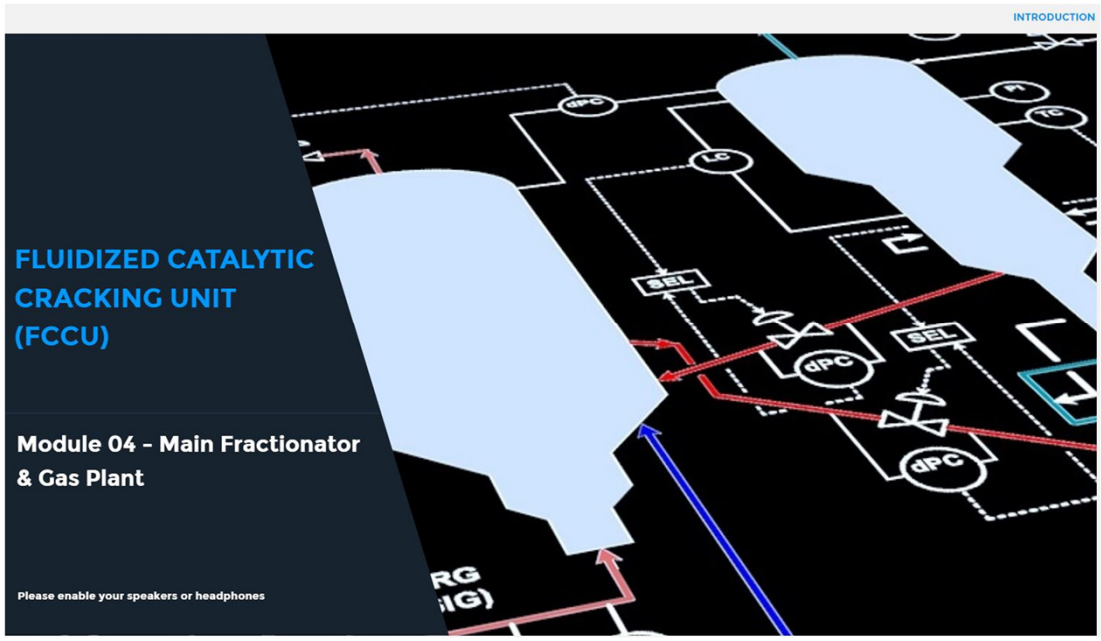
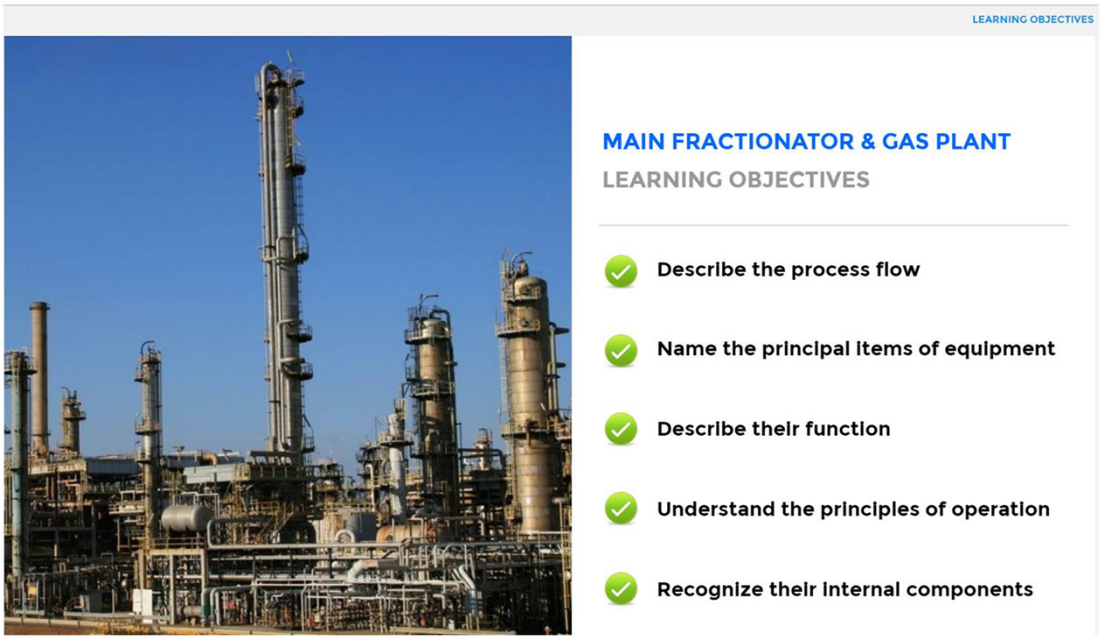
BU MEASUREMENT & ANALYTICS

Refinery Process Units

Fluidized Catalytic Cracking Unit (FCCU) – Module 4: Main Fractionator & Gas Plant



Welcome to the Fluidized Catalytic Cracking Unit Module 04, which covers the Main Fractionator & Gas Plant.

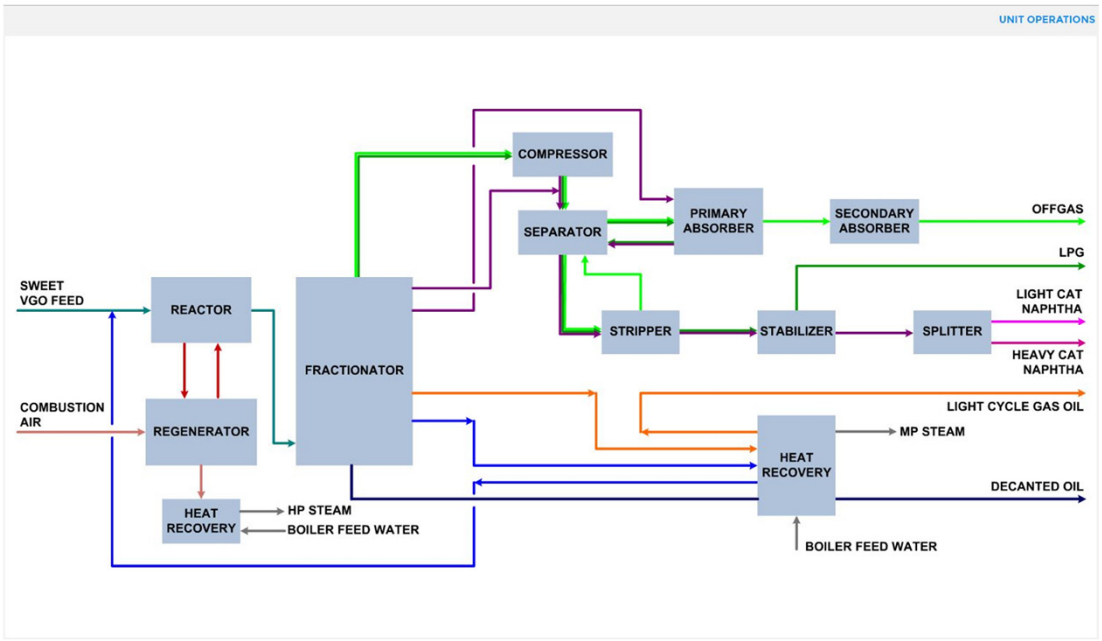


For the Main Fractionator & Gas Plant unit operations, upon completion of this module, you should be able to:

- 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



The Main Fractionator separates the Reactor effluent into overheads, side & bottoms products:

The bottoms product - Decanted Oil, passes either to a downstream Delayed Coking Unit or to the fuel oil blend pool

The lower side product - HCGO, is recycled to the Reactor and processed to extinction

The mid side product - LCGO, is hydrotreated in the DHTU before passing to the diesel blend pool or passed to the fuel oil pool as a viscosity cutter

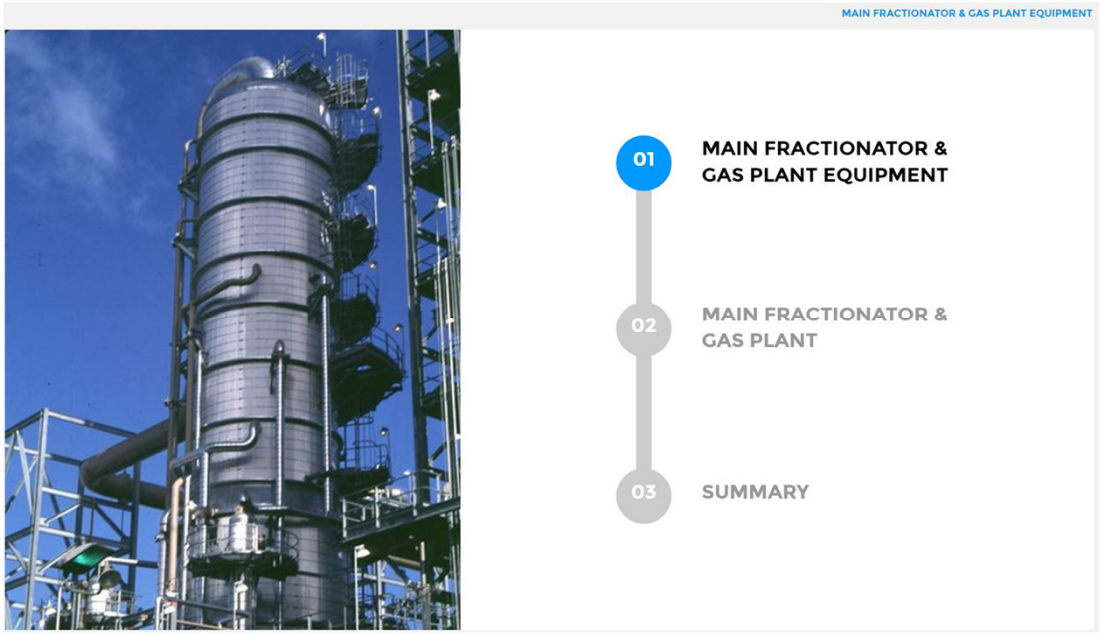
The upper side product - HCN, is purified in the Gas Plant, then Merox treated and passed to the gasoline blend pool

The overheads product - a mix of gas, LPG and LCN, is also purified in the Gas Plant:

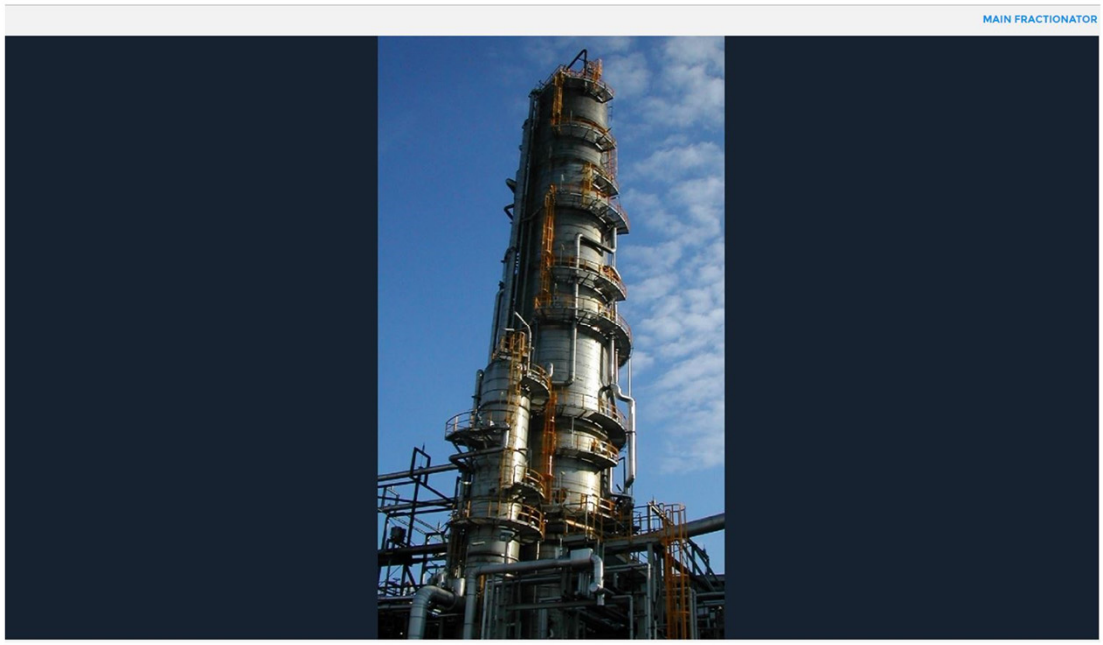
Gas is amine treated and passed to refinery fuel gas

Unsaturated LPG is Merox treated and split with C_3s passing to LPG blending and C_4s passing as Alkylation Unit feed

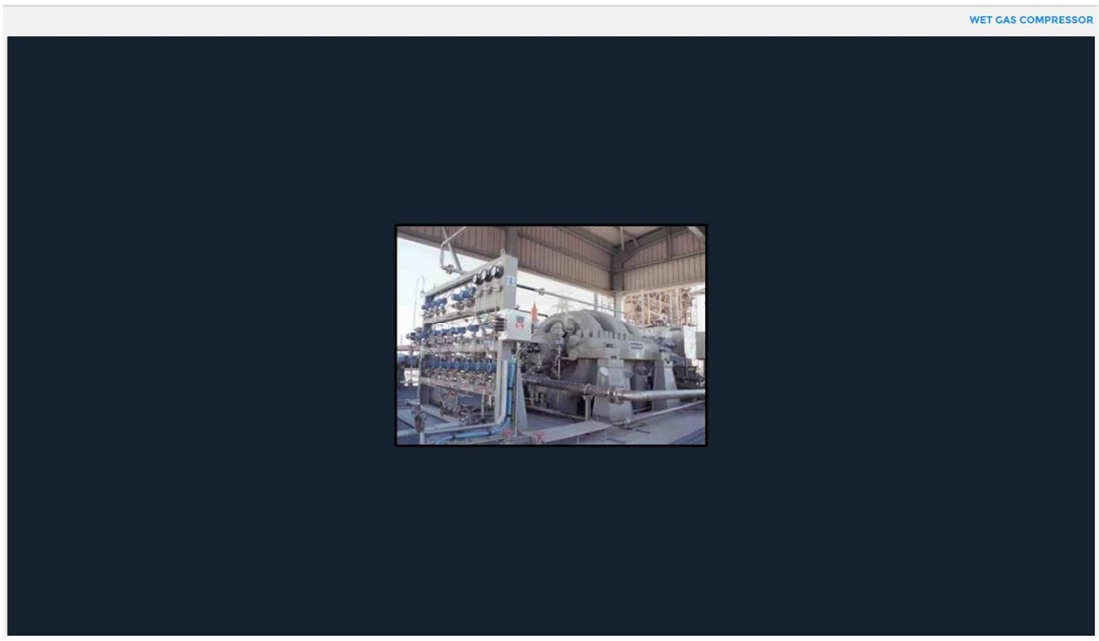
LCN is Merox treated and either blended into gasoline or sold as chemical naphtha depending on its benzene content



Let’s take a look at the Main Fractionator & Gas Plant equipment.

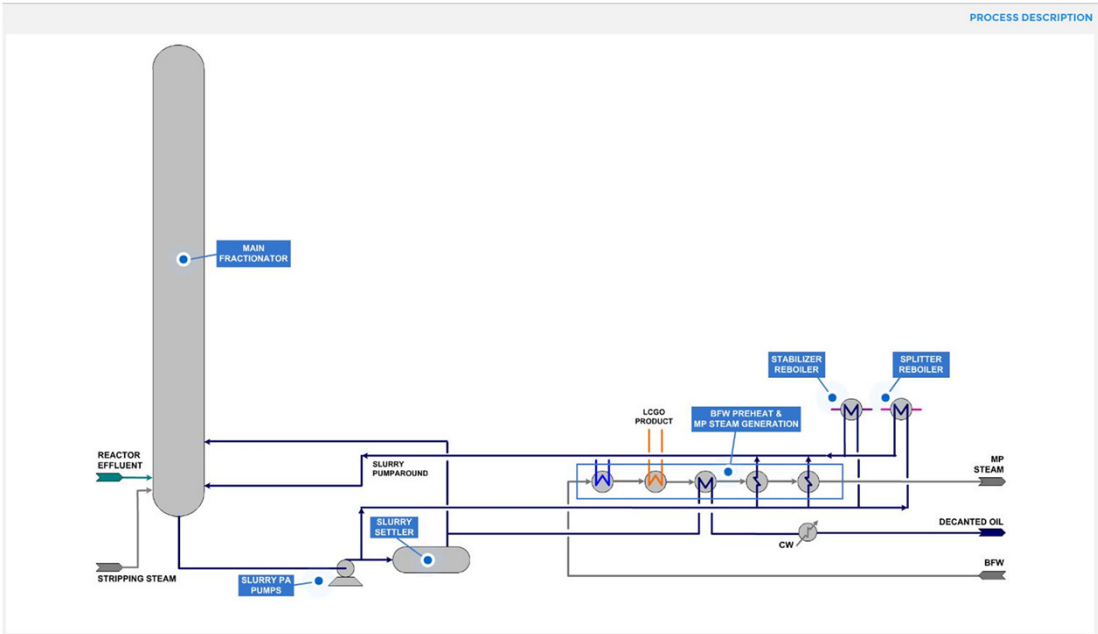


The Main Fractionator is a large tower with two side strippers.



The Wet Gas Compressor pictured here is a large centrifugal machine that compresses the offgas in two stages that are mounted on the same shaft and driven by a steam turbine.

Moving on, let's make a start on the Main Fractionator & Gas Plant.



Process Description

The Main Fractionator feed is reactor effluent vapor, which passes up through the tower.

Slurry (a mix of heavy residue and catalyst fines) is steam stripped to recover lighter hydrocarbons before being withdrawn from the base and pumped to a Slurry Settler (also sometimes called a Clarifier).

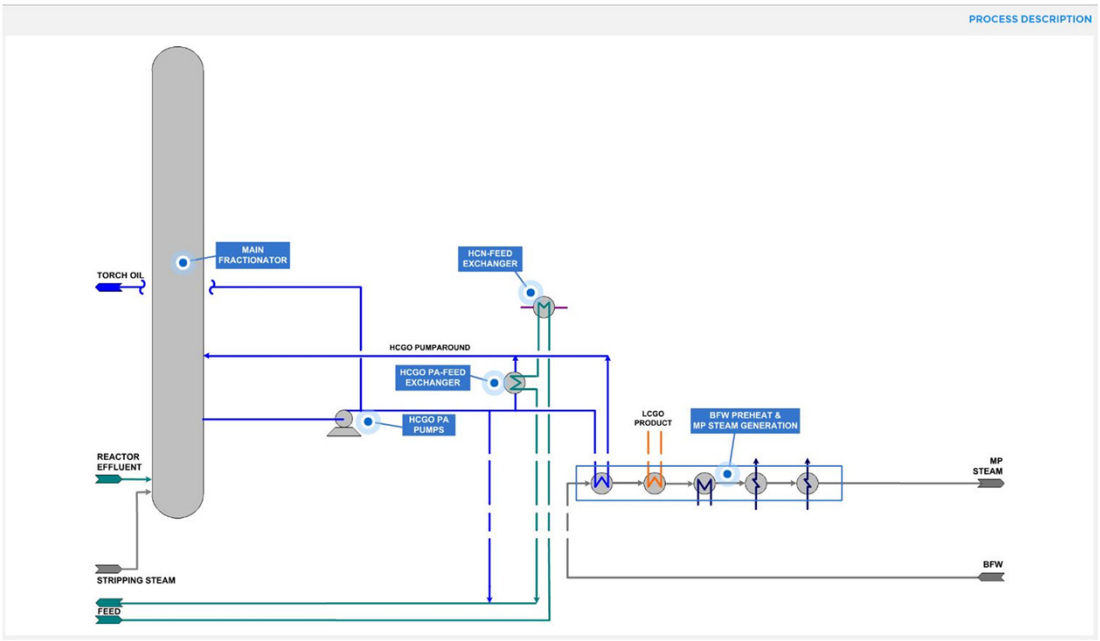
A portion of the slurry is used as a pumparound, reboiling the Splitter and Stabilizer Towers in the Gas Plant, preheating boiler feed water and generating medium pressure steam before returning to the base of the Main Fractionator as quench.

In the Settler, catalyst fines disengage under gravity, accumulate and are periodically withdrawn.

Decanted oil is withdrawn from the top of the Settler:

A portion is returned to the Main Fractionator to keep the tower internals above the flash zone thoroughly wetted at all times

The balance is passed through a heat recovery system and is then water cooled before passing to a downstream Delayed Coking Unit as feed, or to the fuel oil blend pool

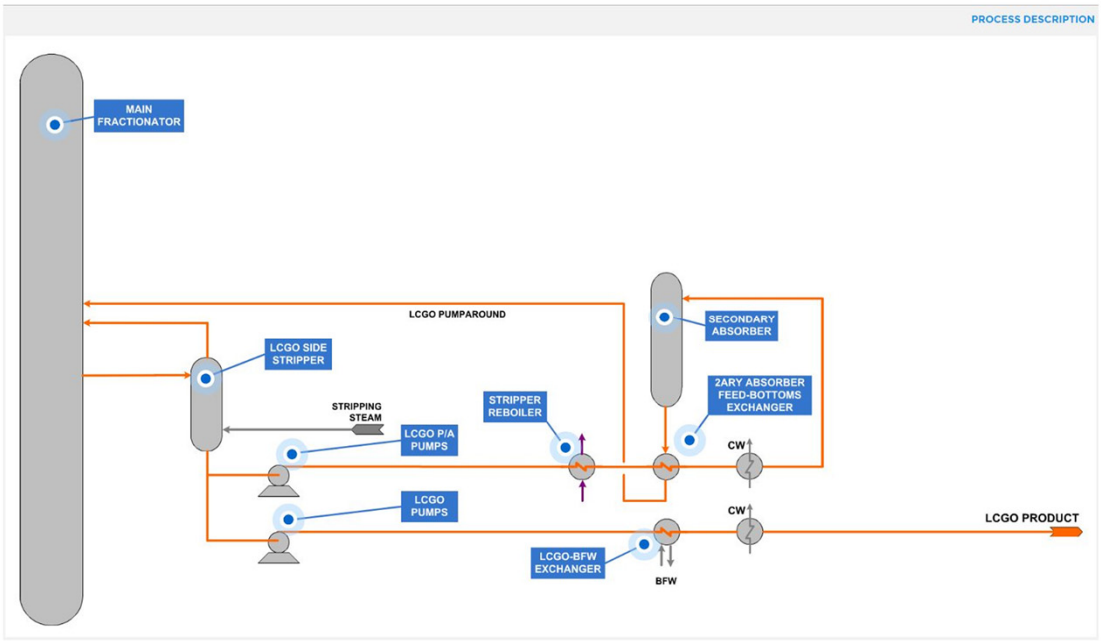


HCGO is withdrawn from the Main Fractionator as a lower side draw:

A portion of the HCGO is pumped around, preheating reactor feed and boiler feed water before returning to the tower

The balance is injected into the feed and recycled to the Reactor, where it is reprocessed to extinction

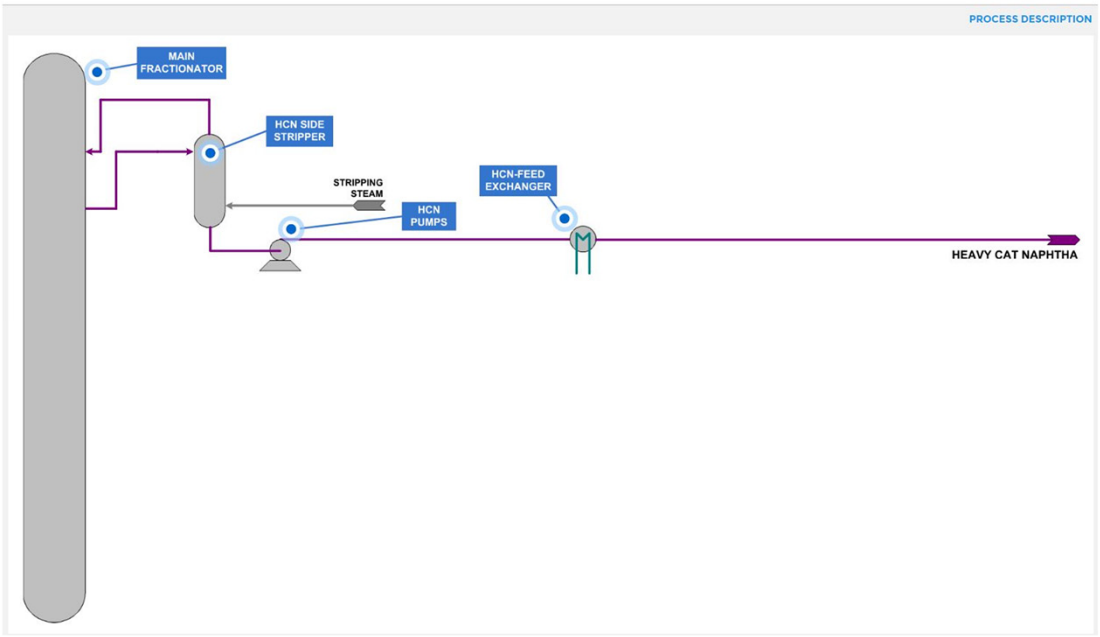
At startups, shutdowns and during process upsets when feed bypasses the Reactor, HCGO is burned as torch oil in the Regenerator, to maintain the catalyst at elevated temperature.



LCGO is withdrawn from the Main Fractionator as a mid side draw and passed to a Side Stripper where it is steam stripped to recover light hydrocarbons that are returned to the tower. From the bottom of the Side Stripper:

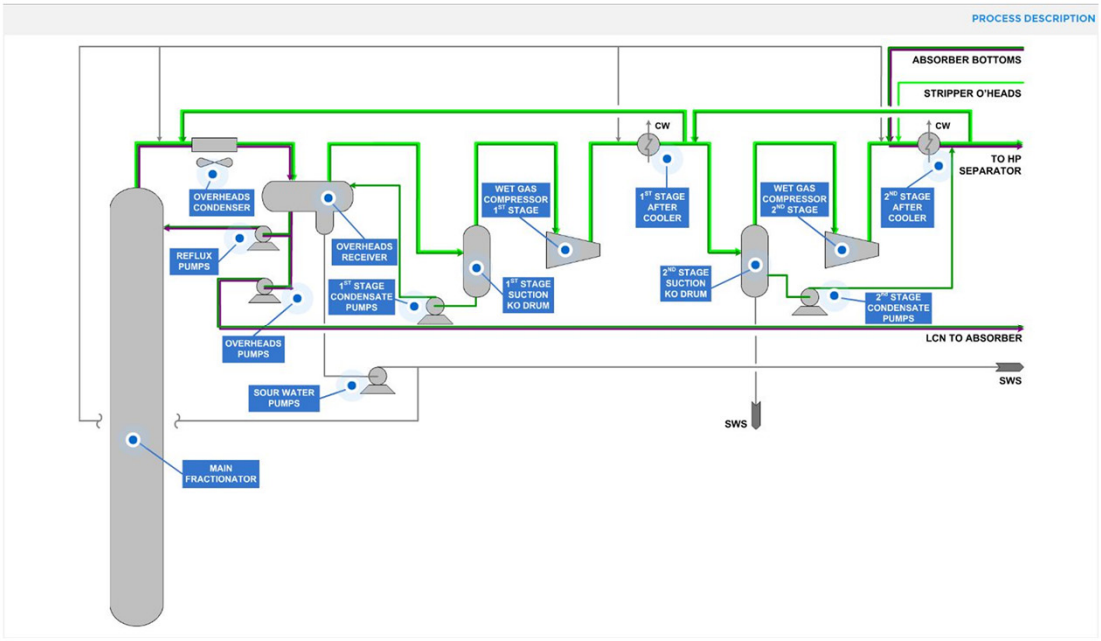
A portion of the LCGO is pumped around the Gas Plant, reboiling the Stripper and then counter-currently scrubbing offgas in the Secondary Absorber to recover entrained naphtha material before returning to the tower

The balance of the LCGO is cooled against boiler feed water and then against cooling water before passing to the DHTU for ultra low hydrodesulfurization and olefin saturation before being blended into diesel or alternatively it is passed to the fuel oil pool as a viscosity cutter



HCN is withdrawn from the Main Fractionator as an upper side draw and passed to a Side Stripper where it is steam stripped to recover light hydrocarbons that are returned to the tower.

From the bottom of the Side Stripper the HCN preheats the Reactor feed before passing to the Primary Absorber in the Gas Plant, where it is used to scrub offgas and recover LPG.



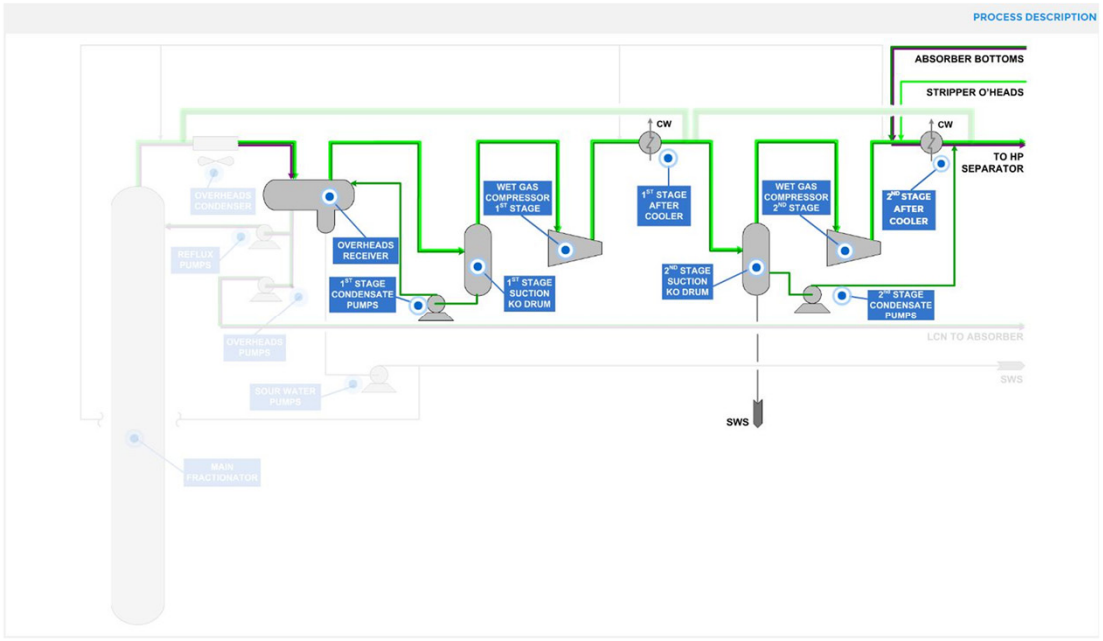
The purpose of the Gas Plant is to separate the Main Fractionator overheads and upper side draw into offgas, LPG and Light and Heavy Cat Naphtha.

The Main Fractionator overheads stream is cooled and partially condensed, collecting in the Overheads Receiver, where it forms three phases:

Offgas, which passes to the 1st Stage Suction KO Drum of the Wet Gas Compressor

Light Cat Naphtha (LCN), part of which is pumped back to the tower as reflux with the balance pumped forward to the Primary Absorber

Sour water, part of which is used to wash salts off the Overhead Condenser, 1st and 2nd Stage After Cooler tubes, preventing fouling and corrosion with the balance passing to the Sour Water Stripper



The purpose of the Wet Gas Compressor is to raise the pressure of the overhead gas high enough to liquefy LPG, enabling it to be separated from the offgas.

The 1st and 2nd Stage Suction KO Drums protect the Wet Gas Compressor against mechanical damage by entrained liquid.

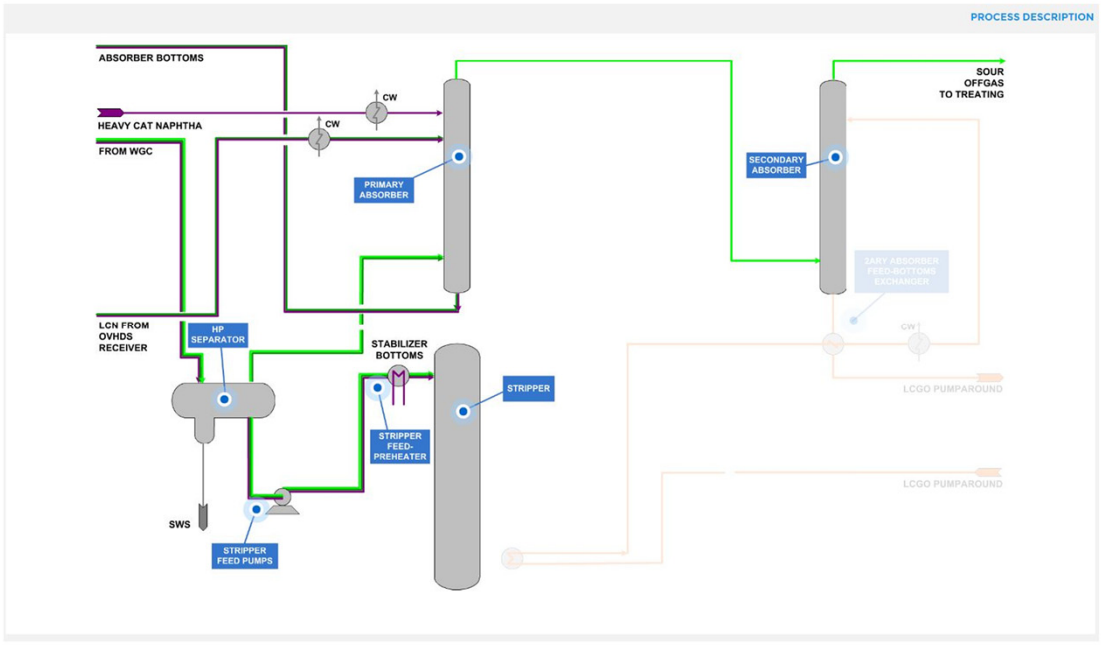
Liquid recovered in the 1st Stage is pumped back to the Overheads Receiver.

Liquid recovered in the 2nd Stage is pumped forward to the High Pressure Separator.

Absorber bottoms and Stripper overheads join the compressed gas as it passes to the 2nd Stage After Cooler.

The Wet Gas Compressor increases the pressure of the overhead gas in two stages. Each stage is cooled after compression.

The two Wet Gas Compressor stages are mounted on a common shaft and share a steam turbine driver.



A mixture of compressed gas, recovered LPG and naphtha enters the High Pressure Separator, disengaging to form three phases:

Offgas, containing potential LPG material, which is passed to the Primary Absorber

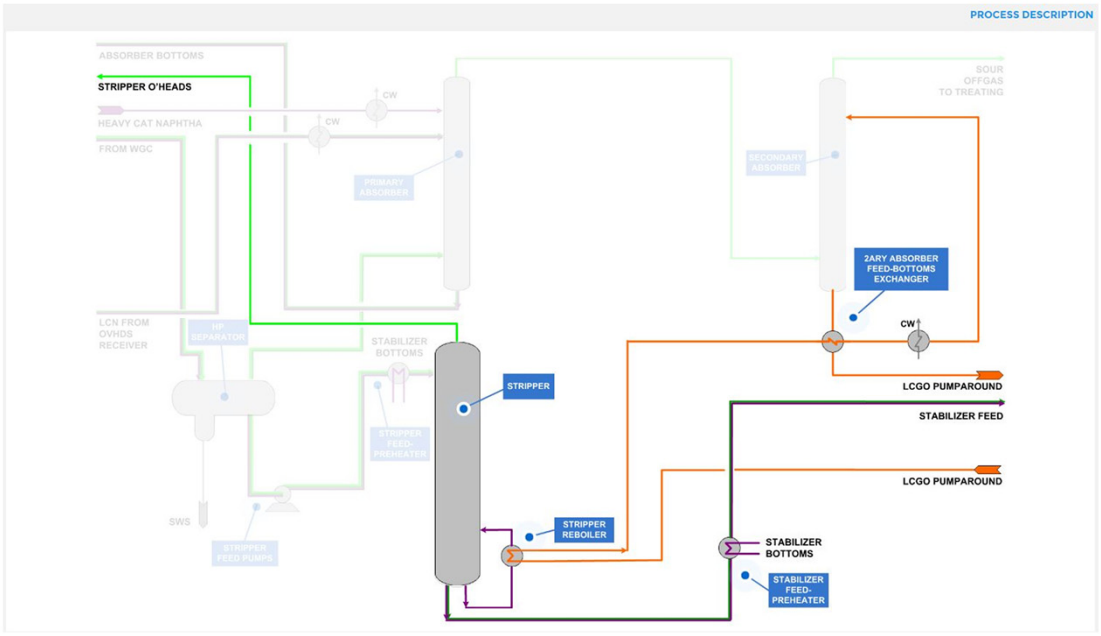
Hydrocarbon liquid, containing naphtha, LPG and small quantities of light gases, which is pumped to the Stripper

Sour water, containing dissolved salts from water washing, which is passed to the Sour Water Stripper

In the Primary Absorber, upflowing offgas is counter-currently scrubbed - first with LCN and then HCN.

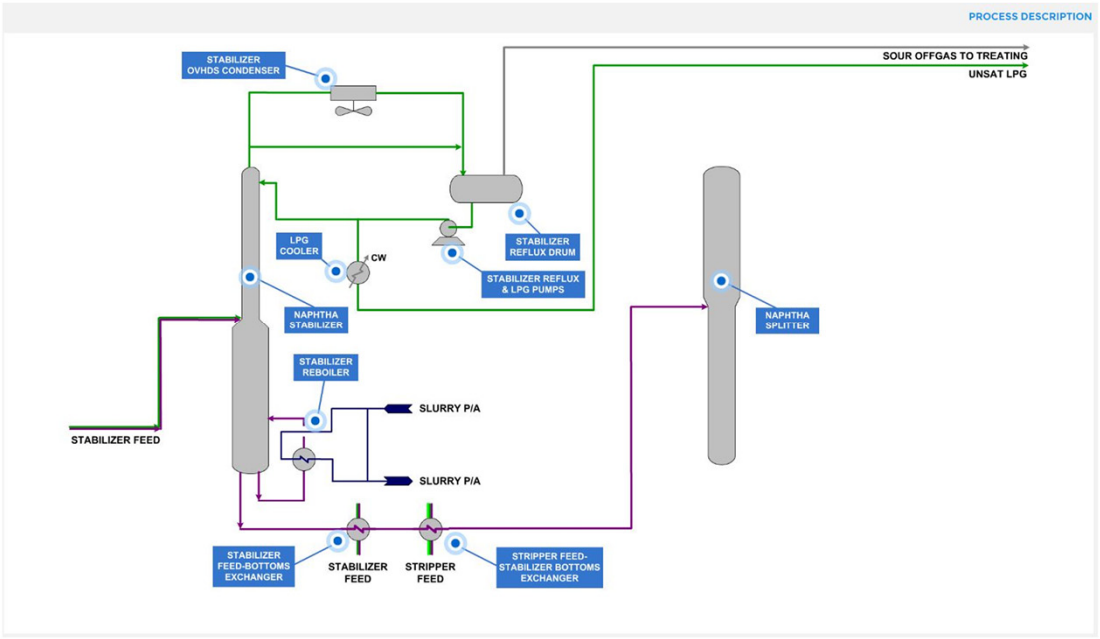
The LPG transfers to the naphtha, which is withdrawn from the bottom of the Primary Absorber and recycled to the HP Separator via the Wet Gas Compressor 2nd Stage After Cooler.

Scrubbed offgas, containing some entrained naphtha passes to the Secondary Absorber where it is counter-currently scrubbed with cooled LCGO pumparound to recover the naphtha.



The Stripper, which is reboiled by LCGO pumparound, removes light gases such as methane, ethane and ethylene, which are withdrawn as an overheads stream and returned to the HP Separator via the Wet Gas Compressor 2nd Stage After Cooler.

The Stripper bottoms, comprising LPG and full range naphtha, is preheated against Stabilizer bottoms before passing as feed to the downstream Stabilizer.

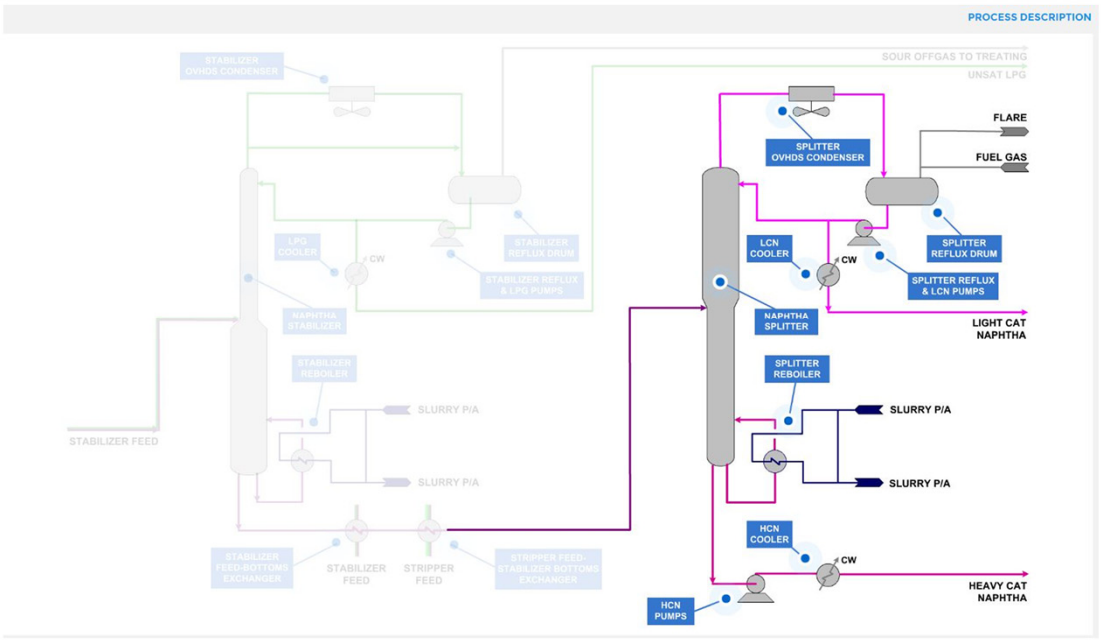


The Stabilizer feed enters the Stabilizer tower, where it is fractionated into:

An overheads stream of LPG, which is condensed and collected in the Stabilizer Reflux Drum - a portion is pumped back to the tower as reflux and the balance passed for treating and blending

A bottoms stream of full range naphtha, which preheats the Stabilizer and Stripper feeds before passing as feed to the Splitter

The Stabilizer is reboiled by the Slurry Pumparound.

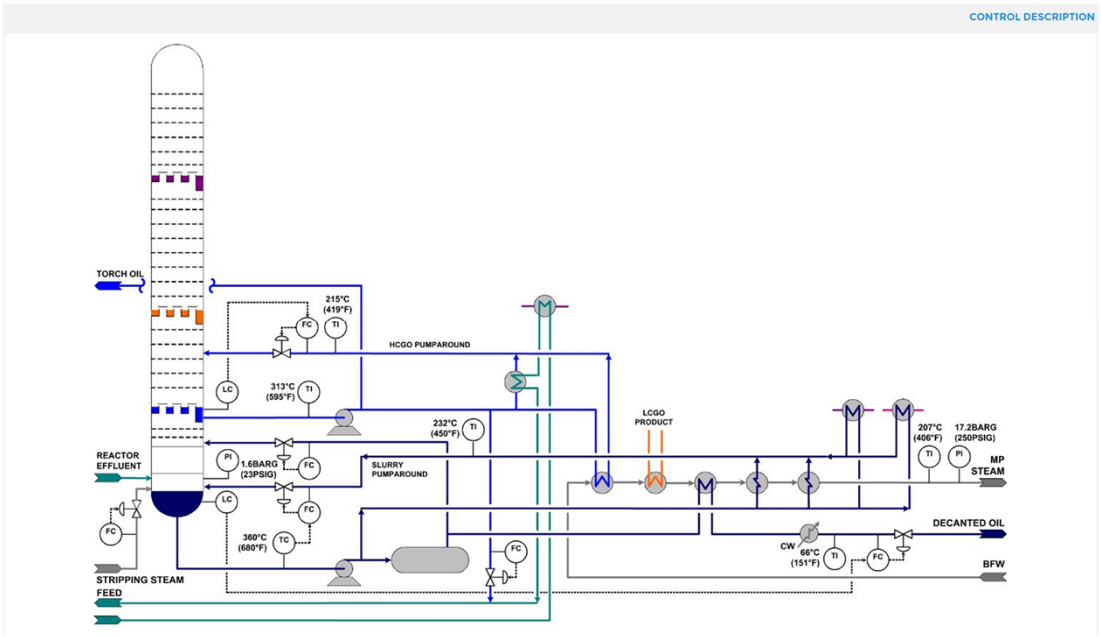


The Splitter feed enters the Splitter tower, where it is fractionated into:

An overheads stream of LCN, which is condensed and collected in the Splitter Reflux Drum - a portion is pumped back to the tower as reflux, with the balance cooled and passed for treating and blending

A bottoms stream of HCN, which is also cooled and passed for treating and blending

The Splitter is reboiled by the Slurry Pumparound.



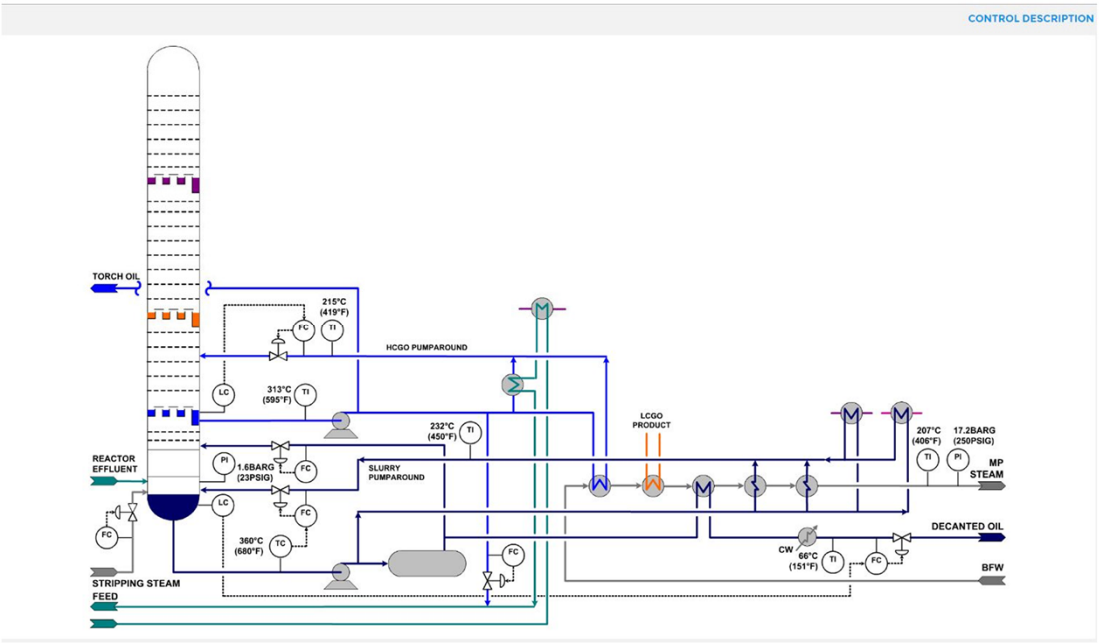
Control Description

Decanted Oil:

The bottoms level is maintained by a master level controller that sends a signal to a slave flow controller in the decanted oil product rundown line.

The Main Fractionator bottoms stripping steam is flow controlled. On many plants like this, you may see the stripping steam flow controlled in ratio to the bottoms rundown flow.

A portion of the decanted oil is recycled to the tower on flow control to ensure the tower internals above the flash zone are kept thoroughly wetted at all times.



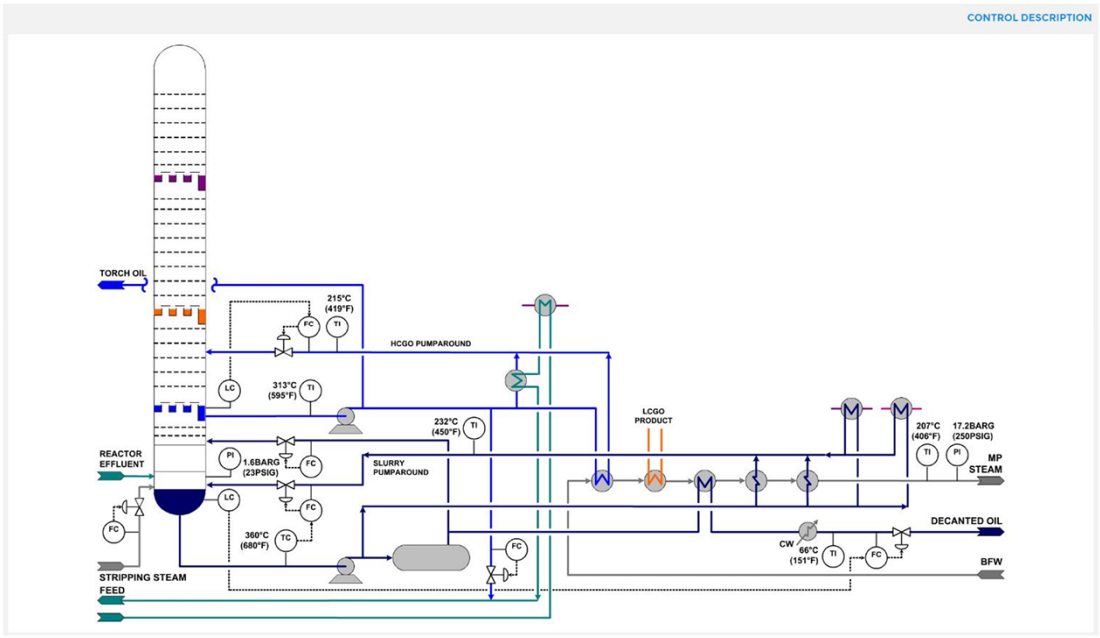
Slurry Pumparound:

The Slurry Pumparound gives up heat by reboiling the Splitter and Stabilizer towers in the Gas Plant - temperature controls are on the towers.

Further heat is given up by preheating BFW and generating medium pressure steam before the Slurry returns to the bottom of the Main Fractionator.

The tower bottoms draw temperature is maintained at 360ºC (680ºF) by a temperature-to-flow cascade control arrangement.

Control of the bottoms temperature is critical to avoiding coke formation during process upsets, particularly on FCCs running feeds with resid inclusion.



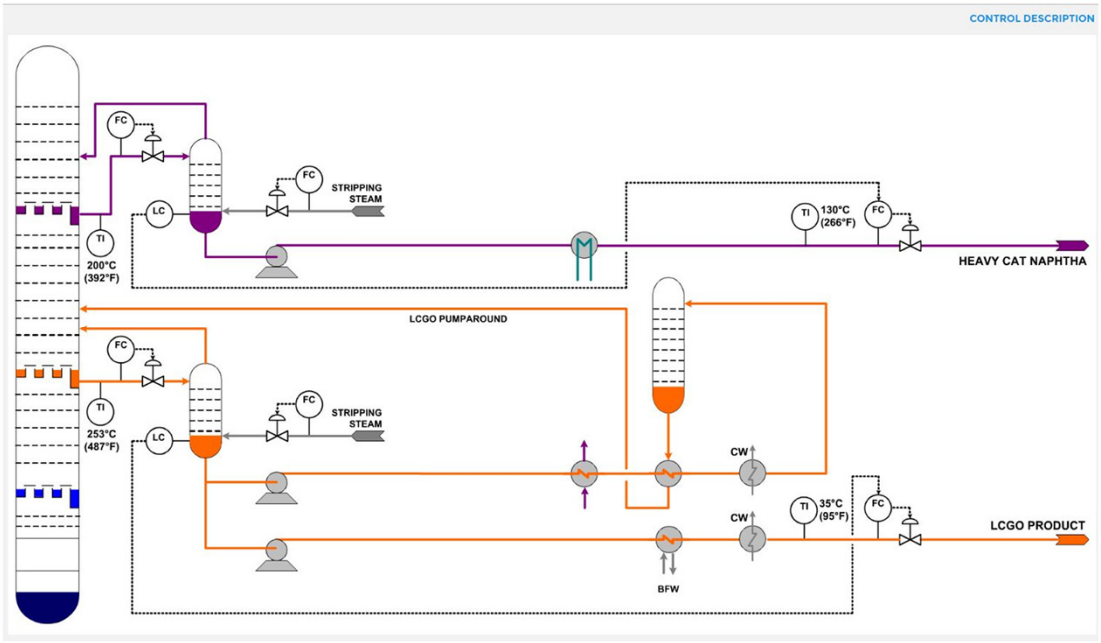
HCGO:

HCGO is withdrawn from the tower at 313ºC (595ºF).

The level in the draw chimney tray is maintained by a master level controller that sends a signal to a slave flow controller in the HCGO pumparound.

A portion of the HCGO is pumped around, giving up heat to BFW and Reactor feed before returning to the tower at 215ºC (419ºF).

The balance of the HCGO is injected into the Reactor feed on flow control.



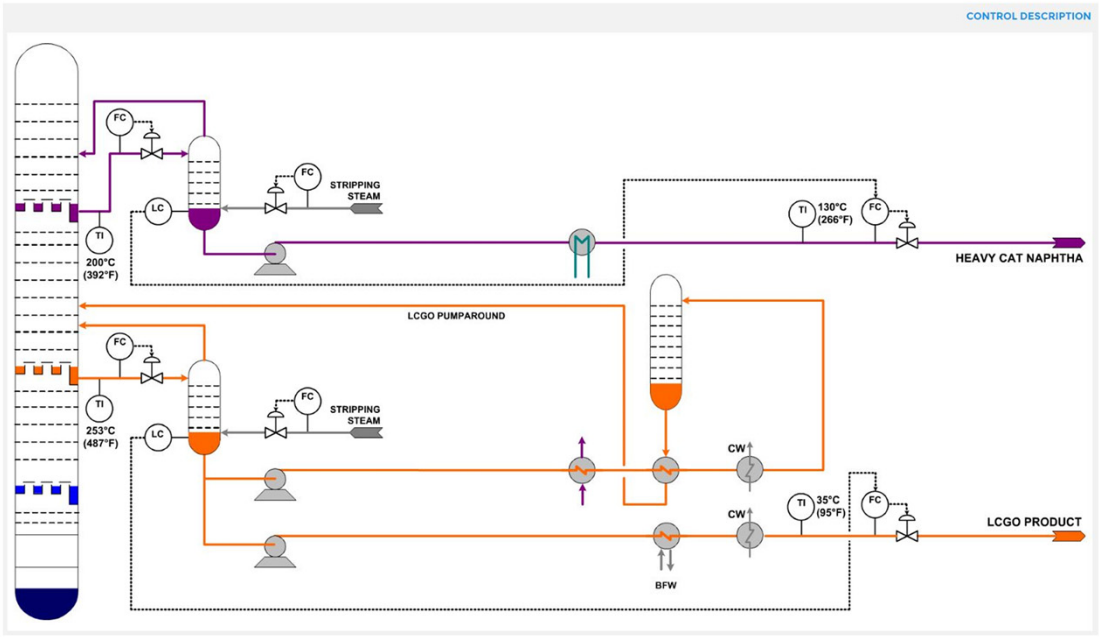
LCGO:

LCGO, at 253ºC (487ºF), is withdrawn from the tower on flow control.

A portion of the LCGO is pumped around, reboiling the Stripper and scrubbing offgas in the Secondary Absorber in the Gas Plant before returning to the tower. Controls are detailed in the Gas Plant.

The level in the LCGO Side Stripper is maintained by a master level controller that sends a signal to a slave flow controller in the LCGO product rundown line.

Stripping steam to the Side Stripper is flow controlled. You may often see this flow ratioed to the flow of LCGO product.

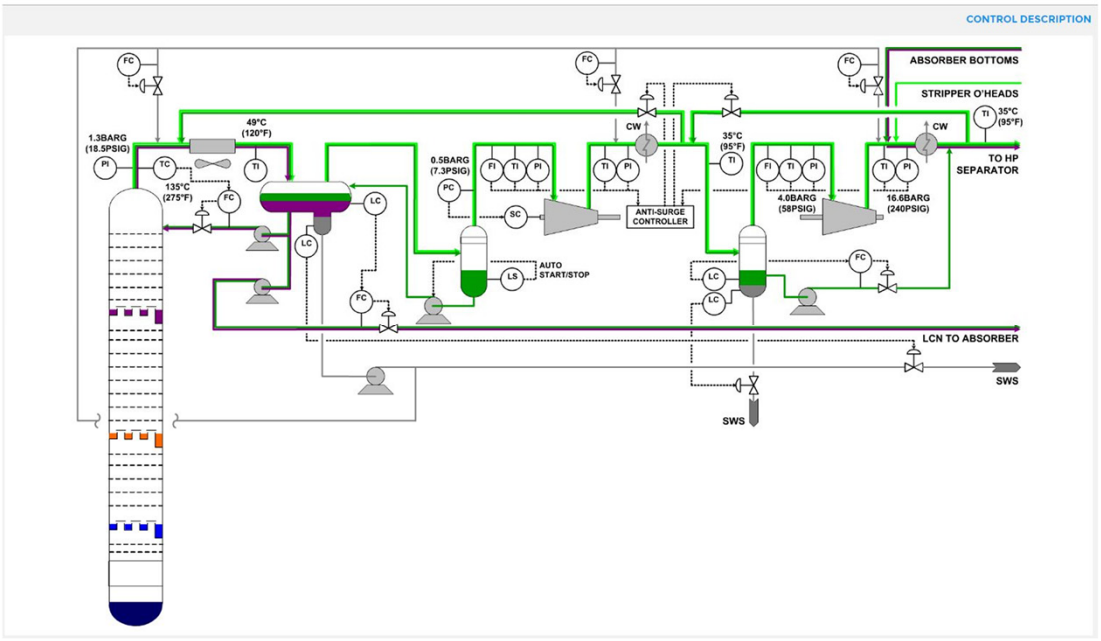


HCN:

HCN, at 200ºC (392ºF), is withdrawn from the tower on flow control.

The level in the HCN Side Stripper is maintained by a master level controller that sends a signal to a slave flow controller in the HCN passing to the Gas Plant Primary Absorber.

Stripping steam to the Side Stripper is flow controlled. Again, you may often see this flow ratioed to the flow of HCN product.



Overheads:

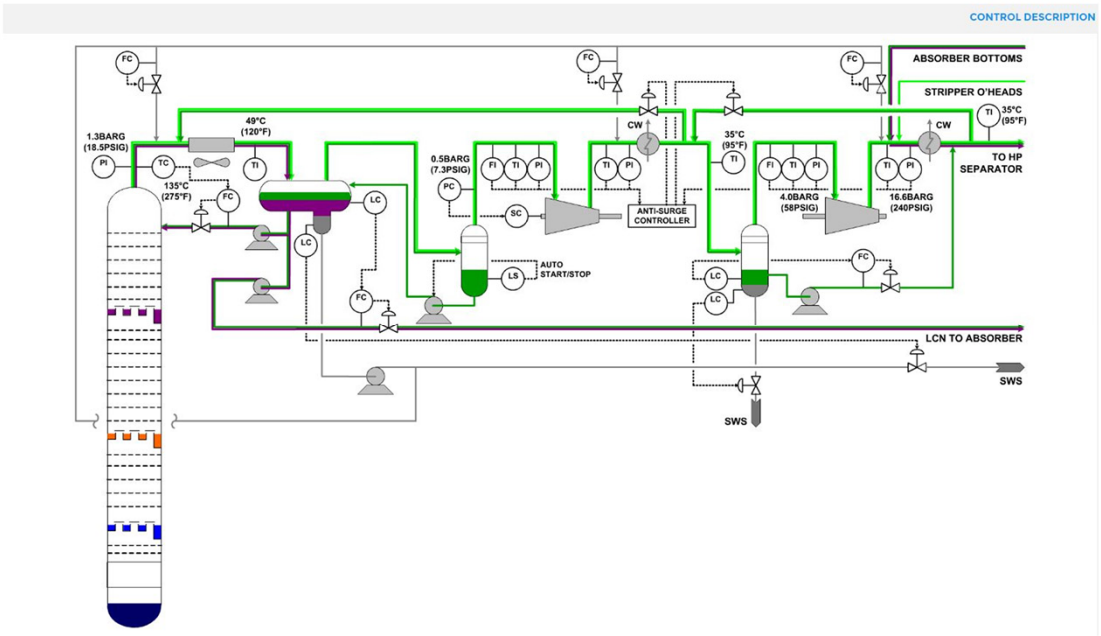
The Main Fractionator top temperature is maintained at 135ºC (275ºF) by a temperature-to-flow cascade control arrangement that returns cold reflux to the tower.

To avoid corrosion, it is critical that this temperature is kept above the dew point.

The hydrocarbon level in the Overheads Receiver is maintained by a master level controller that sends a signal to a slave flow controller in the LCN passing to the Primary Absorber.

Sour water, from the Overheads Receiver boot is passed on flow control to the inlet of the Overheads Condenser and WGC 1st and 2nd Stage After Coolers to wash away salts, preventing fouling and corrosion.

The water level in the Overheads Receiver boot is maintained by an interface level controller that adjusts the sour water rundown to the Sour Water Stripper.



Wet Gas Compressor:

The level in the WGC 1st Stage KO Drum is maintained by a level switch that autostarts and autostops a pump that returns accumulated liquid to the Overheads Receiver.

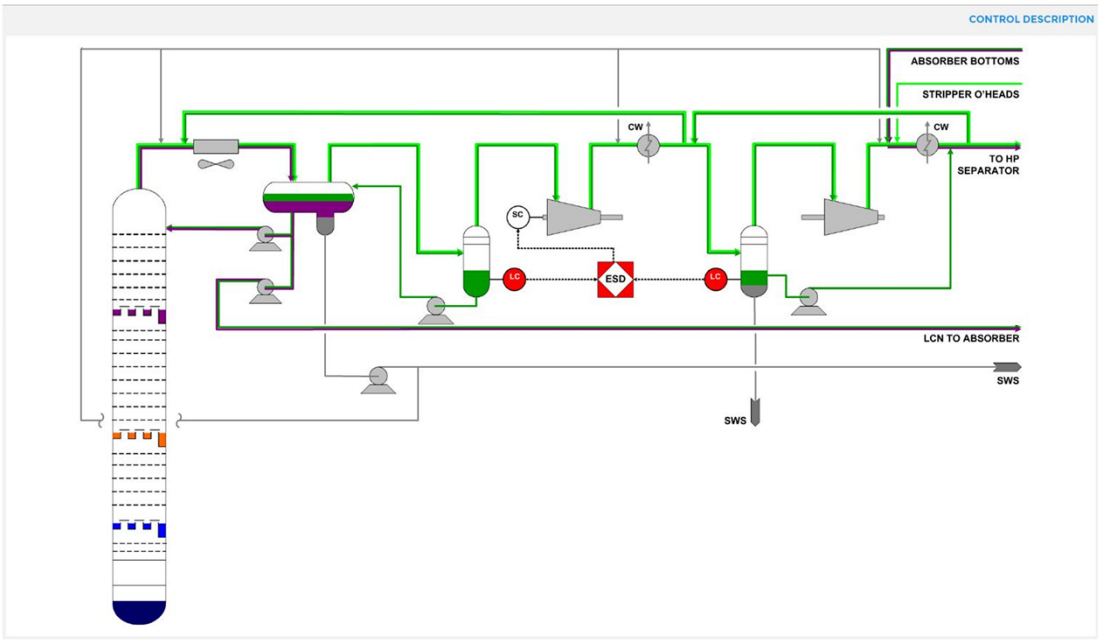
The hydrocarbon level in the WGC 2nd Stage KO Drum is maintained by a level-to-flow cascade control arrangement that passes accumulated hydrocarbons forward to the HP Separator.

The water level in the WGC 2nd Stage KO Drum is maintained by an interface level controller that passes accumulated water to the Sour Water Stripper.

The WGC increases the pressure of the overheads gas from 0.5barg (7.3psig) to 4.0barg (58psig) and then to 16.6barg (240psig) in two stages.

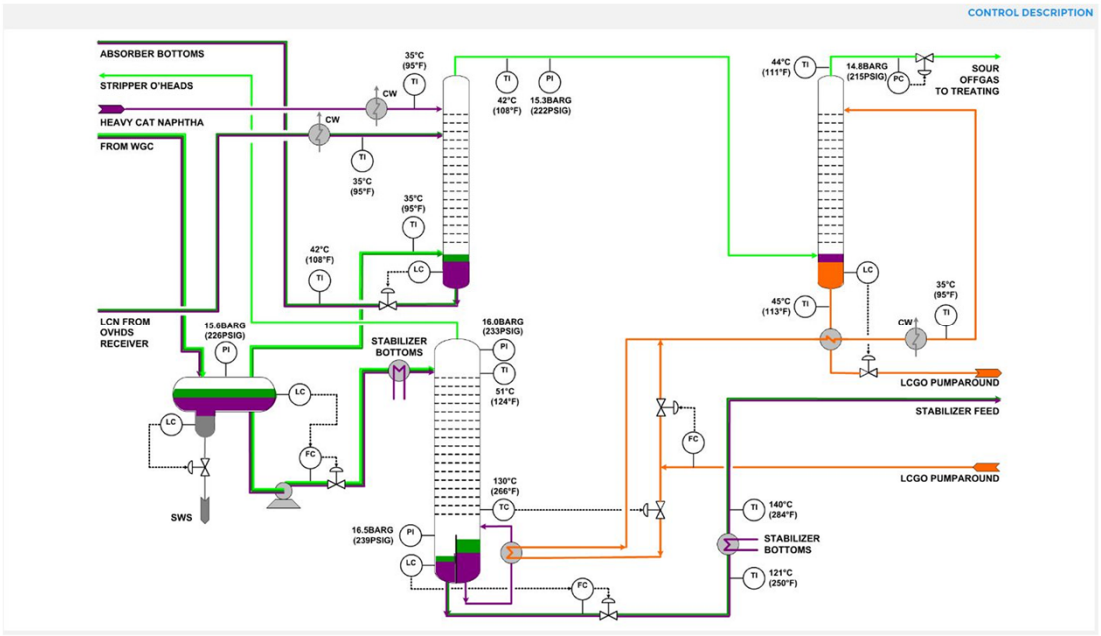
A 1st Stage suction pressure controller adjusts the rotational speed of the compressor.

An anti-surge controller adjusts spillback valves in both stages to keep the machine away from unstable conditions.



The Wet Gas Compressor is protected against mechanical damage due to the presence of liquid in the suction gas by an ESD system that trips the machine if there is a high level in either of the 1st or 2nd Stage KO Drums.

The compressor has additional trips that protect the machine against damage due to insufficient lubrication, loss of shaft seal fluid, mechanical instability and overspeed.



Absorbers:

The Absorbers recover LPG from the offgas before the offgas is treated and passed to the refinery fuel gas system.

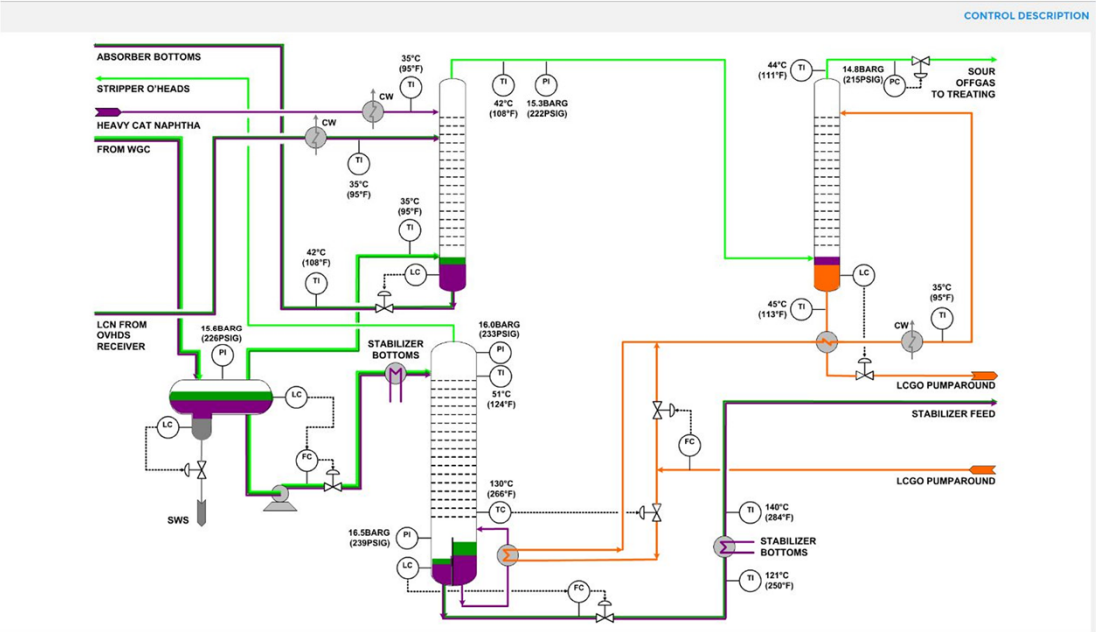
In the Primary Absorber, LPG is scrubbed out of upflowing gas by downflowing LCN and HCN.

The LPG, LCN and HCN accumulate in the bottom of the Absorber and are returned to the inlet of the WGC 2nd Stage After Cooler on level control.

In the Secondary Absorber, entrained LCN and/or HCN is scrubbed out of upflowing gas by downflowing LCGO pumparound and returned to the Main Fractionator on bottoms level control.

A pressure controller maintains the top of the Absorber at 14.8barg (215psig).

During the absorption unit operation, a small amount of heat is evolved - to maximize absorption efficiency, increases in gas and liquid inlet temperatures should be avoided.



HP Separator & Stripper:

The HP Separator disengages gas, LPG, naphtha and water. The Stripper recovers light hydrocarbon gases such as methane, ethane and ethylene - there are limits on light ends in LPG product.

The hydrocarbon level in the HP Separator is maintained by a level-to-flow cascade control arrangement that adjusts the feed to the Stripper tower.

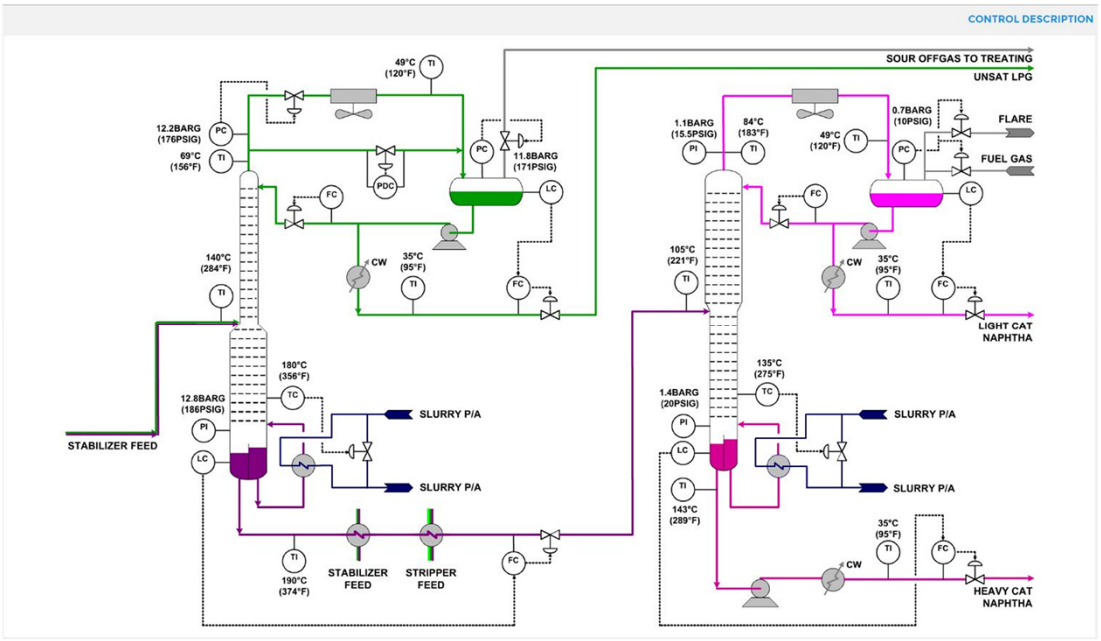
The Stripper feed is preheated by Stabilizer bottoms.

The water level in the HP Separator is maintained by an interface level controller that routes sour water to the Sour Water Stripper.

The Stripper bottom tray temperature is maintained at 130ºC (266ºF) by a temperature controller that adjusts the flow of LCGO pumparound to the Stripper Reboiler.

A flow controller ensures the Stripper temperature control doesn't starve the Secondary Absorber of LCGO pumparound.

The Stripper bottoms level is maintained by a level-to-flow cascade control arrangement - the Stripper bottoms stream is heated against Stabilizer bottoms and passed as feed to the downstream Stabilizer.



Stabilizer:

The Stabilizer separates LPG and full range naphtha.

The Stabilizer tray 3 temperature is maintained at 180ºC (356ºF) by adjustment of the Slurry Pumparound to the Reboiler.

The Stabilizer bottoms level is maintained by a level-to-flow cascade control arrangement - the Stabilizer bottoms stream preheats the Stripper and Stabilizer feed streams before passing as feed to the Splitter.

The Stabilizer overheads system has three forms of pressure control:

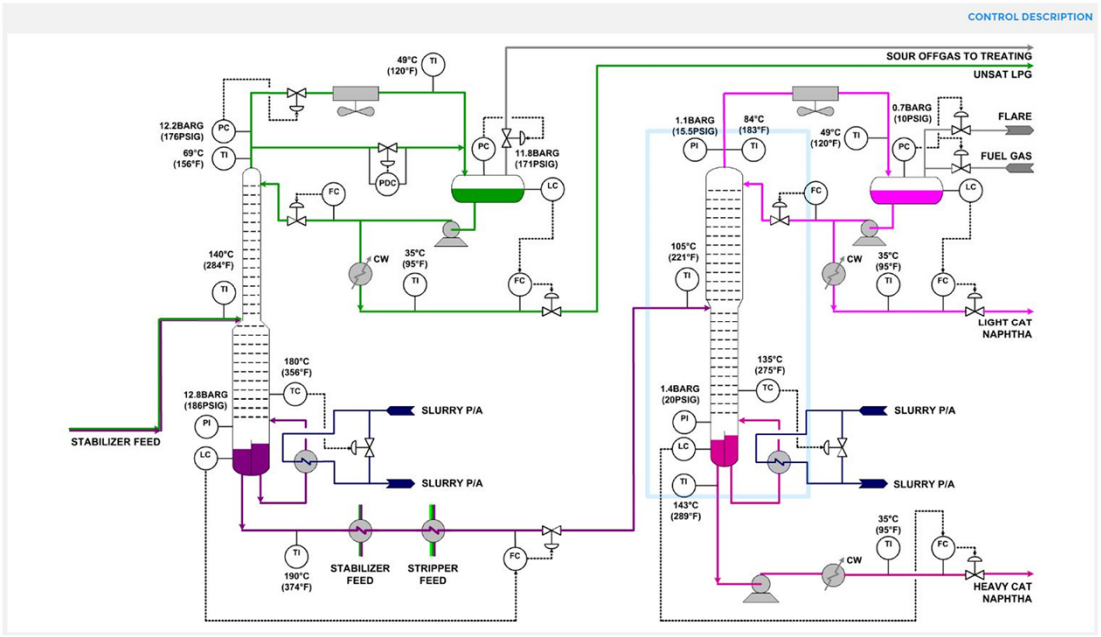
The overheads pressure is maintained at 12.2barg (176psig) by regulating the amount of LPG vapor that is cooled and condensed

A differential pressure controller ensures a portion of LPG vapor bypasses the Overheads Condenser so that the Reflux Drum pressure can be controlled

The Reflux Drum pressure is maintained at 11.8barg (171psig) by venting uncondensed LPG vapor to refinery fuel gas via a treater

The Reflux Drum level is maintained by a level-to-flow cascade control arrangement that passes cooled unsaturated LPG for treating and blending.

Reflux is returned to the top of the Stabilizer on flow control.



Splitter:

The Splitter separates full range naphtha into LCN and HCN.

The Splitter tray 3 temperature is maintained at 135ºC (275ºF) by adjustment of the Slurry Pumparound to the Reboiler.

The Splitter bottoms level is maintained by a level-to-flow cascade control arrangement - the Splitter bottoms stream (HCN) is water cooled before passing for treating and blending into gasoline.

The Reflux Drum pressure is maintained at 0.7barg (10psig) by a split range pressure controller that vents excess gas/vapor to flare on a rising pressure and imports fuel gas on a falling pressure.

The Reflux Drum level is maintained by a level-to-flow cascade control arrangement that passes cooled LCN for treating and blending.

Reflux is returned to the top of the Splitter on flow control.

Functional Description

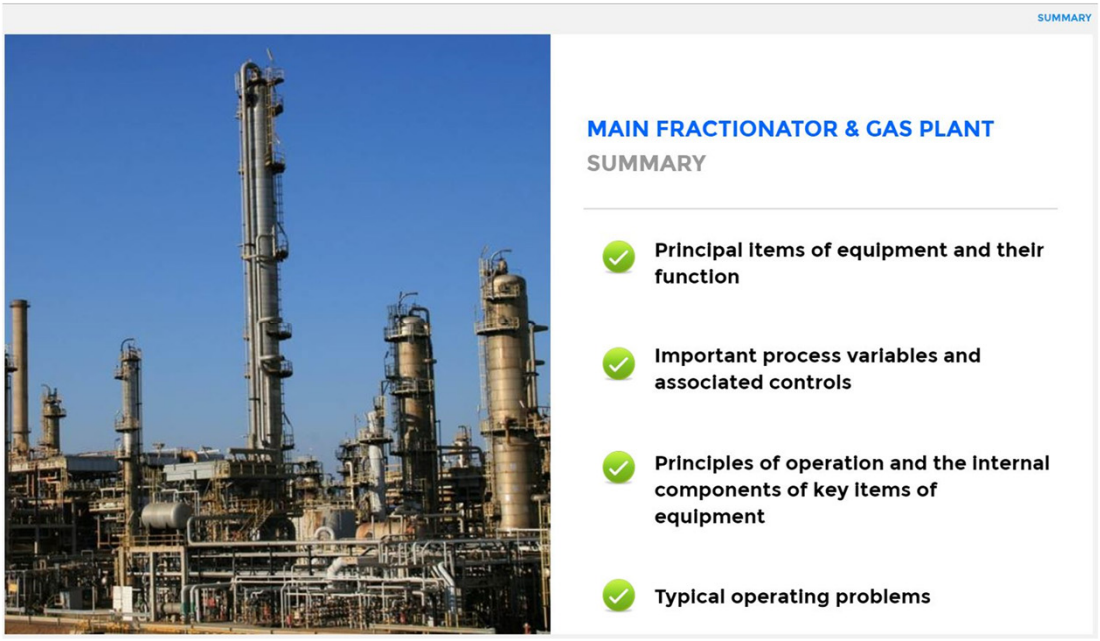
By now, you will no doubt have realized that the FCCU Main Fractionator and Gas Plant have distillation towers, absorbers, separators, drums, heat exchange equipment, pumps and compressors arranged in a very similar configuration to that of the ADU from the Atmospheric Tower onwards.

Operating Problems

Fortunately, Main Fractionators and Gas Plants are relatively problem-free.

A trip of the Wet Gas Compressor is a definite show-stopper, requiring overhead gas to be dumped to flare and feed cut out of the Reactor.

On plants that run heavy feeds (i.e. vacuum gas oils with atmospheric residue inclusion), additional care must be taken to avoid temperature excursions and flow stagnation in the Main Fractionator bottoms, which together can result in coke formation and plugging of the lower parts of the tower.



And this completes FCCU Module 04 in which we've covered the Main Fractionator and Gas Plant unit operations.

To summarize:

The Main Fractionator separates the Reactor effluent into overheads, side & bottoms products:

- The bottoms product - Decanted Oil, passes either to a downstream Delayed Coking Unit or to the fuel oil blend pool
- The lower side product - HCGO, is recycled to the Reactor and processed to extinction
- The mid side product - LCGO, is hydrotreated in the DHTU before passing to the diesel blend pool or passed to the fuel oil pool as a viscosity cutter
- The upper side product - HCN, is purified in the Gas Plant, then Merox treated and passed to the gasoline blend pool
- The overheads product - a mix of gas, LPG and LCN, is also purified in the Gas Plant and then:
  - Gas is amine treated and passed to refinery fuel gas
  - Unsaturated LPG is Merox treated and split - with C_3s passing to LPG blending and C_4s passing as Alkylation Unit feed
  - LCN is Merox treated and either blended into gasoline or sold as chemical naphtha depending on its benzene content

The purpose of the Wet Gas Compressor is to raise the pressure of the overhead gas high enough to liquefy LPG.

The function of the Absorbers is to prevent loss of LPG material to offgas and recover naphtha material.

The function of the Stripper is to recover light hydrocarbon gases that are restricted in the LPG blend pool.

The function of the Stabilizer is to separate LPG and full range naphtha.

The function of the Splitter is to separate LCN and HCN.

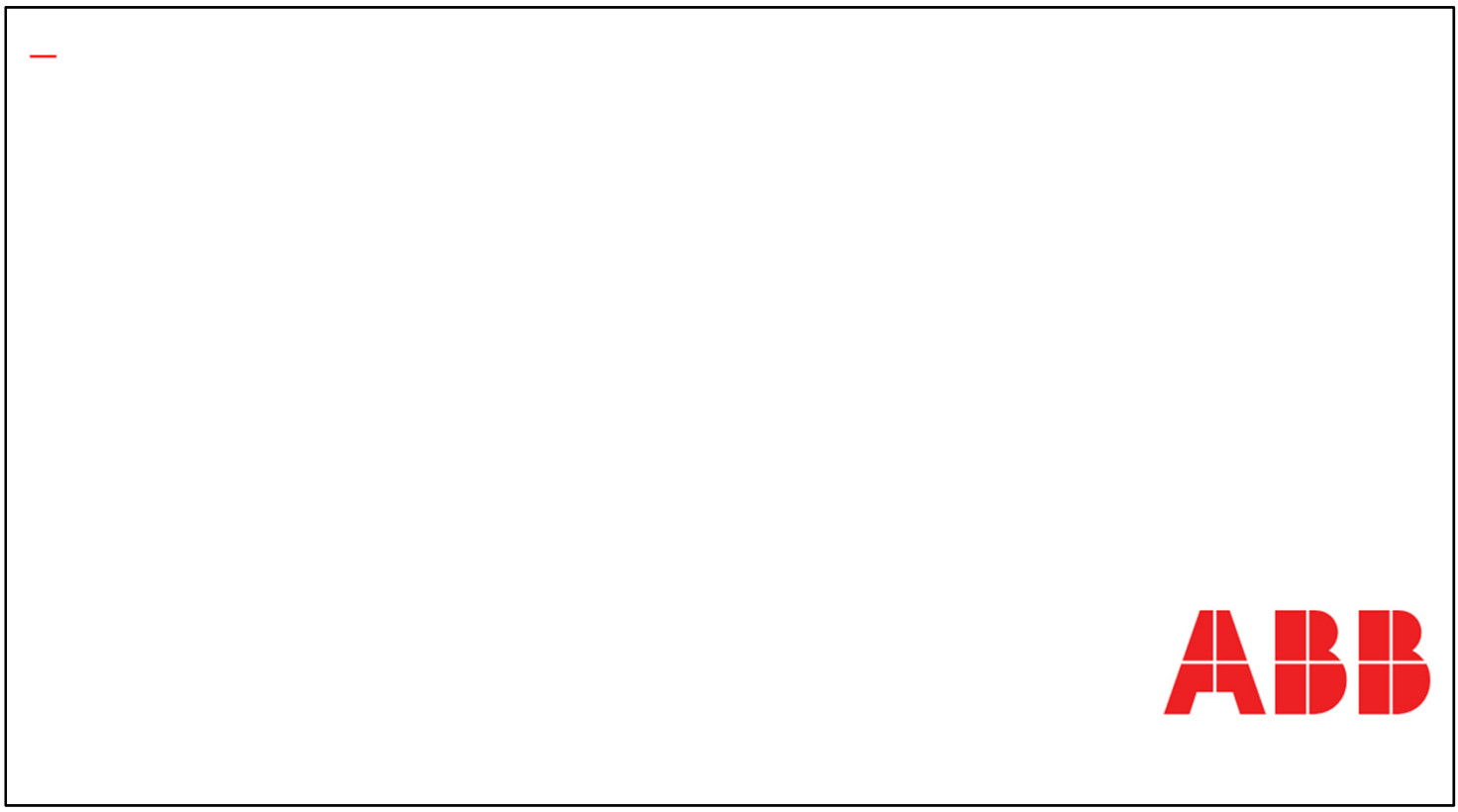
For the Main Fractionator and Gas Plant, you should now be familiar with:

- 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 FCCU Module 04 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.