Improving Fractionator Tower 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 fractionator tower in a refinery.

But even with the wide range of industries and wide range of applications, the actual use of the gas chromatograph tends to fall into three general categories:

1. Better process control and optimization
2. Environmental monitoring and safety measurements
3. Purity of commodity gases and chemicals monitoring

Of the process gas chromatographs used for process control and optimization, most of those are used for the same basic purpose – fractionator control. So whether the chemical process is a simple natural gas plant or a world-scale, complex olefins plant, the vast majority of the process gas chromatographs are being used for the same purpose.

The Need For Compositional Measurement-Based Fractionator Control

Fractionator towers, also called distillation towers, are the primary method for separating a chemical mixture into purified streams. The feed stream containing the chemical mixture enters the tower and is separated into two groups – a lighter stream exiting overhead and a heavier stream exiting from the bottom (see Figure 1).

This chemical separation is made possible by a number of perforated plates inside the tower that allow the liquid to trickle down while the gases bubble to the top. The interaction between the gas flowing up and the liquid flowing down, strips the lighter components out of the liquid and into the gas phase – making each purer. A number of variables determine how efficiently this occurs; temperature and internal pressure of the tower being large factors.

As the gases leave the top of the tower, they are cooled in a condenser, collected in an accumulator and then exit as the overhead product. To further increase the purity of the overhead stream, some of it is recycled (called reflux) for additional processing. The higher the reflux ratio, the purer the overhead product becomes.

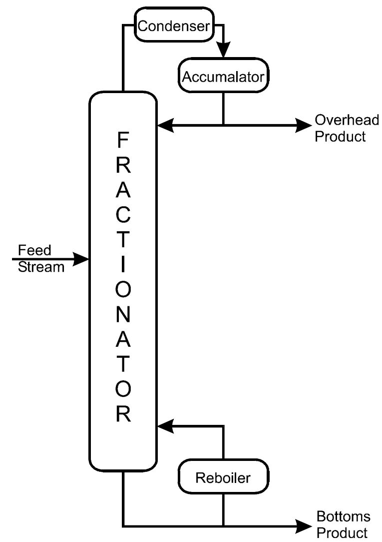

Figure 1 - Typical Fractionator Tower

A similar situation occurs with the bottom product. Some of this liquid is reboiled and reintroduced into the tower to give the liquids impurities another chance to distill, thus exiting out the top of the tower.

In an ideal world, a tower operator would set the proper temperature and pressure for the tower along with the appropriate reflux/reboil rates to get the desired purities. Unfortunately, there are a number of real-world influences that make the tower difficult to control. These include:

- Changes in feed rate to the tower which increases or decreases the demand for more heating or more cooling of the reboiler and condenser
- Change in chemical composition of the feed due to upstream unit upsets which change the conditions needed to get the desired chemical separations
- Change in temperature and/or pressure of the tower due to equipment malfunction or drift

Even the weather can affect operation. A rain shower may cool the tower or a simple weather front may change the atmospheric pressure and alter the pressure in the tower.

To compensate for all these possible errors in the tower's operation, the process operator will typically install a buffer to allow some room for purity drift in the operation without having to worry that the products will violate specifications. For example, if the specification for the overhead product is to have no more than 3% impurity, he may operate the tower at a rate for an average purity of 1% just to be safe. But operating with large buffers can lead to serious economic consequences.

For example, the amount of overhead product that needs to be refluxed (recycled) to get a higher purity is non-linear (see Figure 2) creating a number of problems. First, it means that the amount of buffer needed to keep from violating the purity specification needs to be larger than one would normally think because at lower reflux rates a small change in the reflux rate has a larger impact than it would at larger reflux rates.

Second, the energy consumption for the tower increases since all the additional material to be refluxed has to be heated and cooled. The energy consumed by fractionator towers is a huge cost, typically one of the largest expenses for the plant. In a report issued in the 1980s, it was reported that 3% of all energy consumed in the U.S. was for fractionator tower operation. While this amount has certainly changed over the years, it does give an order-of-magnitude for how much expense is involved.

Finally, the actual throughput capacity of the tower is decreased as the reflux and reboil rates are increased. With so much of the material being reprocessed in the tower, the amount of actual tower throughput drops – possibly creating a bottleneck in the plant's operation.

The result is that there are many benefits of knowing the actual chemical composition of the tower's product streams. By knowing the compositional changes as they occur, the tower can operate closer to design specifications. The process gas chromatograph provides the continual compositional measurement that the plant control system needs.

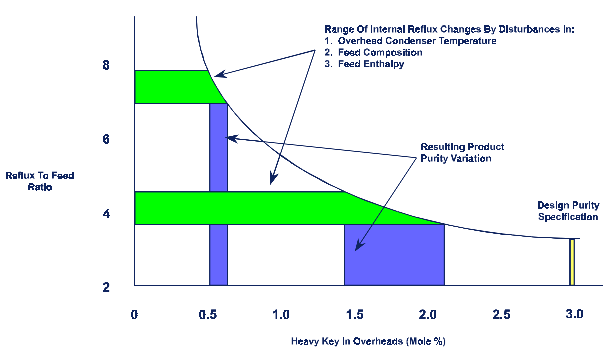

Figure 2 - Relationship Between Reflux Ratio and Product Purity

Improving Tower Performance With Process Gas Chromatographs

The process gas chromatograph taps into the process lines to continually extract a sample for measurement. There are a number of options regarding where the gas chromatograph taps into the tower to perform the measurement (see Figure 3). Each measurement location has pros and cons.

The first option is to tap into the product streams directly since that is what the operator is attempting to control. This is what many installations do, but there can be some difficulty with this. For example, if the accumulator on the overhead stream is large, it can cause a delay in the time that changes in the tower's operation are seen by the analyzer.

If this gap is large, it is possible to measure at the accumulator or even the pipe leaving the top of the tower. However, this can create other problems. For example, there is a tendency for a 2-phase sample to be in the process line, which is completely incompatible with reliable gas chromatograph operation. There is also a slight difference in the chemical composition seen in the overhead pipe versus what leaves the accumulator.

Some plants even sample the top tray (or plate) of the tower to have a very fast response to changes, but this also creates the problem of 2-phase samples and chemical composition differences.

In addition to measuring the product streams, some users with advanced tower control with feed-forward control schemes will often measure the feed to the tower to stabilize tower operation due to feed fluctuations.

Once the choice of sample point is determined, the operator needs to decide what to measure. Some serious consideration needs to be put into this issue. The tendency for some users is to measure everything. Not only does this make the analyzer more expensive and more complicated, it also significantly increases the analysis time of the gas chromatograph, possibly negating the benefit of the real-time analysis.

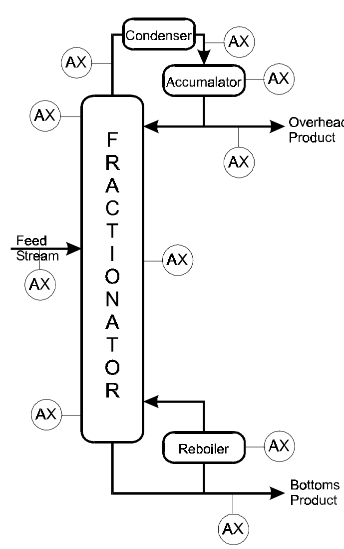

Figure 3 - Common Gas Chromatograph Measurement Locations

In most applications, the analysis can be reduced to just one or two compounds and still meet the requirements of the control system. This is due to the fact that the tower separates by boiling point so if the concentration of one compound remains low, all the compounds that boil higher (or lower for the bottoms stream) will also be kept low. This compound is often referred to as the "key" compound; the light key and heavy key. If these are minimized, all the other impurities are also minimized.

In some plant configurations, it becomes necessary to perform a ratio of one compound to another to help the operation of a downstream processing unit. Measuring the lighter-than-light key or heavier-than-heavy key and then ratioing that to another compound allows downstream product specifications to be met. A good example of where this ratio technique is needed is in a natural gas liquids plant.

In a natural gas liquids plant (see Figure 4), a mixture of methane (C_1) through hexane (C_6) and heavier is separated into various product streams. On the deethanizer tower, a process gas chromatograph typically monitors the ethane product for impurities such as the C_3 to insure that the heavy impurities are kept within specification. However, measuring the lighter compounds like C_1 would be pointless at this stage since it is lighter than the product being made and can't be kept out of the overhead stream no matter at what the reflux ratio is set. To control the lighter compounds in the overheads, it must be controlled before it even enters the tower in the feed stream. A ratio of the C_1 to C_2 on the bottoms of the demethanizer is done to compensate for the compositional changes that will occur in the deethanizer tower.

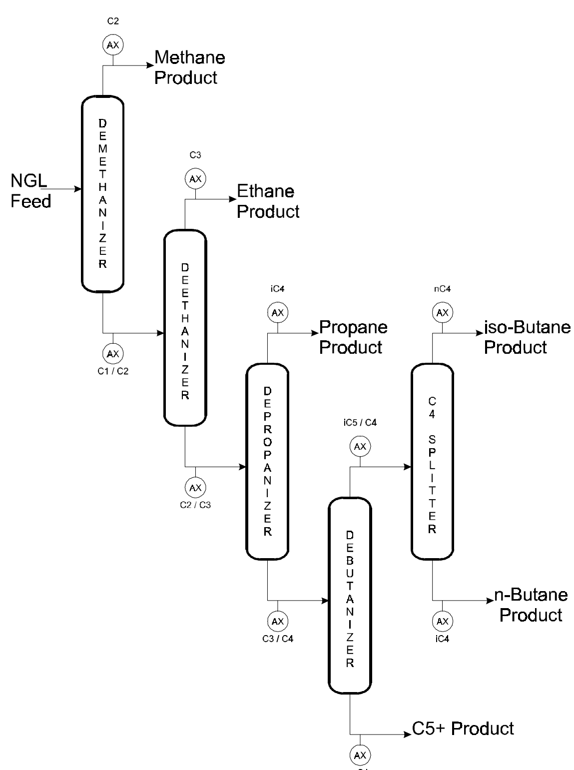

Figure 4 - Typical Natural Gas Liquids Plant Gas Chromatograph Measurement Points

Typical Benefits of Improved Tower Performance

The economic benefits for improved tower operation can be significant. While every tower's situation must be evaluated separately, a few standards of the typical benefits of improved tower performance have evolved over the years (see Figure 5).

One of the biggest benefits is reduced tower energy consumption by 5 – 15% due to lower reflux rates. Also, since the product is no longer being recycled so heavily, the tower's overall throughput often goes up 5 – 10%. This can be especially important for plants that are experiencing operational problems caused by bottle-necks at a certain fractionator tower.

Stable operation of the fractionator towers ultimately leads to improved plant operation overall by minimizing fluctuations in the composition of the process streams.

The Emerson Solution

Emerson has a long history of providing process gas chromatographs for the process industry. Emerson process gas chromatographs have set the standard for fractionator tower measurement by supplying analyzers that are both robust and capable of handling the analytical requirements.

Figure 5 - Typical Benefits of Improved Fractionator Tower Control

- Decreased energy consumption: 5 – 15%
- Increased through-put: 5 – 10%
- Increased product purity control
- Enhanced recovery of valuable products
- Improved performance of downstream units

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