Control Valve Sourcebook — Chemical Unit Operations

Pyrolysis Furnace

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EMERSON™
Process Management

Pyrolysis Furnace

Other Names

cracking furnace, steam cracker, cracker, reformer

I. How It Operates

The pyrolysis furnace is the initial process within an olefins plant. Pyrolysis is the thermal cracking of petroleum hydrocarbons with steam, also called steam cracking. The feed hydrocarbon stream is pre-heated by a heat exchanger and mixed with steam. At this point, it enters a reactor where it is heated to cracking temperature. During this reaction, the hydrocarbons in the feed are cracked into smaller molecules. The cracking reaction is highly endothermic; therefore, high energy rates are needed. The cracking coils are designed to optimize the temperature and pressure profiles in order to maximize the yield of desired products.

A pyrolysis furnace is capable of running different types of feedstock. Some pyrolysis furnaces may be designed just for a single feed. Single-feed designs are intended to optimize the process to achieve maximum yield of ethylene, propylene, butadiene, or any other high value chemical. Producers may want the flexibility of multi-feedstock furnaces, known as mixed-feed crackers, while others prefer to have a few furnaces, each designed for one specific feedstock to maximize the yield of a certain chemical.

Feedstock is pumped through the cracking furnace at a very high rate. The feedstock remains in the furnace only for a fraction of a second. This short residence time is necessary to keep the cracking process from cracking the chemicals into smaller chains of undesired product. A runaway reaction would result in cracking all of the valuable feedstock until only low value coke in the form of carbon and hydrogen remain. In order to control runaway reactions, the feedstock is mixed with steam before it enters the furnace. Adding steam is very beneficial, as it lowers the temperature required for cracking by lowering the partial pressure of the feed. Steam also has a cleansing effect since less coke is formed with the presence of steam acting as a diluent and inhibiting carbonization. This allows for longer run lengths since the furnace tubes do not need to be de-coked as often to prevent clogging and hot spots. Coke deposits inside the tubes act as an insulator, preventing the feedstock/steam mixture from being heated enough for the cracking process to work.

The most important measurements and control parameters are the feed flow, steam flow, and feed-to-steam ratio. When the feedstock/steam mixture goes into the furnace to be cracked at high temperatures, the conversion is controlled by accurately measuring the temperature of the gases leaving the furnace. This is called the coil outlet temperature (COT). This measurement has to be precise, as small deviations can have a major impact on product yield.

In a gas-fired heater, it is also important to measure both the fuel flow rate and the excess oxygen in the stack, which are interconnected. It is desirable to have as little oxygen as possible remaining in the flue gas. This indicates maximum fuel consumption with an optimum amount of heat energy extracted for cracking. Stack oxygen levels are measured and used to control the ratio of fuel to air injected into the burners so that excess oxygen is minimized.

The feedstock/steam mixture is heated very rapidly in pyrolysis furnaces to start the cracking process. The COT is the main control variable because it is a measure of cracking efficiency. Based on this measurement, the fuel flow to the burners is increased or decreased by control valves, so the temperature in a furnace is subsequently raised or lowered. That affects stack oxygen levels, which in turn must be used to adjust the fuel-to-air ratio. If there is a lot of coke deposition on the inside of the tubes, the temperature inside the tubes will be reduced. The COT will reflect this quickly, and the control system will ask for more fuel, causing the burners to deliver more heat in order to raise the COT. This condition can escalate as the coking rate increases at the higher temperatures, causing the COT to drop. This drives the flame temperature up, increasing the coking rate. Again, having tight control will decrease the possibility of a shutdown for maintenance to de-coke.

At some point, the flame temperature will be so high that the tubes in the firing box may reach their metallurgical limit. That could cause tubes to rupture, resulting in the flooding of the firing box with explosive feedstock. To prevent a catastrophic event, the temperature on the outside of the cracking tubes is monitored to indicate when it is time to shut down the furnace and clean or de-coke.

The control problem is even more complicated, since every furnace has multiple burners with many tubes. Consideration should be given to the way feedstocks are distributed through the different cracking tubes and how each individual burner impacts each. Maximizing the yield in a furnace is a multi-variable control problem and needs to be configured accordingly.

II. Where Pyrolysis Furnaces Are Used

Pyrolysis furnaces work with different types of feedstocks to produce high value chemicals. Table 1 shows the most commonly used feedstocks and their typical olefin yields. The table shows that lighter feedstocks, or those with smaller carbon chains, produce lighter end products.

		Feedstocks				
		Ethane	Propane	Butane	Naptha	Gas Oil
Produced Chemicals	Ethylene	80%	40%	36%	23%	18%
	Propylene	3%	18%	20%	13%	14%
	Butylene	2%	2%	5%	15%	6%
	Butadiene	1%	1%	3%	4%	4%
	Fuel Gas	13%	38%	31%	26%	18%
	Gasoline	1%	1%	6%	18%	18%
	Other	-	-	-	-	10%

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Table 1. Common used feedstock and yields

III. Pyrolysis Furnace Application Review

Tight control is critical in the pyrolysis furnace process because of the extremely fast residence times within the furnace. There are three critical control valves that dictate the cracking furnace process: dilution steam ratio, feed gas, and fuel gas control valves. Figure 1 illustrates where to find these three valves in the steam cracking process.

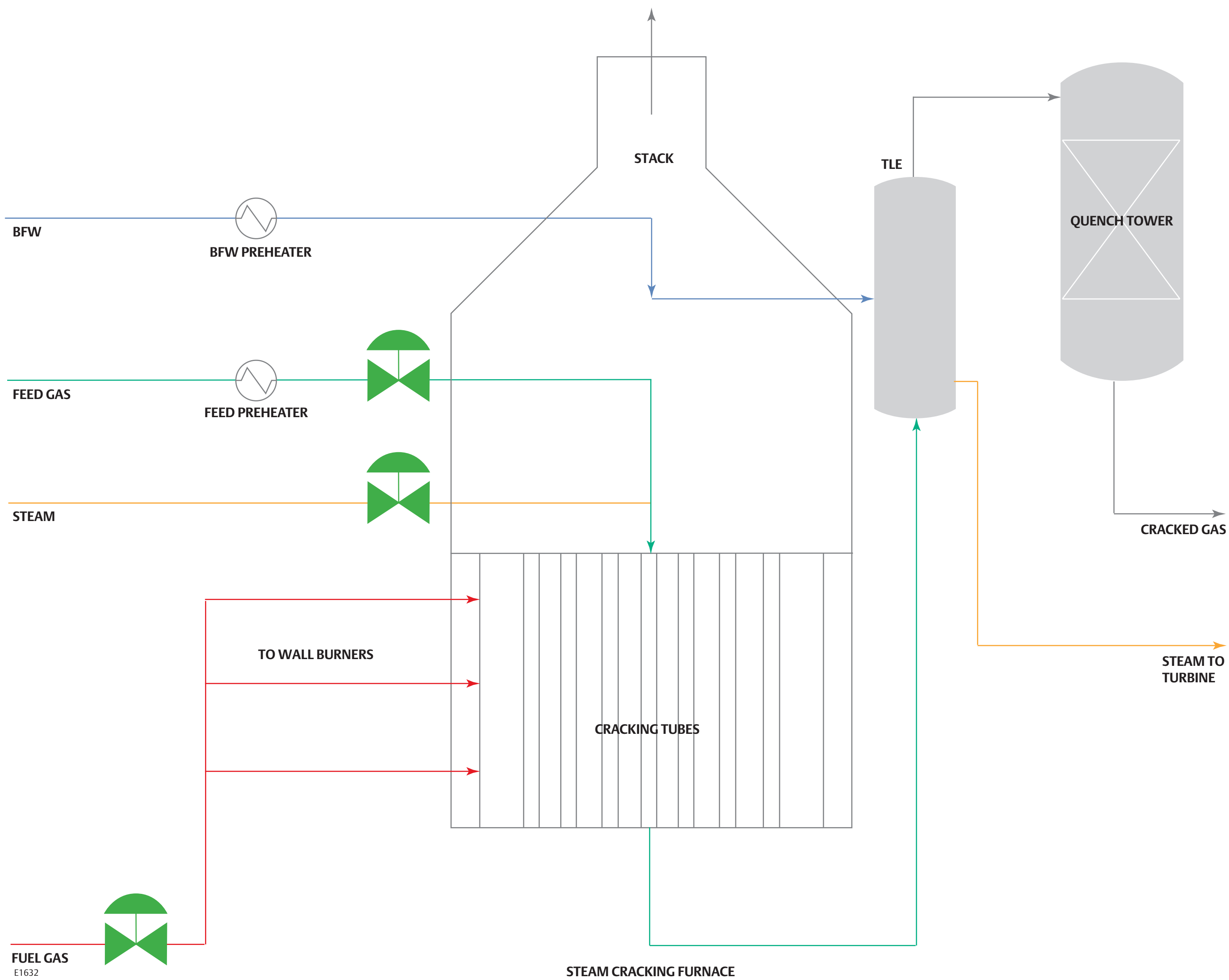

Figure 1. Critical control valves in a pyrolysis furnace

Dilution Steam Ratio Control Valve

The steam in the process acts as a dilution agent to reduce the partial pressure in the cracker coil. A proper steam ratio is critical to aid in the reduction of coke deposits. An improper ratio reduces efficiency of the pyrolysis furnace and increases the maintenance interval for decoking. There are some challenges this control valve will face, the first of which is high process temperature that require graphite packing. This will create high deadband and variability due to packing friction. Lastly, the actuator and accessories may experience high ambient temperatures.

Typical process conditions:

— Fluid = steam

— P1 = 12 bar (174 psig)

— T = 187°C (368°F)

— Q = dependent on process design

Typical valve selection:

— Fisher™ ED or GX valve

— Graphite ULF packing system

— Spring-and-diaphragm actuator

— Fisher FIELDVUE™ DVC6200 digital valve controller with Performance Diagnostics

Feed Gas Control Valve

The feed gas valve controls the flow of feed gas to the furnace. Similar to the dilution steam ratio valve, tight control is necessary to maintain the proper reaction ratio within the furnace. The valve experiences similar challenges as the dilution steam ratio valve. Actuator and accessories may see high ambient temperatures. The valve will typically require low-emission packing to reduce feedstock emissions.

Typical process conditions:

— Fluid = hydrocarbon feed including methane, ethane, propane, butane, naptha, or gas oil

— P1 = 13 bar (188 psig)

— T = 120°C (248°F)

— Q = dependent on process design

Typical valve selection:

— Fisher ED or GX valve

— Fisher ENVIRO-SEAL™ packing system

— Spring-and-diaphragm actuator

— Fisher FIELDVUE DVC6200 digital valve controller with Performance Diagnostics

Fuel Gas Control Valve

The fuel gas control valve regulates the temperature of the furnace by controlling the fuel to the burners. Temperature control of the pyrolysis furnace is critical to ensure efficient cracking reaction of the feedstock. Low-emission packing may be used to reduce the leakage of methane, propane, or any other fuel source. The actuator and accessories may see high ambient temperatures.

Typical process conditions:

— Fluid = hydrocarbon feed including methane, ethane, propane, or other fuel sources

— P1 = 4 bar (58 psig)

— T = 40°C (100° F)

— Q = dependent on process design

Typical valve selection:

— Fisher ED or GX valve

— Fisher ENVIRO-SEAL packing system

— Spring-and-diaphragm actuator

— Fisher FIELDVUE DVC6200 digital valve controller with Performance Diagnostics http://www.Facebook.com/FisherValves

http://www.Twitter.com/FisherValves

http://www.YouTube.com/user/FisherControlValve

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