This is a chapter from the

Chemistry
Resource Kit

The Qenos Chemistry Resource kit has been developed as an information package for secondary students and others who wish to learn about Qenos, plastics manufacturing and the petrochemical industry.

This document is available on the Qenos website at:  www.qenos.com
Production of Ethylene

The Qenos Olefins manufacturing plant at Altona produces three petrochemicals:

- ethylene or ethene (C2)
- propylene (C3)
- butadiene (C4)

This section focuses on the production of ethylene using ethane feedstock. Qenos Olefins can also produce petrochemicals using liquid gas oil feed from the Mobil refinery. The entire plant has the capacity to produce over 180,000 tonnes per year of ethylene (about 28 tonnes per hour). This is about 50% of total Australian capacity. The ethane cracking section of Qenos Olefins produces on average 100,000 tonnes of ethylene per year. Qenos Resins and Qenos Plastics are the customers for the ethylene from Qenos Olefins.

Qenos also makes ethylene from ethane at our Olefines plant in Botany. It provides ethylene to our Alkatuff® LLDPE and Alkathene® LDPE units.

Ethylene

Ethylene is one of the most versatile and widely used petrochemicals in the world today. Its main use is for the manufacture of polyethylene.

Some facts

- Ethylene is a colourless gas
- Ethylene is a hydrocarbon molecule (made up of carbon and hydrogen)
- It burns readily in the presence of oxygen
- Ethylene is written chemically as \( \text{C}_2\text{H}_4 \) i.e. an ethylene molecule consists of 2 C atoms and 4 H atoms. (Refer to figure 2.)

The Process in Detail

The production of ethylene from ethane can be described as a sequence of different processing steps. These are shown in detail in figure 3 overleaf.

Step 1 — Steam Cracker

Figure 1
Ethane cracker at the Qenos Olefins manufacturing plant

Figure 2
The chemical structure of ethylene

Figure 4
Cracking step
Ethylene Production

Step 1  Steam cracker
Step 2  Quench tower
Step 3  Gas compressor
Step 4  Treating
Step 5  Chilling train
Step 6  Fractionation

Figure 3
Simplified process diagram
The ethane, piped from Bass Strait via Long Island Point, is fed into five gas-fired furnaces.

Steam is injected into the ethane feed immediately prior to entering each furnace. Steam is added at controlled rates in order to increase the petrochemical yield and to minimise carbon deposits (coke) forming in the furnace tubes. Coke deposits prevent the feedstock from heating to the right temperature thereby reducing the effectiveness of the cracking reaction.

The ethane is subjected to a one second surge of extreme heat, between 750°C–900°C, causing the splitting of the molecule into other hydrocarbons. Steam cracking refers therefore to the process whereby a hydrocarbon feedstock—in this case ethane—in the presence of steam and heat, changes to other hydrocarbons. The reaction is:

\[ \text{C}_2\text{H}_6(g) \rightarrow \text{C}_2\text{H}_4(g) + \text{H}_2(g) \]

Over 60% of the ethane is reacted in the furnaces. The composition of the furnace effluent (the gases coming from the furnace) is approximately 50% of ethylene, 35% of ethane (by weight) with the remainder being hydrogen, methane, acetylene, propane, propylene and some other hydrocarbons. The uncracked ethane is fed back into the furnaces later in the process.

Steam crackers are designed to operate at conditions that make full use of the basic chemical and physical conditions favouring the formation of ethylene.

The important conditions for successful operation of steam crackers include:

- **High temperatures**
- **Short residence time**

  The ethane is pumped through at a rapid rate as there is an optimum time for the cracking reaction to transpire. There has to be enough time for a high yield of ethylene to be produced but not too long so that the ethylene itself is cracked to form lower value by-products. Typical residence times for the molecules in the furnace tubes are less than one second.

- **Low hydrocarbon concentration**
- **Rapid quenching or cooling to minimise secondary reactions.**

This brings us to our next main processing step: Quenching.
Ethylene has been produced by the cracking reaction. However, it is mixed in with many different hydrocarbons. It needs to be separated out so that it can be sold as a product that is over 99% wt pure.

The remainder of the process steps are to get the ethylene separated out so that it can be sold to our customers.

**Step 3 — Gas Compressor**

The conventional method of separating hydrocarbons is in distillation columns. This requires the furnace effluent to be liquefied. The way to liquefy a gas is to increase the pressure of the gas and then cool it down until a liquid is formed. Gas compression increases the pressure of the gas.

![Gas compressors](image)

**Figure 7**

Gas compressors

The cracked gas stream from the quench tower is compressed using a centrifugal compressor. The gas compression in this section of the plant occurs in four stages. Heat exchangers are used to cool the gas between each stage of compression.

This is necessary because when a gas is compressed it heats up. You therefore need to break up the compression steps to stop the gas becoming too hot.

The gas is compressed to a pressure of approx. 3500 kPa.

**Step 4 — Treating**

The cracked gas stream contains impurities that need to be removed before the ethylene can be sold. These impurities include carbon dioxide, hydrogen sulphide and acetylene. Treatment of the cracked gas to remove impurities occurs between the third and fourth stages of the compressor.

The hydrogen sulphide and carbon dioxide are removed in the caustic tower.

![Treatment to remove impurities](image)

**Figure 8**

Treatment to remove impurities

The caustic’s tower’s purpose is to remove these unwanted chemicals from the ethylene. In this tower, the gas stream is contacted with dilute sodium hydroxide. The following reactions occur in the caustic tower:

\[
\begin{align*}
2\text{NaOH}(aq) + \text{H}_2\text{S}(g) & \rightarrow \text{Na}_2\text{S}(aq) + 2\text{H}_2\text{O}(aq) \\
2\text{NaOH}(aq) + \text{CO}_2(g) & \rightarrow \text{Na}_2\text{CO}_3(aq) + \text{H}_2\text{O}(aq)
\end{align*}
\]

The waste sodium hydroxide stream is removed from the caustic tower. It is treated on site in the Spent Caustic Carbonation Unit which uses waste flue gas from a boiler to convert the stream into a benign baking soda solution prior to disposal. The carbonation unit is unique ‘world first’ technology that does not require any acids or oxidisers to treat the sodium hydroxide waste stream.

The acetylene is removed in a vessel called the acetylene converted. This is a large oval-shaped vessel filled with a nickel-iron catalyst. As the gas stream passes the catalyst the following reaction occurs:

\[
\text{C}_2\text{H}_2(g) + \text{H}_2(g) \rightarrow \text{C}_2\text{H}_6(g)
\]

(There are other different catalysts that can also be used). This catalyst is used to selectively promote only the hydrogenation of acetylene. Some of the other undesirable reactions include:

\[
\text{C}_2\text{H}_4(g) + \text{H}_2 (g) \rightarrow \text{C}_2\text{H}_6(g)
\]

This reaction is undesirable because it is a loss of valuable ethylene.

The gas stream now needs to be ‘dried’. As the gas stream is going to be cooled to temperatures as low as −100°C, any remaining water would form ice compounds thereby blocking pipes etc.

The drying is achieved by passing the gas stream through an apparatus (the molecular sieve desiccant) that is designed to absorb water. It is now necessary to cool the gas stream.
Step 5 — The Chilling Train

![Image of the chilling train process]

**Figure 9**
Chilling train process

The chilling train is a series of three heat exchangers. On one side of the heat exchanger is the gas that needs to be cooled.

On the other side of the heat exchanger is the refrigerant, liquid ethylene or propylene, which cools the gas. Neither stream comes into direct contact with the other.

The gas is cooled and then it condenses or liquefies.

The liquid stream can now go to the distillation columns to separate out the different chemical compounds.

Step 6 — Fractionation

![Image of the fractionation process]

**Figure 10**
Fractionation process

There are three distillation columns. The way in which one of these columns works is shown in figure 11.

The first column is the de-methaniser. This separates out hydrogen and methane from the remaining components. The hydrogen and methane are used as fuel gas.

The remaining heavy gas exits from the bottom of the de-methaniser (e.g. ethylene and ethane), and is then fed into the second distillation column.

This is called the de-ethyleniser. This column separates ethylene from the heavier components of the de-methaniser bottom.

It operates at a pressure of 1950 kPa, (nine times the pressure in your car tyre) and produces ethylene product at a purity greater than 99.85 %w.

The ethylene product is heated to 20°C and sent, via a pipeline, to Qenos Resins and the Qenos Plastics manufacturing plant.

The third column, the de-ethaniser, separates ethane from the propylene and heavier components in the de-ethaniser bottoms.

The overhead ethane stream is recycled back to the furnaces for cracking. The bottoms stream is sent to the gas oil cracker plant for further separation.

**Ethylene Manufacture from Liquid Gas Oil**

Qenos Olefins produces ethylene using a liquid gas oil feed in a completely separate plant to the ethane cracking plant. The process of ethylene manufacture from liquid gas oil is very similar to the ethane cracking process.
Qenos Altona — Olefins Manufacturing

Figure 12
General plant information

Unit operations: Steam-cracking furnaces  
Heat exchange  
Compression  
Distillation  
Liquid-liquid extraction  
Catalytic reaction  
Steam generation  
Pumps  
Molecular-sieve drying

What engineers do: Plant monitoring/troubleshooting  
Design for plant modifications  
Design for new projects  
Process control hardware/software design/selection/installation  
Plant supervision

Feed  
Pyrolysis furnaces  
Mixture of products  
‘Hot Ends’  
Purification/separation  
‘Cold Ends’  
Pure products