).

AT28: AMBIENT AIR MONITORING

**MEASURES:** BTEX 1,3-Butadiene

**PRODUCTS:** ProMaxion

Industries producing hazardous substances, or using such substances in their manufacturing process, are required to monitor the environment in and around the plant to ensure that the concentrations of known pollutants remain below the exposure limits. Of particular concern is a class of compounds known as volatile organic compounds (VOCs). These include the hazardous VOCs: Benzene, Toluene, Ethylbenzene, and Xylenes, which are collectively referred to as BTEX (or BTX), and the highly reactive VOCs: ethylene, propylene, 1,3-butadiene and butanes, EDC and VCM.

StreamPro

Reliable compact process mass spectrometer providing real-time gas analysis of components in multiple sample streams for processes.

- Deethanizer Bottom Gas
- Demethanizer Off Gas
- Demethanizer Bottom Gas
- C₂ Fractionator Bottom Gas
- Hydrogenator Inlet and Outlet
- C₃ Fractionator Bottom Gas
- Propylene Product
- Debutanizer Overhead Gas

5100HD

High sensitivity, analytic specific, fast-response measurements for critical industrial applications.

- Demethanizer Off Gas
- Hydrogenator Inlet and Outlet
- Demethanizer Bottom Gas
- Propylene Product
- Tank Head Space Monitoring

WDG-V

Quadrupole process mass spectrometer providing fast, accurate component and BTU content measurements, even when confronted with widely changing flare gas streams.

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3050-DO

Proven, accurate quartz crystal microbalance (QCM) technology with built-in verification provides operators with increased measurement confidence.

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AMETEK Process Instruments delivers worldwide sales and service support through a network of direct and factory-trained global distribution channels.

AMETEK Service Assistance Program plans offer coverage up to 24 hours a day, 365 days of the year.

As worldwide experts in the manufacture of process analyzers and instrumentation, we have supplied solutions to industry since 1962, providing the widest range of analysis technology available.

Through process application consulting, we create custom-designed solutions that meet the needs of your specific application or process.