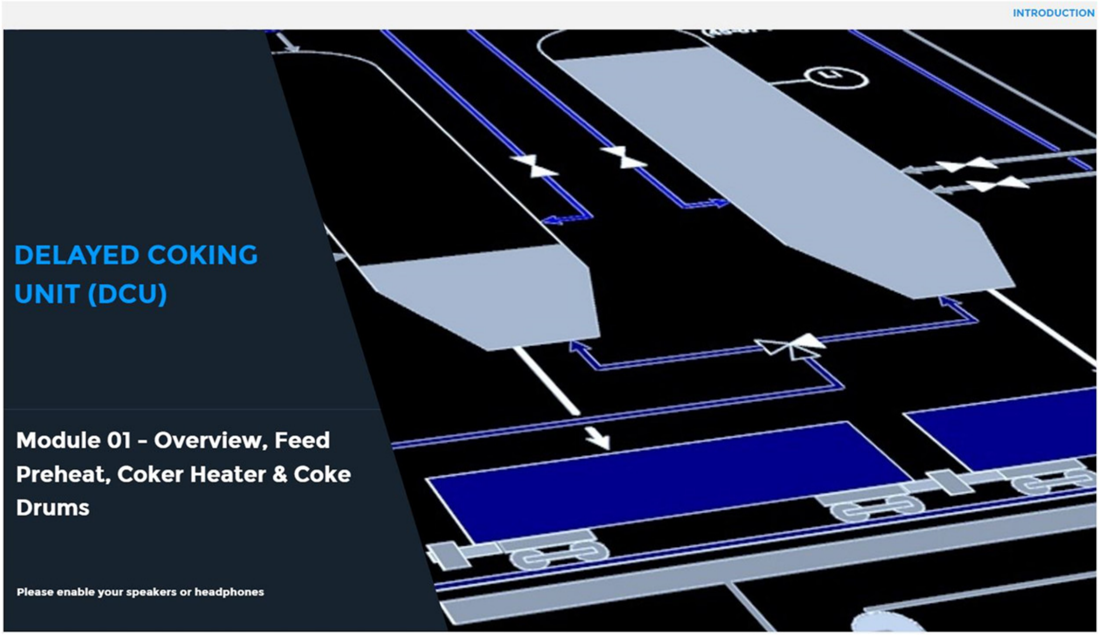
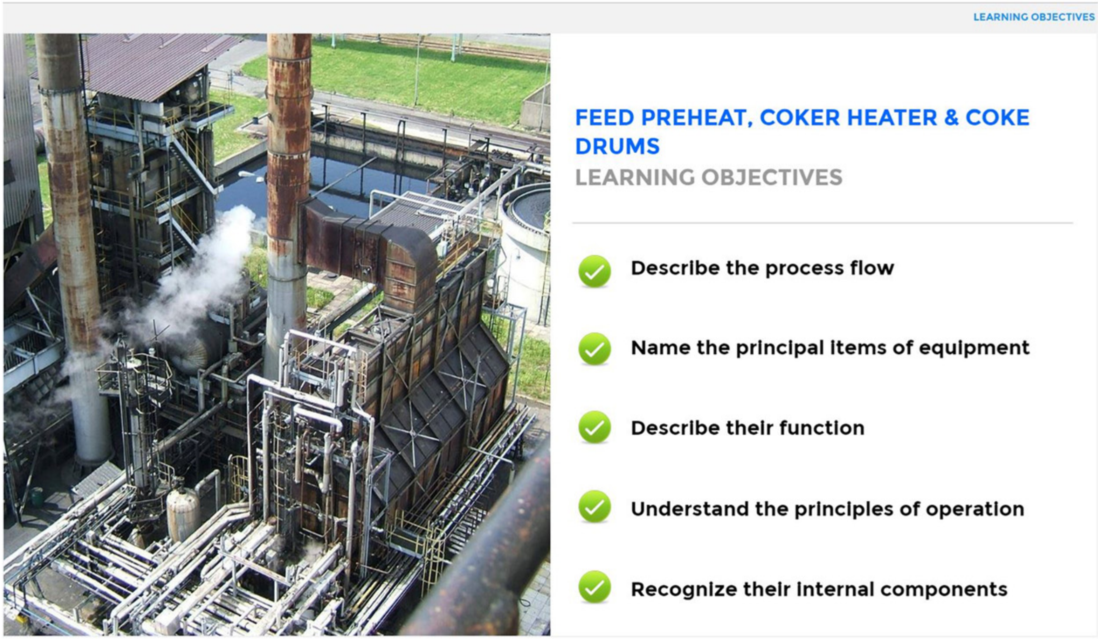
BU MEASUREMENT & ANALYTICS

Refinery Process Units

Delayed Coking Unit (DCU) – Module 1: Overview, Feed Preheat, Coker Heater & Coke Drums



Welcome to the Delayed Coking Unit Module 01, which gives you a brief overview and covers the Feed Preheat, Coker Heater and Coke Drum unit operations.



For the Feed Preheat, Coker Heater and Coke Drum unit operations, upon completion of this module, you should be able to:

Describe the process flow

Name the principal items of equipment

Describe their function

Understand the principles of operation

Recognize their internal components

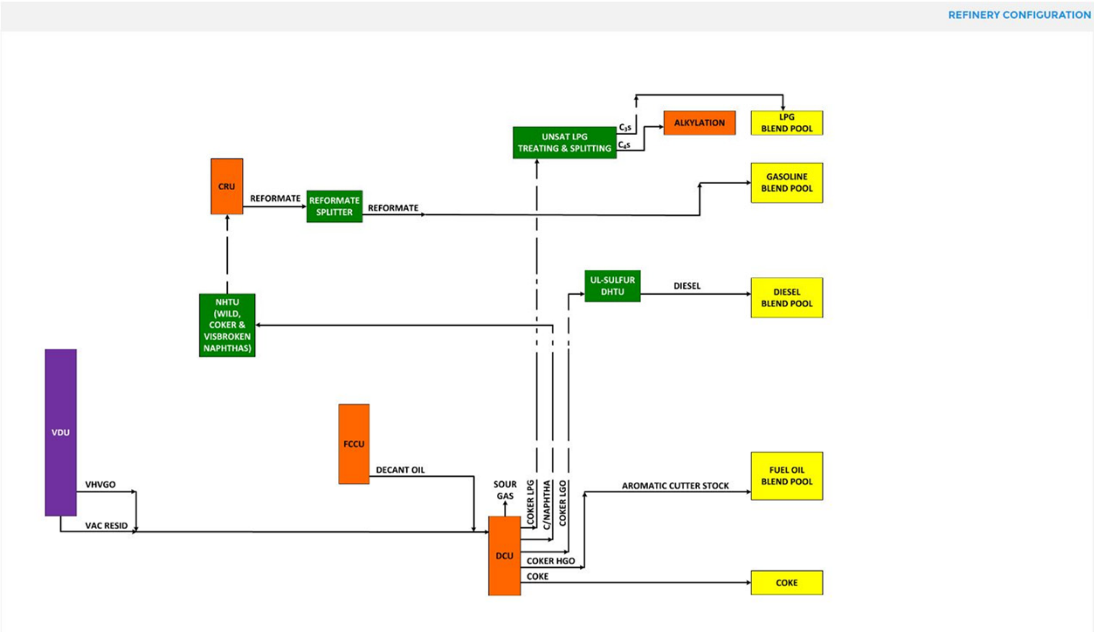
Additionally, you should be able to demonstrate an awareness of:

Important process variables and how they're controlled

Major operating constraints

Typical operating problems

Let’s start with a brief Overview of the DCU.



Here's our now-familiar Refinery Configuration Diagram that shows the Primary Separation Units in purple, Secondary Conversion Units in orange, Tertiary Treating Units in green and Export Products in yellow.

The DCU is a Secondary Conversion Unit that thermally cracks Vacuum Residue, Very Heavy Vacuum Gas Oil and occasionally FCCU Decanted Oil to produce:

A by-product of Sour Gas

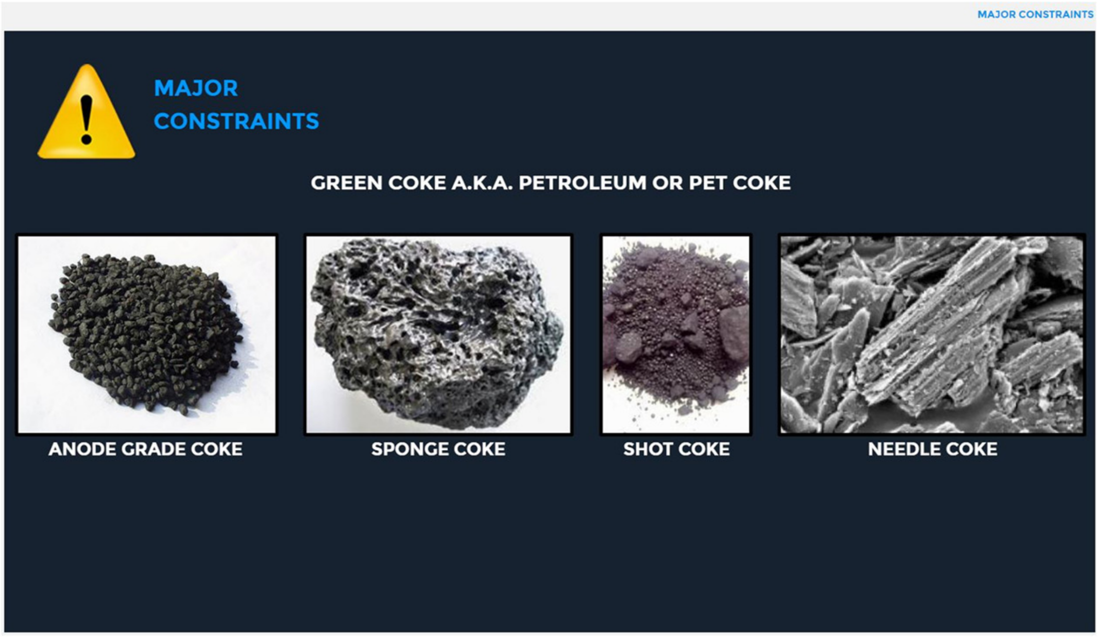
Coker LPG that is treated, split and used as LPG blendstock and Alkylation Unit feed

Coker Naphtha that is hydrotreated, catalytically reformed and blended into gasoline, as shown here. This is actually a slight over-simplification, as Coker Naphtha is usually split into Light and Heavy Naphtha, with the Light Naphtha being combined with FCCU LCN, Merox treated and blended into gasoline or sold as chemical naphtha depending on its benzene content

Coker LGO that is hydrotreated and blended into diesel

Coker HGO that is used as a fuel oil viscosity cutter

Green coke that is calcined and sold as anode grade coke



Constrained by factors such as the parent crude oil feedstock and the source of feedstocks from upstream process units, DCUs can produce cokes with a range of uses and values.

Green coke, also known as petroleum or pet coke, is a term used to describe the raw material that is formed in the Coke Drums:

> Green coke that is low in metals and sulfur content is classified as anode grade coke, calcined and used in the aluminum, steel and titanium smelting industries
>
> Green coke that is high in metals and sulfur content is known as sponge coke and is used as a fuel in power generation units
>
> Green coke that is manufactured from vacuum residues high in asphaltenes and contains globules of tar is classified as shot coke - this is an undesirable product that is typically blended with sponge coke and sold as low grade fuel

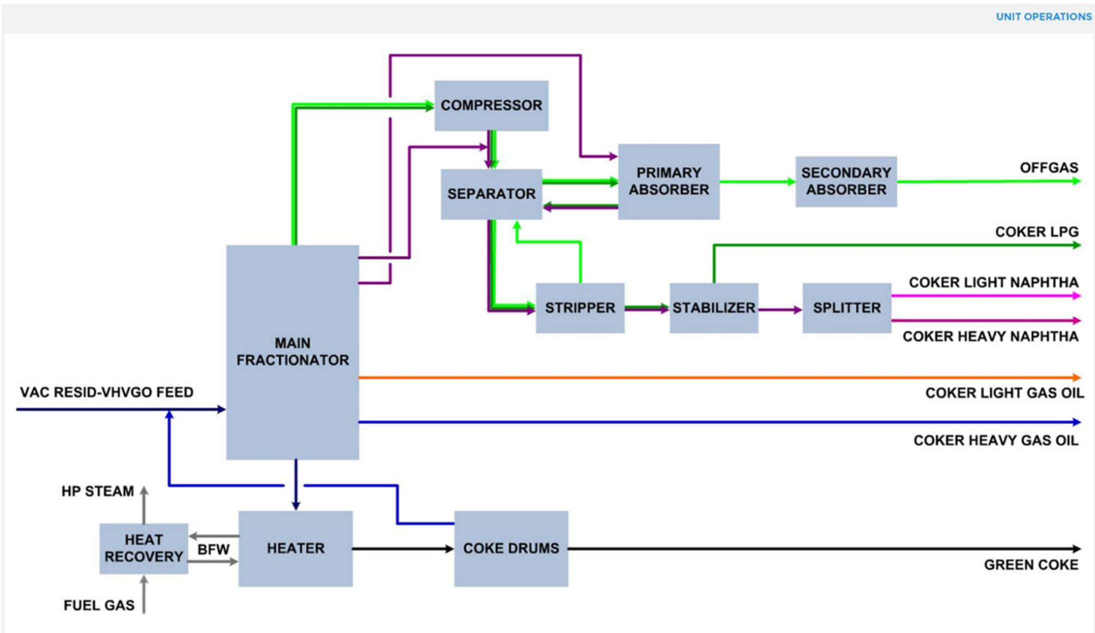
Green coke that is manufactured exclusively from FCCU decanted oil is called needle coke and is used in the production of electrodes for the aluminum and steel industries

The plant we shall be studying produces anode grade coke.

Refineries producing anode grade and sponge coke must pay particular attention to feed quality – DCU feed tanks can become a dumping ground for flushings, off-specification fuel oil and black slop that, when fed to the DCU, can result in unintentional production of shot coke.

Also, variations in refinery crude oil sources may push up the metals and sulfur content of the coke produced, forcing it to be downgraded from anode grade to sponge coke.

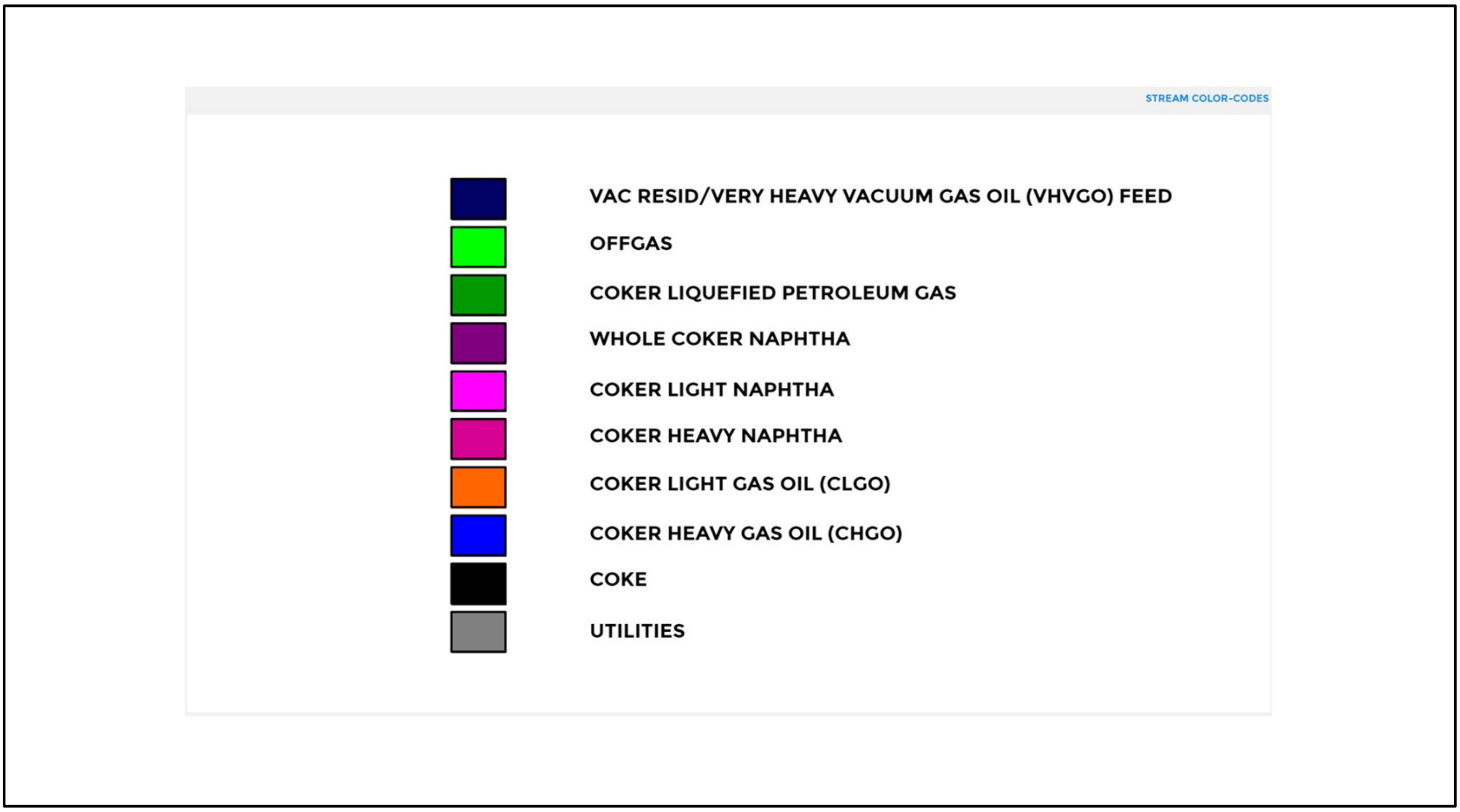
DCUs producing needle coke must ensure complete segregation of the FCCU decanted oil feed.



We've divided the DCU into two modules:

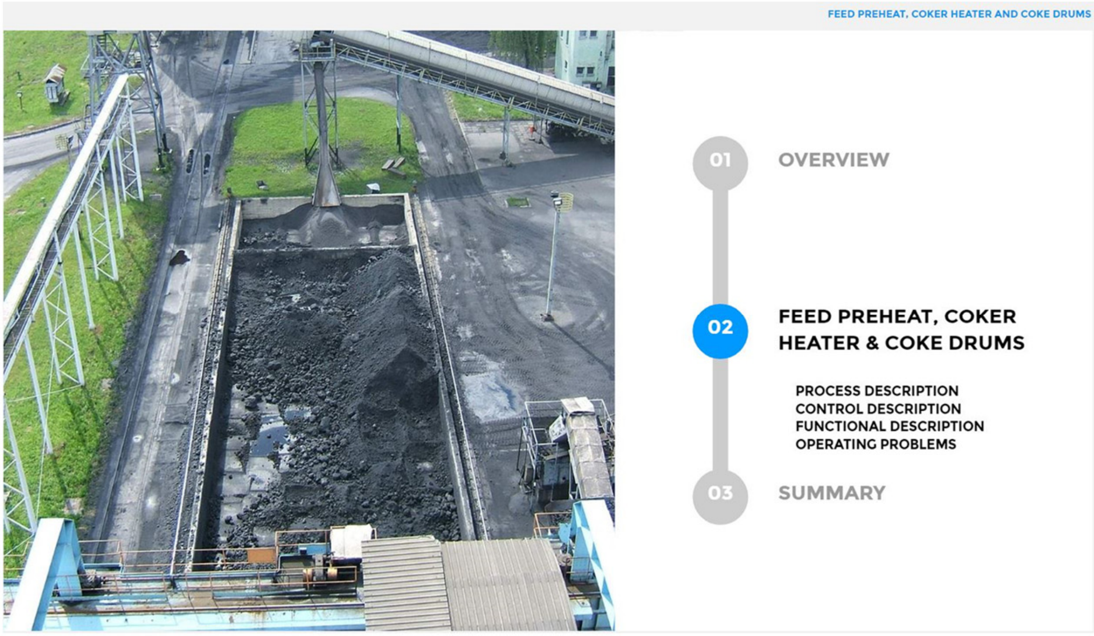
Coking - comprising Feed Preheat, Coker Heater and Coke Drum operations

Purification - which covers the Main Fractionator and Gas Plant, very similar in configuration to the back end of the ADU and FCCU



Here are the stream color-codes that we're going to be using. You'll find these are consistent with those we have used in earlier programs.

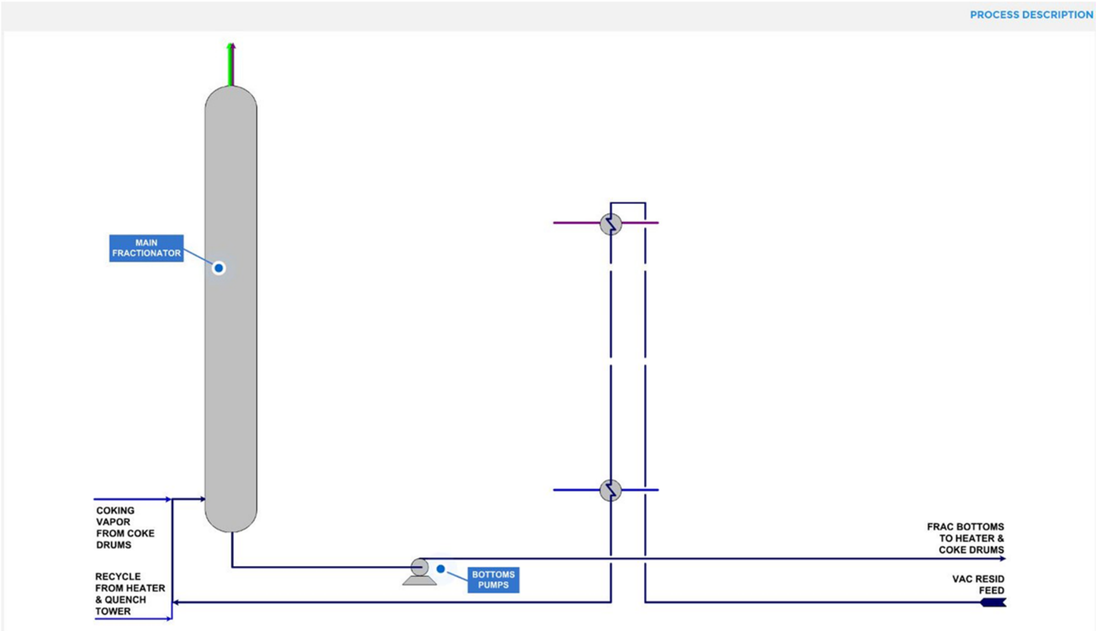
Please take a moment to familiarize yourself with the color-codes, the stream names and their abbreviations and then click next when you are ready to move on.



Ok, now you've had a brief overview, we'll make a start on the Feed Preheat, Coker Heater and Coke Drums.

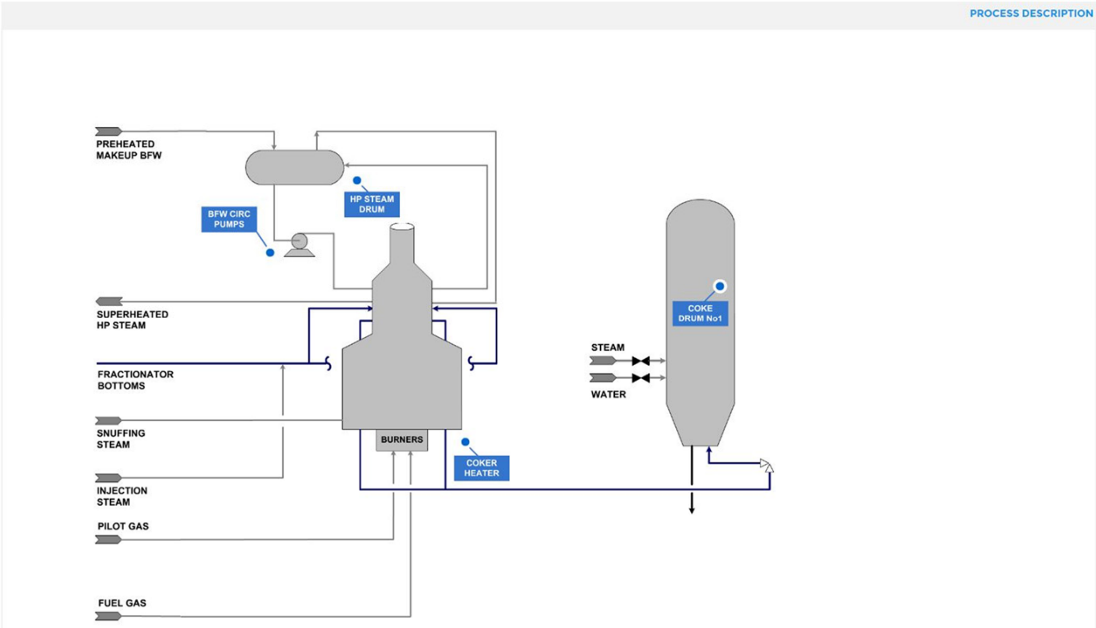
Process Description

This image shows a Delayed Coking Unit that has been in service for around 30 years.



Vacuum Residue feed, containing a small amount of Very Heavy Vacuum Gas Oil (VHVGO) is preheated against Heavy Naphtha and then Heavy Gas Oil before mixing with hot coking vapor from Coke Drum operations and recycled material from the Quench Tower and Coker Heater before entering the Main Fractionator below the flash zone.

A portion of the feed flashes to vapor, which passes up through the tower. The remainder forms a liquid level in the base of the tower, from where it is pumped to the Coker Heater.



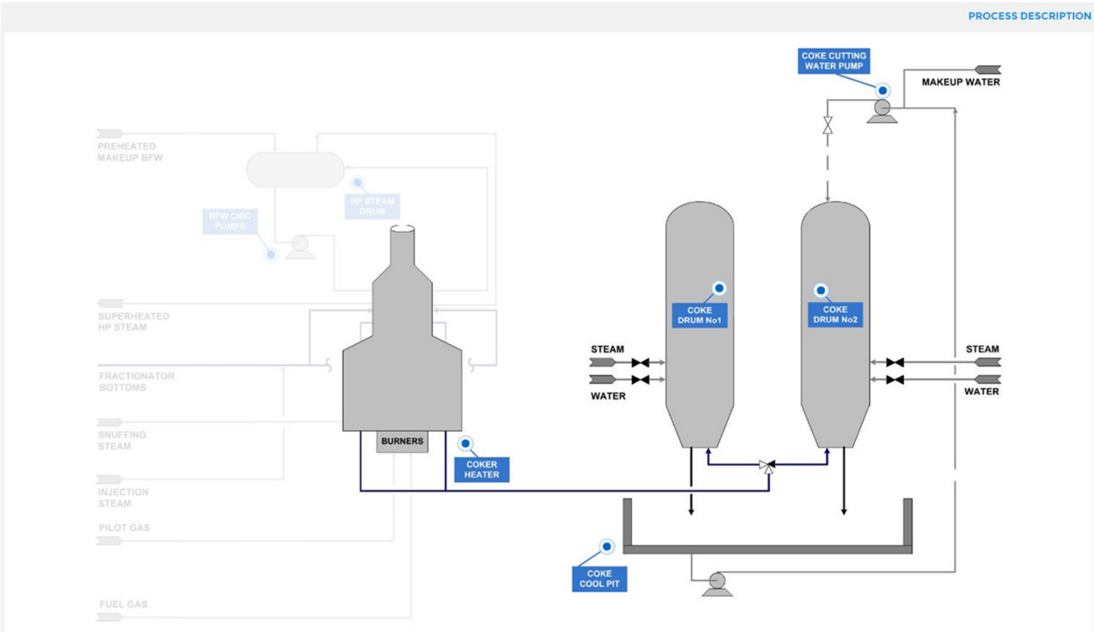
Fractionator bottoms passes through the lower convection and radiant sections of the Coker Heater, where it is brought up to a temperature at which it will thermally crack.

Thermal cracking begins in the transfer line between the Coker Heater and the Coke Drums, completing in the on-line Coke Drum.

Steam is typically injected into the Coker Heater radiant passes to maintain in-tube velocities, minimizing deposition of coke on the inner wall of the Coker Heater radiant tubes.

The Coker Heater has a heat recovery system where upper convection section coils heat boiler feed water under forced circulation to raise saturated high pressure steam and then superheat it.

This image shows a typical cabin-type Coker Heater with a heat recovery steam generation system.



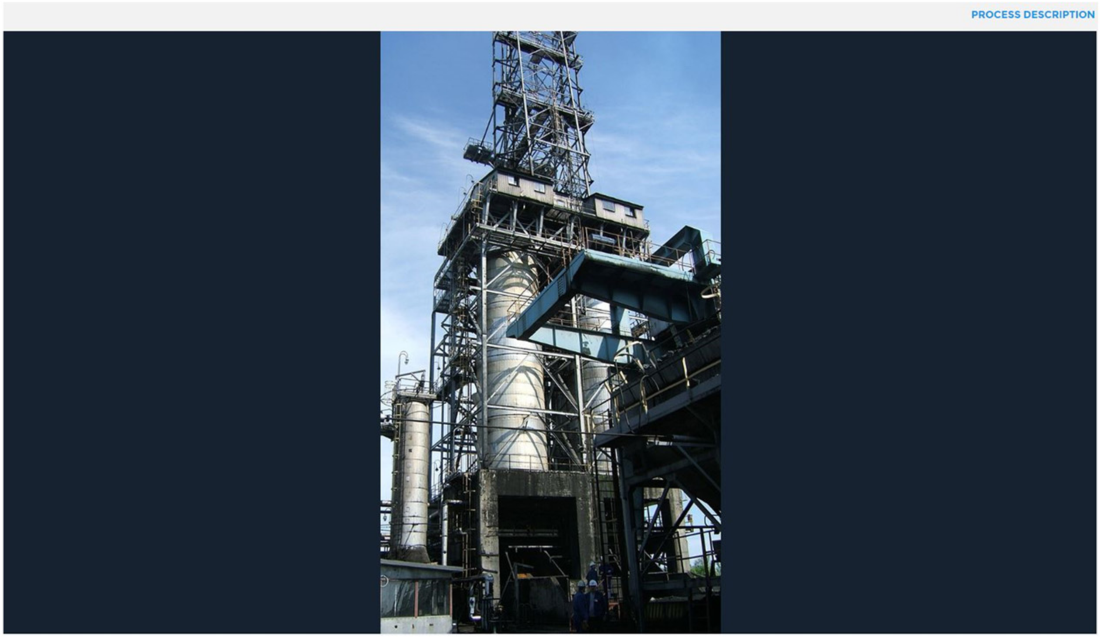
From the Coker Heater, the hot feed enters the bottom of one of the Coke Drums.

The two Coke Drums are operated in cycles.

While one drum is on-line and filling with coke, the off-line drum is steam purged and water cooled, then opened at the top and bottom to mechanically cut out the coke and drop it into a Coke Cool Pit.

From the Coke Cool Pit the coke is passed by conveyor to a Calciner. Water, recovered from the pit, is reused as coke cutting water.

Once emptied of coke, the Coke Drum is brought up to temperature and pressure in preparation to be switched into service when the on-line drum becomes full.



This image shows a pair of Coke Drums with a derrick that assists movement of equipment used in Coke Drum top head removal and coke cutting.

Delayed Coking is an endothermic process with the Coker Heater supplying the necessary heat of reaction.

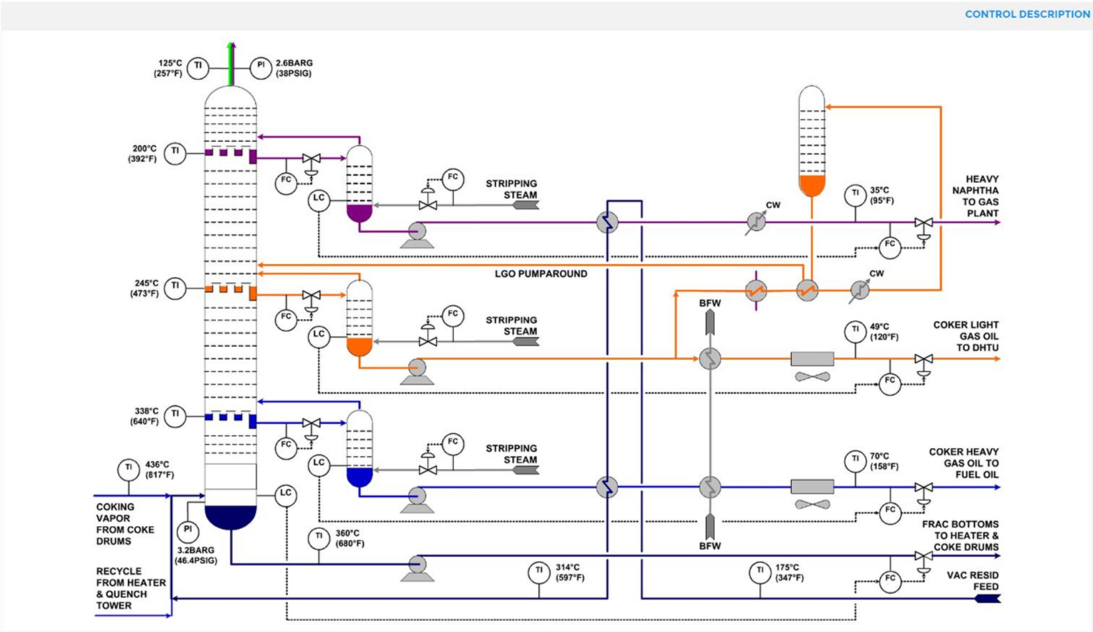
The exact mechanism of coking is so complex that it is not possible to determine all the chemical reactions occurring. Three distinct steps do take place:

> Partial vaporization and mild cracking (visbreaking) of the feed as it passes through the Coker Heater
>
> Thermal cracking of hydrocarbon vapor as it passes up through the Coke Drum
>
> Successive cracking and polymerization of hydrocarbon liquid trapped in the Coke Drum until it is converted to hydrocarbon vapor and coke.

As cracking takes place in the Coke Drum, coke starts to form and gas oil and lighter components are released as vapors.

The solid coke that is retained in the coke drum has a porous structure that allows vapor to flow through, exiting the top of the Coke Drum and passing to the flash zone of the Main Fractionator.

Depending upon the overall coke drum cycle being used, a coke drum typically fills in 16 to 24 hours.



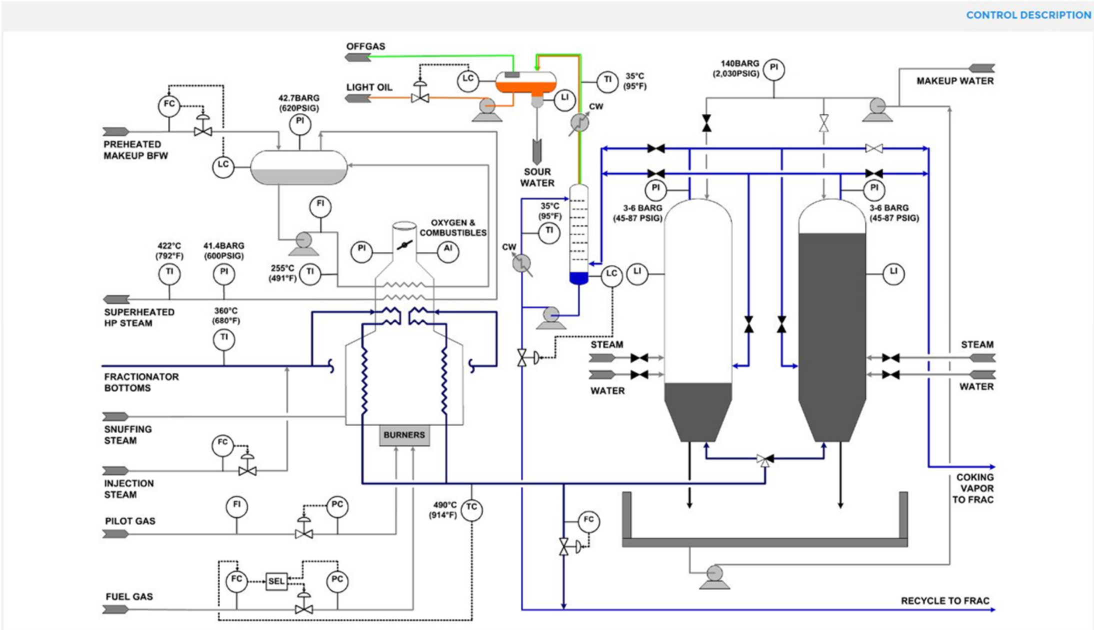
Control Description

Feed Preheat and Main Fractionator Bottoms

Vac resid feed is preheated from 175ºC (347ºF) to 314ºC (597ºF) by heat exchange with Heavy Naphtha and Heavy Gas Oil before mixing with hot vapors and recycled material from Coker Heater and Coke Drum operations and entering the flash zone of the Main Fractionator.

Main Fractionator bottoms, at 360ºC (680ºF), is pumped to the Coker Heater.

The Main Fractionator bottoms level is maintained by a master controller that sends a signal to a slave controller in the flow to the Coker Heater.



Coker Heater

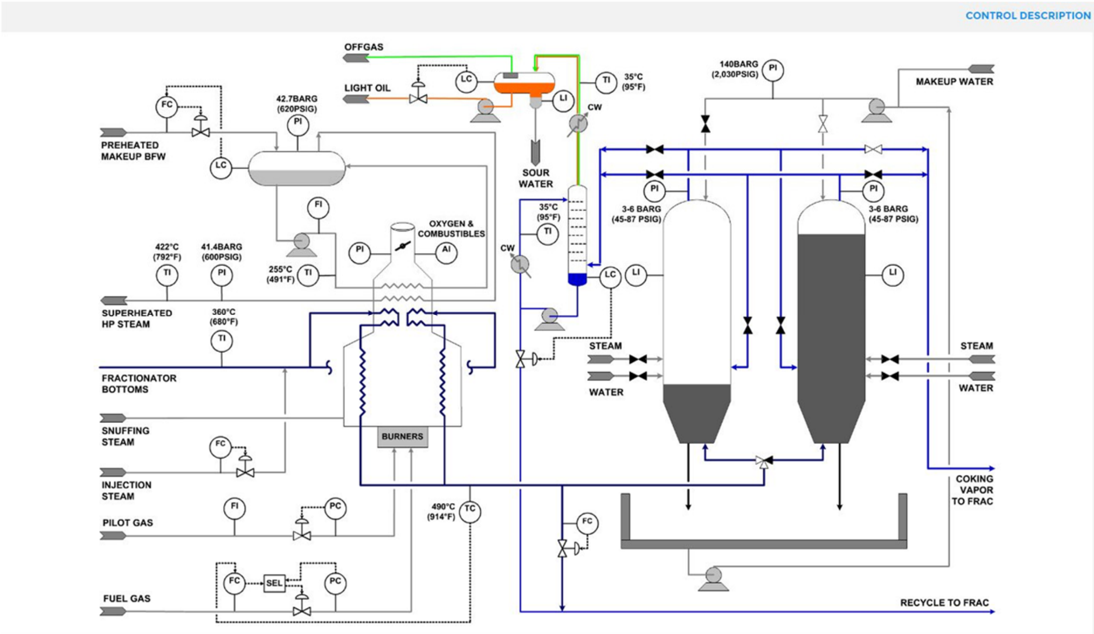
Before the Main Fractionator bottoms stream enters the Coker Heater, injection steam is added on flow control to maintain in-tube velocities and prevent coke formation on the inside of the Coker Heater radiant tubes.

The combined outlet temperature of 490ºC (914ºF) is maintained by a master temperature controller that resets a slave flow controller in the fuel gas supply to the burners. A constraint controller maintains the fuel gas pressure at the burners within safe firing limits.

The firebox draft is maintained by adjustment of the stack damper. Flue gas oxygen and combustibles targets are maintained by adjustment of the burner air registers.

High pressure steam generation and superheating take place in tubes that run through the upper convection section of the Coker Heater.

A level-to-flow cascade control arrangement imports preheated boiler feed water to maintain the HP Steam Drum level.

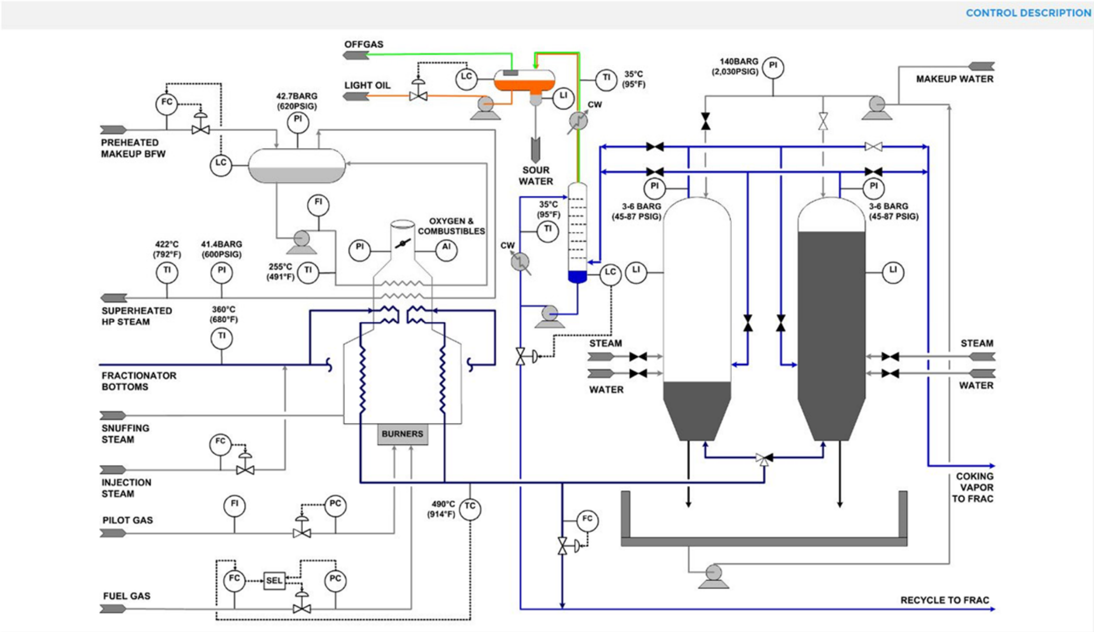


On-line Coke Drum

A portion of the Coker Heater outlet stream is recycled to the Main Fractionator on flow control.

A radioactive level detector updates the operators on the filling progress of the on-line Coke Drum, giving them time to empty and prepare the off-line Coke Drum for switching into service.

The Coke Drum operating pressure varies between 3 and 6 barg (45-87psig). The operating temperature is just a few degrees below the Coker Heater outlet temperature of 490ºC (914ºF).



Off-line Coke Drum

When a Coke Drum is switched from on-line to off-line, the coke is first steamed to purge out any trapped hydrocarbon gas, vapor or liquid to a Quench Tower.

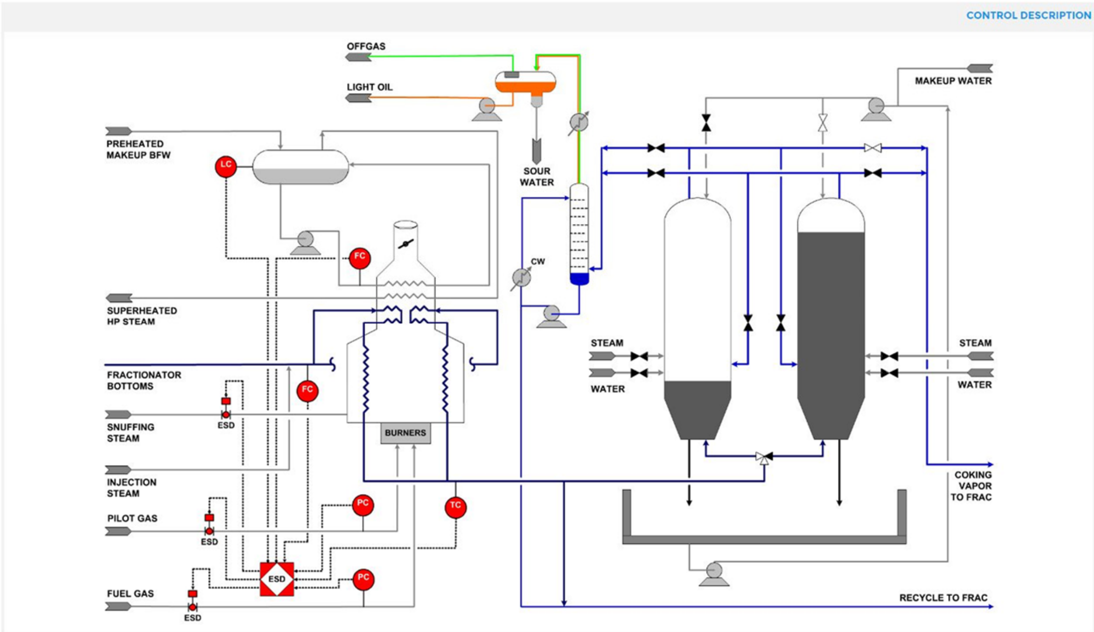
The Quench Tower bottoms is circulated through a cooler and returned to the top of the tower - a portion is withdrawn on level control and recycled to the bottom of the Main Fractionator.

The Quench Tower overheads is further cooled, collecting in a Separator, where it forms three phases:

> Sour water - an interface level indicator enables the operators to determine when the boot needs to be manually drained to the Sour Water Stripper
>
> Recovered light gas oil - which passes to slop on level control
>
> Offgas - which is compressed, treated and passed to the refinery fuel gas system

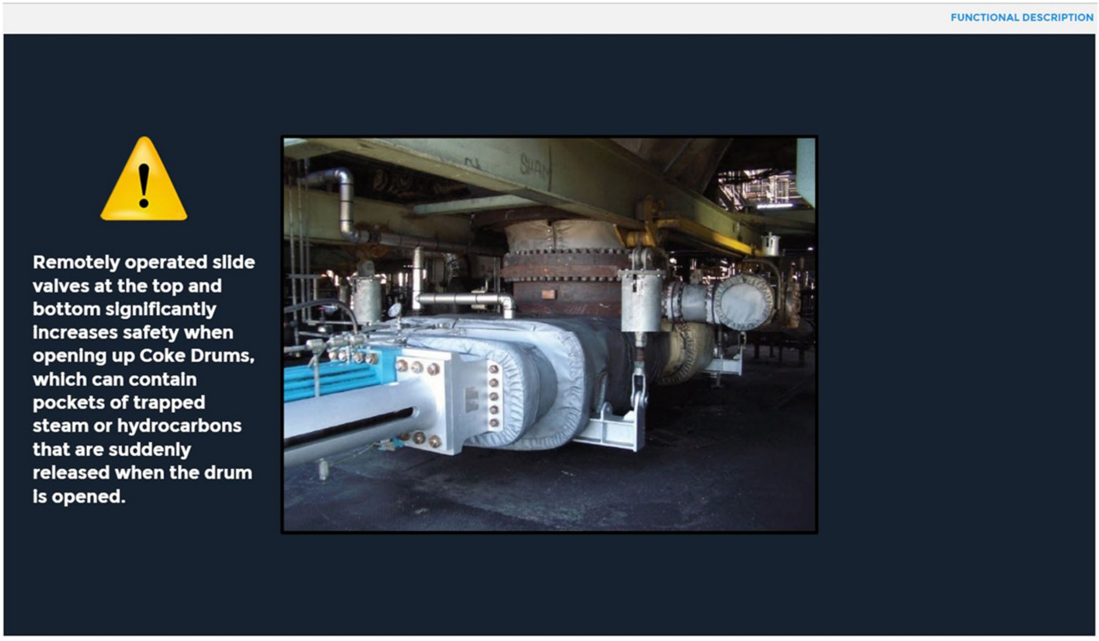
When the coke has been thoroughly steamed and hydrocarbon gas, vapor and liquid removed, it is quenched with water.

When the coke has cooled, the Coke Drum top and bottom heads are removed and cutting commences. Cutting equipment is hydraulically powered by high pressure water at 140barg (2,030psig).



The Coker Heater is protected against unstable burner firing pressures and low or no flows in the convection and radiant section tubes by a high integrity emergency shutdown (ESD) system that isolates pilot gas and fuel gas to the burners and admits snuffing steam to the firebox.

The ESD system trip initiators and actuators are shown here.

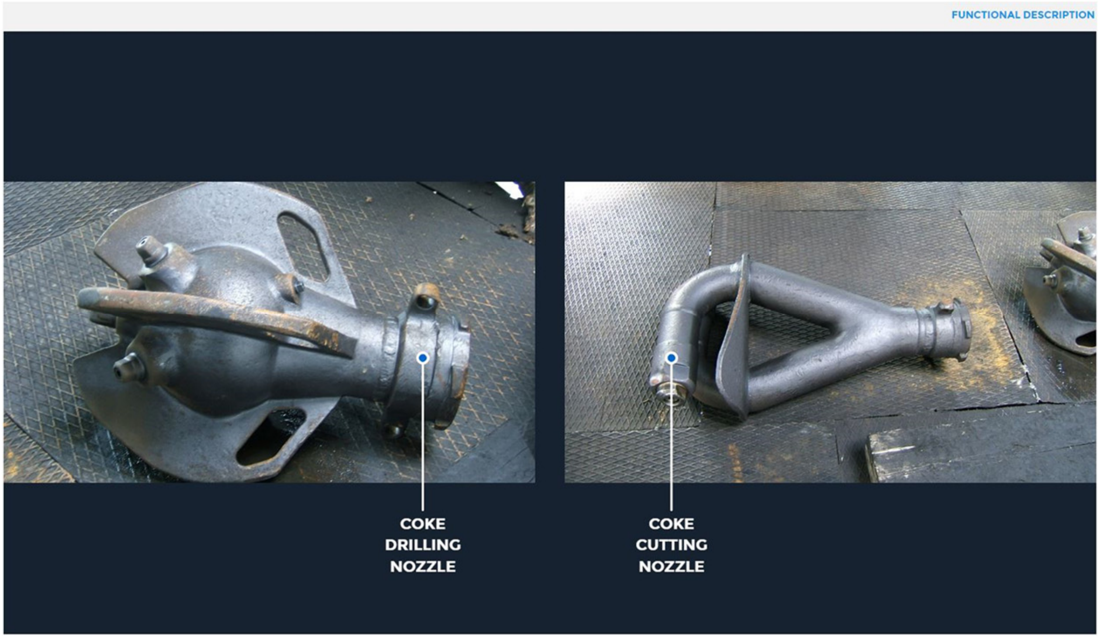


Functional Description

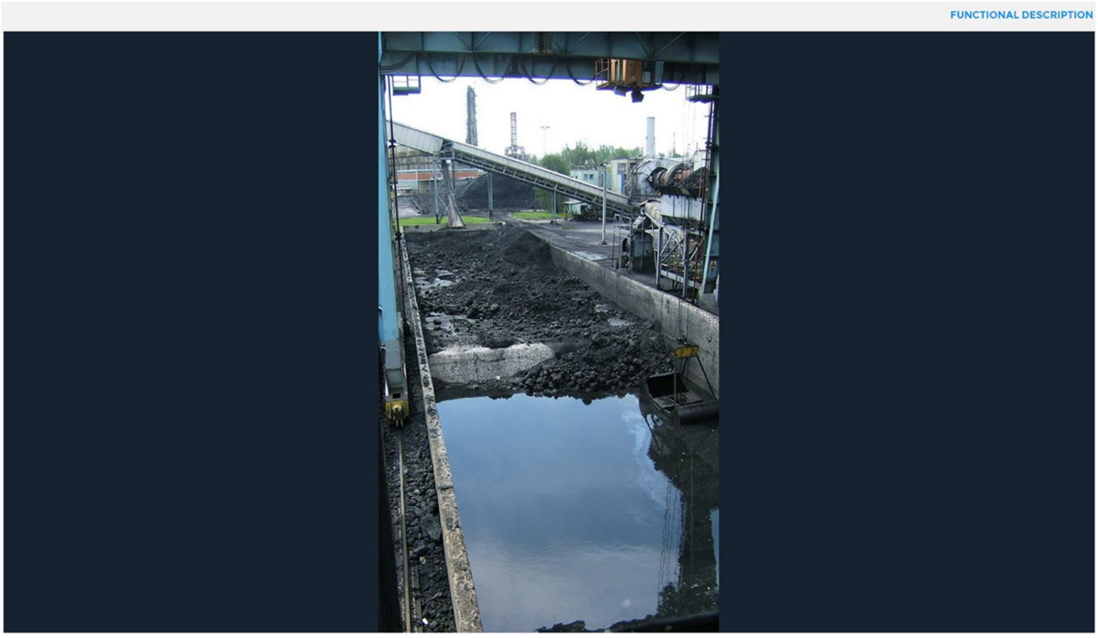
The plant we are studying is old and the Coke Drum top and bottom heads are still manually removed for coke cutting.

Modern and revamped DCUs have Coke Drums that are fitted with remotely operated slide valves at the top and bottom - this significantly increases safety when opening up Coke Drums, which can contain pockets of trapped steam or hydrocarbons that are suddenly released when the drum is opened.

This can be particularly problematic when shot coke is produced.



Coke is cut from the Coke Drum using drilling and cutting nozzles, powered by water at very high pressure.



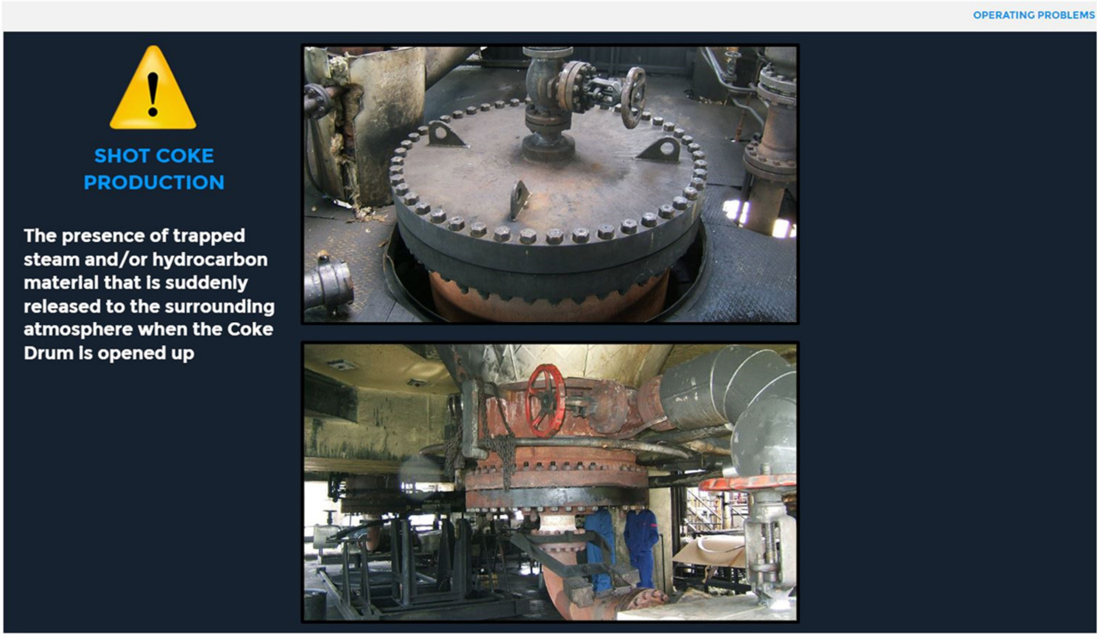
Coke, cut from the Coke Drum drops into a Cool Pit, where water is recovered and recycled for cutting.

Further processing of green coke by calcining in a rotary kiln at 1,300ºC (2,375ºF) removes residual volatile hydrocarbons from the coke.

The calcined coke can be further processed in an anode baking oven in order to produce anode coke of the desired shape and physical properties.

The anodes are mainly used in the aluminum, titanium and steel industries.

From the Cool Pit, green coke is transferred by conveyor to the Calciner.



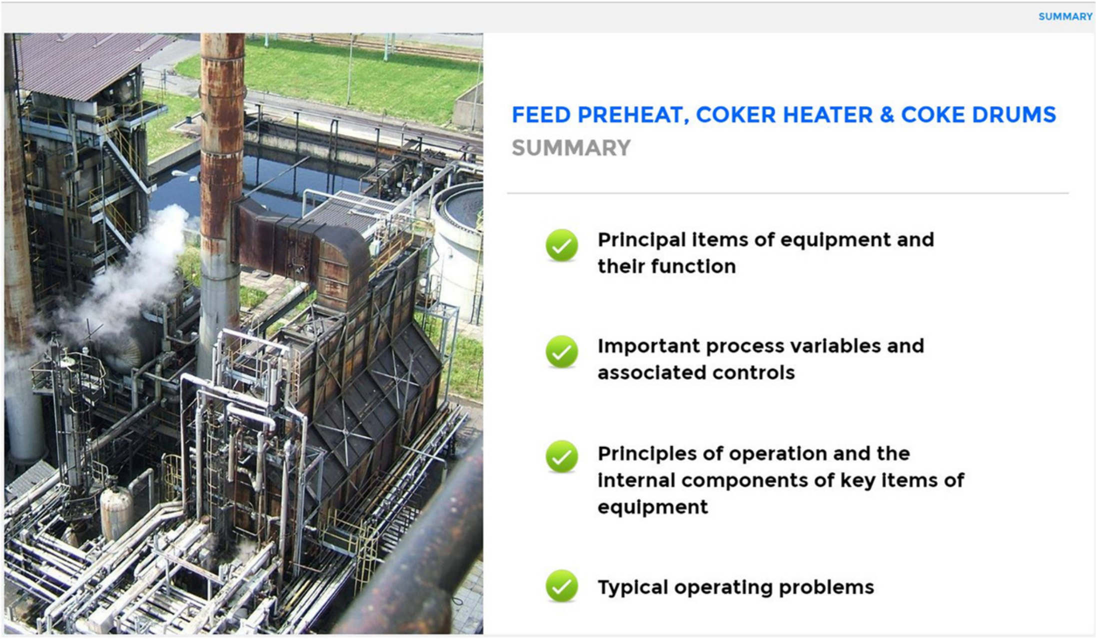
Operating Problems

There are two operating problems associated with coke cutting and handling.

The first, which often occurs in shot coke production, is the presence of trapped steam and/or hydrocarbon material that is suddenly released to the surrounding atmosphere when the Coke Drum is opened up - this has been mentioned in an earlier slide.

The second relates to air-borne coke dust, which is an environmental nuisance.

Depending on local environmental regulations, trucks and railcars may be covered with sheeting during transportation and conveyors to jetties or overland customers may be fully enclosed.



And this completes DCU Module 01 in which we've covered the Feed Preheat, Coker Heater & Coke Drum unit operations.

To summarize:

Feed preheating recovers heat from recycled hot coking vapors, Heavy Naphtha and Heavy Gas Oil, conserving fuel consumption in the Coker Heater.

The Coker Heater raises the temperature of the vacuum residue feed sufficient to initiate thermal cracking.

The Coke Drums operate in cycles, one filling with coke, while the other is steam purged, water cooled, opened up and emptied of coke.

For the Feed Preheat, Coker Heater and Coke Drum unit operations, you should now be familiar with:

- Principal items of equipment and their function
- Important process variables and associated controls
- Principles of operation and the internal components of key items of equipment
- Typical operating problems

Your task now is to take the DCU Module 01 Quiz to ensure you have fully understood the material.

If you find the questions challenging, you should consider repeating this module before moving on to the next one.

Good luck!

You can now close this module.